EMPIRICAL RESEARCH

Building Cultures of Collaboration That Promote Instructional Change

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Background: National calls to improve engineering education have prompted educators to explore ways to implement change. We need a better understanding of how research-based instructional strategies (RBISs) are sustainably adopted among faculty. Prior studies indicated that developing collaborations and a shared vision among faculty facilitates adoption, but few studies demonstrate successful efforts to create these collaborations.

Purpose/Hypothesis: We seek to understand the process of developing a culture of collaboration among STEM faculty interested in implementing instructional innovation in engineering and to characterize the process of how the STEM faculty community of practice (COP) develops and functions. To achieve this, we investigated two research questions: 1) How do participants describe their experience in the SIIP – a program designed to promote and support collaborations around teaching innovation? 2) What patterns and themes emerge in the experiences of participants?

Design/Method: We applied an exploratory phenomenological approach, using semi-structured interviews with 12 STEM faculty members across academic ranks. Interviews were analyzed using a thematic analysis process with multiple rounds of coding.

Results: The participants' experiences revealed that social capital and shared accountability support building a collaborative culture among engineering faculty engaged in instructional innovation. The community of practice provided organizational support and resources to STEM faculty that enabled community behaviors including knowledge sharing about teaching.

Conclusions: Building a community of practice among STEM faculty for education reform requires invested faculty, structural support by the institution (e.g., instructional initiatives programs), and a collaborative environment. Recommendations are provided for building a local version of a STEM faculty learning community committed to improving instruction.

Keywords: STEM faculty; community of practice; social capital; instructional change

Introduction

Reports such as The Engineer of 2020 or Rising Above the Gathering Storm have created a national conversation that has called for engineering education reform. Unfortunately, implementation of these desired reforms has been slow or minimal (Borrego et al., 2013; Henderson & Dancy, 2007, 2009; Henderson et al., 2011). Consequently, recent research has focused on identifying barriers to engineering faculty incorporating research-based instructional strategies (RBISs) into their teaching practice. For example, the literature review of Henderson et al. (2011) revealed that traditional *develop and disseminate* efforts have largely been ineffective at mitigating instructional challenges within engineering education. In contrast, they suggested that change efforts focus on developing shared vision and emergent change approaches from communities of faculty may be more promising. There is a limited body of work that can be used to guide the creation of shared vision models. Therefore, we offer this work as a contribution to engineering faculty looking for a systematic approach to improve instruction within their engineering college or department.

This study aims to fill this gap in the literature by documenting how a culture of collaboration around instructional innovation was successfully developed among STEM faculty. We examined the Strategic Instructional Innovations Program (SIIP) at a large, research-intensive Midwestern university. We chose to examine SIIP because the program has facilitated a dramatic increase in the number of engineering faculty who are using RBISs (Herman et al., 2018) and because the SIIP was designed with the goal of creating a community of faculty committed to innovating large lecture courses in the college. The success of the program is in part revealed by the rapid increase of educational research and scholarship among participants: over 50 participating faculty have since submitted their first educational scholarship articles and over 30 have submitted their first educational research grant proposals to external funding agencies. The SIIP program has since expanded to include engineering courses from across the undergraduate curricula and has begun to incorporate faculty from the physical sciences and mathematics departments.

The faculty in this program describe it as a broad SIIP community of practice (COP) with several smaller "innovation teams" responsible for reforming individual courses or a closely related set of courses within a single department or academic unit. Within these innovation teams, faculty members typically meet on a regular basis (e.g., weekly) to plan, implement, and evaluate changes in how they teach their courses. The goal of these innovation teams is to develop a set of teaching practices and curricula that are mutually owned and refined by the larger COP. Each innovation team comprises at least three faculty members.

The innovation teams interact with the broader SIIP COP through a network of mentors. These mentors, called Education Innovation Fellows (EIFs), were first members of innovation teams and were recruited to join the leadership team to recruit new members to the SIIP COP because of their demonstrated leadership and instructional innovation efforts. The SIIP leadership, comprising staff from the Center for Teaching and Learning and EIFs, provides mentorship to each of the innovation teams, develops the policies and procedures of the SIIP program including evaluation, and determines how to allocate the program's funds. Members of this leadership team meet regularly with each other (typically biweekly) and each EIF is assigned to mentor at least one innovation team comprised of at least three faculty members. Rather than create a hierarchical structure, the goal of SIIP is to create an interconnected, faculty-led innovation COPs. The interconnected relationship between the innovation teams including the faculty participants to the larger SIIP COP is depicted below in **Figure 1**. In **Figure 1**, the circles represent individuals, dotted ovals organize individuals based on who interacts with whom.
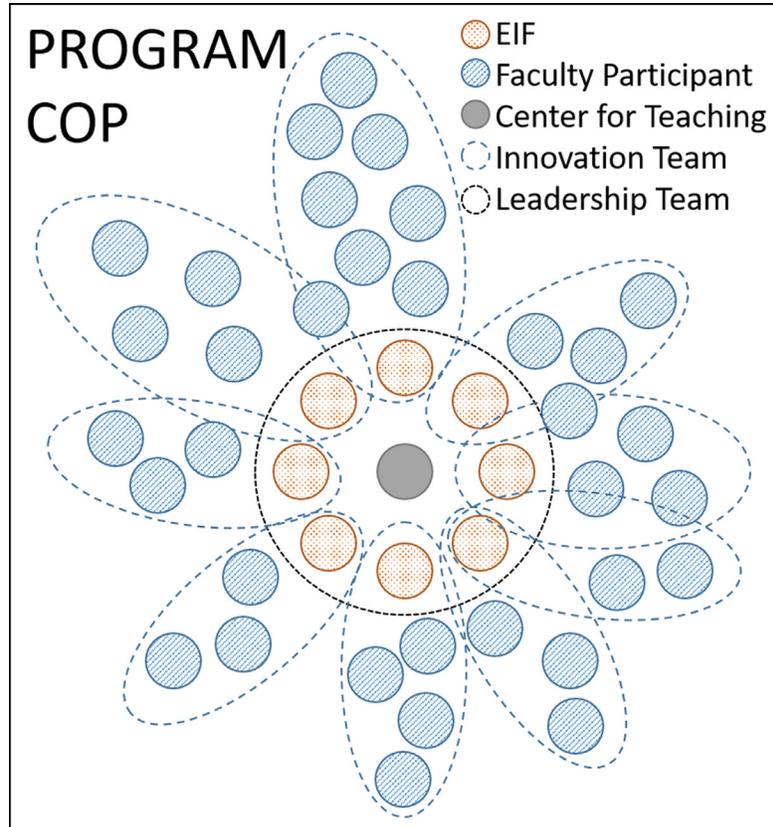

Figure 1: SIIP Organizational Structure.

We interviewed 12 members of the SIIP community leadership, identifying them as key informants. Because the leadership team met weekly with all the innovation teams and the EIFs were also participants in innovation teams, they could provide insights into both the holistic functioning of SIIP and how individual innovation teams functioned. In this study, we present the characteristics of collaboration exhibited by the leadership team as they supported innovation teams and highlight rich descriptions of how the leadership team functioned to build a sustainable SIIP COP.

Purpose of the Study

The purpose of this exploratory phenomenological study is to understand the process of developing a culture of collaboration among STEM faculty interested in implementing instructional innovation. Our goal is to understand and accurately characterize the process of how the SIIP COP developed a collaborative process to adopt RBISs as seen through the eyes of the program participants, not to predict community behaviors (Gill, 2014).

The overall guiding research question is: How does a culture of collaboration for improving undergraduate engineering education develop among engineering faculty? We explore this question by examining two sub-questions: 1) How do participants describe their experience in the SIIP community—a program designed to promote and support collaborations around innovative teaching? 2) What patterns and themes emerge in the experiences of participants, who are key informants, engaged in teaching innovation within the SIIP community?

Structure and Design of SIIP

SIIP is an internal, competitive grant program conceived by the deans of the College of Engineering in response to deep concerns about the quality of the large, introductory service courses in the college. Faculty, tenure and teaching track, from all departments are encouraged to submit proposals, but proposals must include teams of at least three faculty. Proposals can focus on redesigning curricula, implementing RBISs across many courses, or developing instructional tools.

Faculty first submit pre-proposals that briefly describe their goals. Pre-proposals are reviewed based on their strategic value to the college: proposals must have the promise to affect hundreds of students or multiple courses, or significantly advance institutional understanding of how to use RBISs. Proposals should not simply be an individual instructor's efforts to improve their teaching, such as flipping a course or adding project-based learning. Proposals must be sufficiently ambitious such that they require the input and effort of multiple faculty members.

After the review of pre-proposals, the leadership team works alongside these teams for two to five months (typically), to refine their ideas, develop evaluation plans, connect faculty with similar proposals, and observe group dynamics. At the end of this collaborative proposal development phase, proposals are again reviewed for funding based: 1) on administrative support (e.g., will department heads support teaching assignments that align with project goals?), 2) collaborative development (e.g., is the proposal team acting like a COP or just one highly ambitious individual who added other names to the proposal?), 3) evaluation plan (e.g., does the proposal team have a plan for collecting outcomes data?), and 4) sustainability (e.g., does the team have a plan for continuing their efforts after funding expires?).

If chosen for funding, teams become innovation teams. Innovation teams are expected to participate in regular community building activities, including weekly meetings of the innovation team with a member of the leadership team in attendance and Also, the innovation team gather semi-annually with all COP members to share about their projects. Leaders from these innovation teams are asked to join the SIIP COP as rotating members, a.k.a. Education Innovation Fellows (EIFs), serving for one- to three-year terms. All EIFs in the first two years of the program were tenured faculty from a variety of departments, but EIFs now also include promoted teaching faculty. EIFs help define the policies and procedures of the SIIP COPs, determine which project proposals will be funded, and provide mentorship to the other innovation teams. EIFs develop and institute annual reviews for the innovation teams. In addition to EIFs, the SIIP COP includes a faculty development staff member from the college's teaching academy and engineering education research faculty. To maintain administrative support and engagement, the leadership team reports to the associate dean for undergraduate programs.

Based on recent research (Borrego & Henderson, 2014), the SIIP COP developed a simple rallying message to describe SIIP: "teach like we do research." While this message broadly encompasses the idea of being scholarly about teaching, it is also a commentary about the methods and culture of the program. The message encourages faculty to take their best practices for conducting research—frequently discussing ideas with colleagues, scheduling weekly meetings to monitor progress, and taking risks—and apply them to their teaching. Although no theoretical framework guided this study, the program was loosely developed on the principles of a COP. Therefore, in this review of relevant literature, we provide an overview of literature to explain faculty behaviors within the SIIP community, including their social capital and beliefs.

Relevant Literature

To understand how a community of collaboration forms among STEM faculty, we review literature on COPs, social capital in STEM, and faculty beliefs related to adopting research-based instructional strategies (RBISs).

Communities of Practice (COPs)

A COP is defined as people who engage in an enterprise through interaction and communication that supports individual and collective learning (Serrat, 2017; Wenger, 1999, 2010). Thus, COPs form around shared interests and common goals while action is organized around shared responsibilities and practices (Wenger, 2000). Our research study is grounded in the conceptual framework for communities of practice (COPs; Cambridge et al., 2005; Sherer et al., 2003; Wenger, 1998) and leadership readiness (Cunningham et al., 2002; Kezar et al., 2007). In the context of our study, the SIIP COP shared a common interest in improving undergraduate engineering education with a common practice of collaborative teaching. Communities of Practice have three core characteristics: the domain, the community, and the practice (Sherer et al., 2003). Members have a shared domain of interest and a commitment to that domain; in this project, the domain is promoting better and collaborative teaching in engineering. COP members learn from each other through social participation in the community; they engage in learning, knowledge sharing, and taking actions. The program requires the innovation teams to have regular meetings for sharing knowledge gained from working collectively on improving teaching practices and constant communication with their assigned EIF. Members of a community of practice must be practitioners (Sherer et al., 2003). Over time, they develop shared resources that support their practice: in this project, the members co-developed tools to improve instruction or course designs which were made available to all community members. Successful COPs depend on high levels of collaboration (Probst & Borzillo, 2008) but effectively decrease the learning curve for novices, reduce creation of redundant resources or reenactments of failures, and promote creativity (Wenger, 1998).

While most research on faculty COPs has focused on how faculty form research-based COPs, a few studies have explored the formation of teaching-based COPs and other collaborative teaching models. Sherer et al. (2003) demonstrated that faculty collaboration through an online portal could enhance faculty development and sustained engagement. Henderson et al. (2012) similarly demonstrated the value of co-teaching for helping faculty to change their teaching practices. Finelli et al. (2014) showed that collaborative discussion groups about teaching promoted faculty development and encouraged discussion group members to implement research-based teaching practices in their classrooms. Our study adds to these prior findings by understanding the experiences that contributed to the formation and sustainability of teaching-focused COPs among STEM faculty.

Social Capital in STEM

Multiple recent studies have explored social capital in STEM education. Some authors explored the role of social capital in the experiences of community college students transferring into four-year institutions (Jorstad et al., 2017; Kruse et al., 2015; Starobin et al., 2016). Mishra (2020) and colleagues performed a systemic review of literature on social networks, social capital, and social support. The review generated evidence that the social networks of students including their family, ethnic and religious affiliations, friends, and faculty play a role in academic success and described how professional networks complement each other to contribute to the academic success of underrepresented groups (Mishra, 2020). Similarly, Saw (2020) used social capital as a tool to leverage broadening participation efforts and found that social capital derived from STEM students' families, peers, teachers, and professional networks enhanced their educational outcomes and career selection. Moote et al. (2020) considered social capital in the specific context of science education, which the authors named science capital. The authors found that science capital was a useful theoretical framework to predict adolescents' career aspirations and was strongly related to engineering and math attitudes. Finally, Mondisa (2020) considered the role of social capital in building effective mentoring relationships with undergraduate African American STEM students.

Social capital in engineering consists of social networks and social norms that allow resources to be accrued through relationships and status within the engineering culture (Brown et al., 2005; Martin et al., 2014). Interestingly, the engineering education literature typically focuses on how social capital impacts the undergraduate experience. For example, Brown and colleagues discussed educational methods to increase students' social capital (Brown et al., 2005). Social capital was found to impact engineering students' decisions and was attributed in part to non-academic characteristics such as parental educational attainment and occupation (Trenor et al., 2008). Additionally, researchers considered how social capital impacted marginalized students such as Hispanic women (Martin et al., 2013), first-generation students (Martin et al., 2014; Martin, 2015), and students of color (Samuelson & Litzler, 2016). More recent research found racial differences in the levels of social capital that could influence students' persistence and retention (Skvoretz et al., 2020). Finally, social capital has been related to key student outcomes in engineering including the sense of belonging for first-generation students (Simmons & Martin, 2014), knowledge sharing in student design teams (Zhang & Cheng, 2015), and success (e.g., retention and persistence) with multiple types of support (Martin et al., 2020). However, this paper extends our understanding of the impact of social capital on students in engineering, and we explore the role of social capital on faculty learning communities and COPs.

Higher education literature provides some connecting social capital to faculty teaching. For example, Benbow and Lee (2019) found that both faculty and organizational investment are needed to develop teaching-focused social networks and social capital among college faculty. Furthermore, academic leaders are encouraged to align instructional innovation within

local context including faculty experience and time commitments (Benbow & Lee, 2019). Kanev (2016, pg. 11) investigated the incentive structure of higher education in terms of social capital and found that the major role of social capital in higher education because "it can substantially increase educational revenues and decrease personal and transaction costs". Other researchers sought to understand how social capital works in a group mentoring program to develop specific strategies that benefit both individuals and the institutions within a community of practice (Morgan, 2014). This paper contributes to the dearth of the research on the role of social capital in faculty developing teaching practices and pedagogical beliefs in engineering. For example, is there a relationship between social capital and faculty beliefs?

Individualistic versus Collaborative Teaching and Change Efforts

Efforts to change faculty teaching practices have generally relied on *develop-disseminate* efforts that focus on changing the teaching practices of individual faculty (Beach et al., 2012; Borrego & Henderson, 2014). This emphasis on changing the teaching practices of individuals reflects the presiding belief and practice that teaching is an individualistic endeavor (Lane et al., 2019; Tanner & Allen, 2006). Most faculty teach in isolation with little input from peers or faculty development staff. For example, Spalter-Roth et al. (2010) found that 75% of sociology faculty primarily teach alone and therefore lacked the social capital to effectively change their teaching practices. Unfortunately, this focus on changing the teaching practices of individuals has been largely unsuccessful (Beach et al., 2012; Borrego & Henderson, 2014). There has consequently been a growing interest in how collaborations between faculty may provide more fruitful avenues for helping faculty improve their teaching and sustain those changes (Olmstead et al., 2019).

A growing number of recent studies have been revealing that instructors who talk about teaching with other faculty are more likely to change their teaching practices and adopt evidence-based instructional practices (Daly, 2010; Judson & Lawson, 2007; Lane et al., 2019; Ma et al., 2019; Macdonald et al., 2019; Neal et al., 2011; Penuel et al., 2009). For example, instructors are more likely to begin using a new teaching method after seeing a peer use that method (Neal et al., 2011), but if teaching is individualistic, we forfeit these types of opportunities. With few opportunities to learn from peers, instructors are more likely to "teach how they were taught," perpetuating ineffective passive lecturing (Marbach-Ad et al., 2014). Collaboration and other team-based models for teaching can provide critical opportunities and support for instructors to receive feedback on their teaching and improve their practice (Ma et al., 2018).

There is also immense structural potential for using teams of instructors to improve teaching rather than individuals (Olmstead et al., 2019). By changing the teaching practice of a lone instructor, changes to the course may last only as long as that instructor remains with the course. However, if a team of instructors coordinate changes to a course or to multiple courses, the team has a greater chance of sustaining and continuously improving those courses over many offerings (Marbach-Ad et al., 2007; Marbach-Ad et al., 2014; Reinholz & Apkarian, 2018). By working in teams, faculty can also obtain more control over their teaching environment, for example by having more power to influence teaching assignments, than they could individually (Elrod & Kezar, 2017; Gehrke & Kezar, 2017; Reinholz & Apkarian, 2018). This increased control can further help faculty develop feelings of ownership and investment in improving courses (Elrod & Kezar, 2017; Reinholz & Apkarian, 2018).

In this study, we hope to understand the development of teaching collaborations, specifically faculty COPs focused on improving teaching.

Method

We used an exploratory phenomenological approach to understand how STEM faculty cultivated a culture of collaboration for the purpose of improving undergraduate engineering education. Phenomenological research focuses on describing and understanding the lived experience of the participants based on their common or shared experience with the phenomenon of interest (Creswell, 2007). The phenomenon of interest in the current study is STEM faculty collaborating to enhance teaching and learning in engineering. The participants in our study are a subset of those in the SIIP COP. We captured the common experience of our participants by describing what they experienced, how they experienced it, and the meanings they made of their shared experience (Moustakas, 1994). A key epistemological point of a phenomenological study is that the outcome produced by the work is a synthesized description of the essence of the experience, but not an explanation for the experience (Smith et al., 2009). The assumption restricts the interpretation to the description provided from the perspective of the participants and does not consider other perspectives. Data was collected from semi-structured interviews with 12 STEM faculty and staff in the SIIP COP who were identified as key informants.

We selected this qualitative approach for three specific reasons. First, the study is exploratory, as little is known about the process of building a COP among STEM faculty to enhance teaching. We see a need to understand this process or phenomenon from the point of view of those who have experienced it. Second, community building that supports instructional innovation implementation is highly contextual, and generalizability was not an objective of the project. The exploratory nature of the study utilizes significant features of the participants' descriptions to capture the essence of the experience and enhance our understanding of how the culture of collaboration developed among STEM faculty within our institutional

Table 1: Participant Demographics Summary List.

Pseudonym	Rank	Role
Ashley	Associate Dean*	Administration
Cynthia	Associate*	EIF
DeWhite	AP	Faculty Development
Jack	Full*	EIF
James	Associate*	EIF
Jamie	Full*	EIF
Marge	AP	External Evaluator
Peyton	Full*	EIF
Ricky	AP	EIF
Sarah	AP	Faculty Development
Taylor	Associate*	EIF
Tim	Associate*	EIF

Note: The listed pseudonym does not reflect the gender of the participant; AP = Academic Professional, EIF = Education Innovation Fellows.
* Tenure-track professors.

context. Third, the research design developed for the study was influenced by recent calls for education researchers to apply a phenomenological approach to understand organizational functionality and processes (Gill, 2014). Using the phenomenological approach allowed the research team to use personal narratives as valid data that illuminates the relationship between the significant event and the context of the event at both the individual and organizational levels. Therefore, the exploratory phenomenological approach provided an effective methodology to answer our research questions.

Participants

Because the goal of our study was to understand the phenomenon, that is, how cultures of collaboration arise within an institutional context, leaders of the SIIP were selected as informed participants in the COP. The faculty participants experienced the phenomenon of interest and helped develop and oversee the department-level innovation teams. We used purposeful sampling to recruit study participants who were identified as leaders of SIIP, either formally as part of the leadership team or faculty who had been invited to join the leadership team (N = 12). The total sample of 12 participants makes up more than 10% of the total number of faculty currently participating in SIIP. Sample populations in phenomenological studies are not usually large as the data collection requires an in-depth study of the human experience. The sample, however, must be large enough to offer different experiences of the phenomenon (Moustakas, 1994). The participants, who were initially contacted by email and then interviewed in person, came from a variety of departments, and represented a mixture of diverse demographic factors including gender, professional experience, academic standing (e.g., academic professionals, tenured professors, or administrators) and teaching levels (e.g., large introductory courses or smaller upper-division courses). All the participants played distinct but overlapping roles within the SIIP COP (see **Table 1**). To ensure anonymity of the participants, we assigned pseudonyms.

Data Collection and Instrument

Qualitative data was gathered using semi-structured in-person interviews. The goal of the interviews was to elicit the participants' accounts about their experiences within and about the SIIP COP. The research team collaboratively constructed the interview protocol as the primary instrument for data collection. The protocol was composed of open-ended questions to allow participants to describe their experiences in their own way. The research team also provided a copy of the project timeline to aid participants' reflection on significant events. The interviews included questions regarding participants' backgrounds, self-reported roles, relationships with others in the program, and descriptions of what did and did not work well within the overall program. Sample items include: "How did you first get involved in the SIIP community?" and "After being involved in SIIP, describe your current views regarding improving teaching and learning in the college." Each interview was audio recorded and later transcribed verbatim. The interviews lasted 45–60 minutes and the research team scrubbed identifying information to maintain anonymity of the participants. At the end of each interview, the research

team completed a debriefing document that included draft field notes and analytical memos, which are components to promote quality of qualitative research (Creswell, 2009; Patton, 2002).

Data Analysis

Data analysis consisted of 1) using open coding to construct a codebook to capture the variety and nuances of the participants' experiences, and then 2) using the codebook to holistically evaluate each participant's interview to allow themes of the group's experiences to emerge based on the research team consensus and feedback from intellectual neighbors. Intellectual neighbors are people outside the community that can offer feedback with no risk of getting ensnared in the community decisions (Wenger et al., 2002) and engage in robust discussion (Walther et al., 2017). Three members of the research team coded the interviews independently using MaxQDA, a word processing software where codes are associated with sections of texts. We first randomly selected three of the 12 interviews for open coding. Open coding involved reading through the data repeatedly and creating tentative labels for chunks of data that sum up participants' descriptions. We created analytical memos during the coding process for reference in meaning construction and developing the codebook.

After each member coded the three interviews, codes were compared and similar codes were grouped and/or renamed, resulting in 12 distinct emergent codes. Following the process detailed in MacQueen et al. (1998), we gave each code brief and full definitions, guidelines for when and when not to use the code, and examples of texts where the code was used. With negotiations throughout the data analysis, we grouped related codes into clusters and interpreted the clusters to create themes for the experiences.

Reliability and Validity

Considering that the phenomenological approach we have taken involves presenting descriptions of how the participants experienced the process of collaboration, we also recognize that we as researchers may have preconceived perceptions of the phenomenon. Procedures to assess the reliability and validity of our data analyses involved the use of phenomenological reduction and the concern for essences (Giorgi & Giorgi, 2003). Reduction implies bracketing, wherein we purposefully set aside our personal beliefs and preconceived knowledge that might be used to explain the phenomenon being investigated.

Hycner (1985) emphasized that disclosing personal bias is a step in bracketing. Although the research team members who analyzed the data were not part of the SIIP COP and were chosen because of their expertise in the research methods for the study and their sufficient distance from the program, they have professional working relationships with the study participants and teaching experience that may be sources of bias. We conscientiously made the effort to bracket bias by developing a standardized codebook (see Appendix). Using multiple people to code the data afforded the ability to check the consistency between one's interpretation and that of others. Responses were coded independently and then compared to measure intercoder reliability. Specifically, intercoder reliability was measured by agreement in terms of the percent of text to which the research team assigned the same code in addition to the consistency of the codes assigned to a segment of text (Lombard et al., 2002). The codebook was essential in data analysis and provided a mechanism to establish intercoder agreement. Through multiple rounds of coding (e.g., open, axial), we achieved an intercoder agreement of 83% for all 12 interviews.

Other strategies to ensure reliability, such as member checking, were not plausible for the current study as many community members were not always conscious of their implicit views about educational reform or institutional change (Kezar et al., 2015). However, we applied the guidelines for phenomenological analysis of interview data according to Hycner (1985) and developed analytical memos throughout the analysis to discuss with the entire research team and colleagues to monitor researcher subjectivity. Moreover, we consulted with colleagues who were familiar with qualitative research methods to review and affirm the soundness of our protocol and findings. Preliminary results from this project were peer-reviewed and presented at the 2016 American Society for Engineering Education (ASEE) annual conference.

Results and Discussion

We present our results in the order of the research questions:

> **Research Question 1:** How do participants describe their experience in the SIIP community—a program designed to promote and support collaborations around innovative teaching?

Overall Phenomenological Statement

The SIIP COP was formed as a group of STEM faculty engaged in a process of collective learning and cooperation to improve undergraduate engineering education. They experienced this process through a series of successive, interconnected events that afforded each member personal growth opportunities including expanded teaching practices and professional networks. Generally, the participants found the SIIP community useful for learning and positive for collaboration but stressed the importance of shared leadership and peer recognition of individual talents and expertise. In this study, two themes unfolded from the participants' accounts related to the community: building a COP and behaviors that lead to sharing community knowledge.

Research Question 2: What patterns and themes emerge in the experiences of participants, who are key informants, engaged in teaching innovation within the SIIP community?

Consistent with the phenomenological reduction process, participants' descriptions of a community event or what was experienced related to the phenomenon were extracted from the interview transcriptions, then grouped into codes, then clusters, and finally into themes (Groenewald, 2004; Moustakas, 1994). In **Table 2**, we present the results of the reduction process and how we operationalized the cluster under each core theme that emerged from the interview data.

Next, we present the two overarching themes and their respective clusters in connection with the participants' textural descriptions, as well as their structural descriptions. For the participants' textural descriptions (i.e., what the participants experienced while they were in the program), we highlighted significant representative statements using their own words to communicate their unique perceptions of how the culture of collaboration developed among faculty. We noted community activities/events they identified and how they talked about them. For the structural description (i.e., how the participants experienced the community), we examined the interpretations and sense making of community participation articulated by the participants. Then, we developed an overall phenomenological statement encapsulating the participants' lived experiences.

Theme 1: Building
Community building was operationalized as the participants adjusting to in-group behaviors that were consistent with the goals of the innovation teams or the SIIP COP. This theme was considered a function of social capital. This advantage of having social capital with colleagues creates value and can be mobilized to facilitate action on behalf of the individual (Adler & Kwon, 2002; Seibert et al., 2001). Adler and Kwon (2002) described three benefits of social capital: 1) access to broader sources of information, 2) power and influence to achieve goals, and 3) solidarity to encourage compliance and minimize the need for formal rules. Social capital has been shown to improve organizational development and growth through knowledge transfer (Inkpen & Tsang, 2005, 2016) and knowledge sharing (Zhang & Cheng, 2015).

The Community Building theme included two clusters: Community Entry or First Contact and Motivation to Join. Both clusters were associated with social capital as they depended on relationships and interactions made prior to or during program participation. The first cluster, *Community Entry*, was defined as the experience of the participants that led to their awareness and knowledge of the goals of the SIIP program. The second cluster involved the participants' *Motivation to Join* the SIIP COP and was related to their personal identity in the context of social identity (e.g., in-group vs. out-group). We defined motivation as the reasons for a SIIP COP member speaking/acting in a particular way, whereas personal identity was defined as the professional character or the self-perception of one's SIIP COP membership within the context of their department culture.

Community Entry or First Contact
Some participants were recruited informally by peers or colleagues within their department, or by people from other departments with whom they had previously collaborated. For example, Sarah heard about the program when it started because she knew people who were on the innovation teams already: "… I knew some of the people who were on the teams who were originally involved, but I didn't start until fall 2013." James said he "had informal connections with SIIP… so both [NAME] and [NAME], I know personally. I know [NAME] a little bit more; I know her both personally and as a colleague…" His interactions with people he knew and worked with on previous research projects led him to participate in

Table 2: Summary of Themes and Clusters and Operationalized Definitions.

Community Themes	Cluster	Operationalized Definition
Building	Entry and First Contact	Participant experiences that led to their awareness and knowledge of the goals of the program and how they joined the leadership team
	Motivation	The professional character or the self-perception of their COP membership within the context of their department culture and the reasons for a COP member speaking/acting in a particular way
Behaviors	Shared Leadership	Team dynamics were collaborative and collegial that fostered respect among colleagues by emphasizing collective ownership of innovation. Effective program management, communal decision making, and collective accountability
	Teamwork and cooperation	Coordinated and collective effort by the leadership team interacting with the innovation teams to support the interests of the common community goals

the program. Similarly, Taylor specified that she was approached by colleagues in a different department to get involved in the program, "…the first year that the SIIP was introduced, I was contacted by a colleague, someone else from another unit, about having some stuff put in our numerics courses…" She had a previously established relationship with these colleagues through research collaborations. Other SIIP COP members were approached directly or indirectly by administrative personnel (e.g., dean, director), asking for ideas on how to improve teaching. These members were ultimately encouraged to get involved with the SIIP program. Ashley mentioned that "…Dean [NAME] wanted to put some college money into strategic research initiatives and to put some money into teaching." Ricky recalled receiving a forwarded email from the dean. Since Ricky was working on innovations in engineering education, his colleague said that "you should pay attention to this SIIP."

Participants were individually recruited to join the SIIP COP by current members of the SIIP COP or administrators of the university who were promoting the teaching initiative to bolster the instruction of the college. Previous research suggests that participating parties must be convinced of the importance of the commitment and focus (i.e., mission) when building a collaborative group (e.g., SIIP COP) in higher education endeavors (Kezar, 2005). Interestingly, recent studies provide evidence that STEM faculty minimized the influence of personal relationships and asserted that data alone would motivate and drive change efforts (Kezar et al., 2015). However, more recent studies suggest that instructional collaborations can directly impact curriculum changes tied to improving student success (Bush et al., 2016).

Motivation to Join Community and Personal Identity
In addition to describing how they became aware of the program; participants also described the personal and/or professional motivation behind their decision to participate in the program. According to Cynthia,

> …at the beginning I had been talking with [NAME], one of the other co-PIs, about educational initiatives because we've both been interested in using technology to enhance education.

In this case, she wanted to make changes to her instructional delivery techniques based on her ideas of what constitutes effective or good teaching. Similarly, while talking to a colleague in the physics department with education research training, Peyton recalled,

> We both saw the need for research and substantive change in instruction …, so we should be conducting research as a university on teaching and education.

Peyton's description indicates a shared understanding of a common need. According to Peyton, research-intensive institutions, regarded as primary producers of the engineering workforce, should conduct studies on teaching and learning. His statement also reflects the drive to apply research to improve undergraduate engineering teaching and learning, which is his primary motivation to participate in SIIP. Peyton implies that as members of this academic community, he and others are responsible for conducting the necessary research to improve undergraduate engineering education.

In addition to learning something new, program participation created a means to learn from others. As James put it, "I figured it would be a good opportunity for me to learn how to do it, and that I would be able to then replicate that in [other course]." James's quote exemplifies that course improvement played a large role in his willingness to engage with the SIIP. The "good opportunity" that James speaks of is critical as it made him see the SIIP COP as an opportunity to learn and a place where he could get support for his commitment to add his idea of educational innovation to the materials science curriculum. On the other hand, Jamie expressed, "…to some extent I wanted to put my own practices, my own teaching in some sort of formal framework where I understood what I was doing, and I also understood other best practices so I could improve my own teaching."

Most of the participants expressed their motivation to join the COP based on some individual-level motivations. Some participants talked about their previous teaching experiences, courses they taught, and their interest in improving their teaching. As explained in Wenger's work, a COP needs an explicit, joint goal for the community to form and thrive (Wenger, 1999, 2011). In this case, the community focused around a specific task of curriculum change. The *Community Building* theme suggests that the introduction to the SIIP COP and personal relationships that motivated the participants to join are critical to facilitating the developmental process or building stage of collaborations in higher education initiatives to change, such as improving teaching practices. Actively participating in updating the curriculum, the participants articulated their motivations and reinforced the importance of shared goals. These results suggest that social capital, both at institutional and departmental levels, is needed to foster change in cultural values and beliefs. The effectiveness of social capital for improving outcomes is mediated by task contingencies and personal values (Adler & Kwon, 2002).

In summary, entry and participation in SIIP seems to be driven by personal and professional social capital factors. Participants learned about the program from people they previously had connections with and the person who recruited them to be part of the SIIP COP. Furthermore, personal improvement and gain motivated them to join the program. The participants saw how the program/project goals aligned with their goals (i.e., improve teaching and learning) and recognized benefits from participating in SIIP. This finding is consistent with other research that suggests that personal relationships and social networks on campus are critical to facilitating the developmental process or stage of building a collaboration within a higher education institution (Kezar, 2006). Thus, the motivation to join the SIIP COP and engage in community activities is a function of their individual identity and willingness to embrace the role as a local change agent.

Both clusters in the *Community Building* theme suggest that social capital is instrumental in recruiting new members to the community. Social capital helped increase the number of people involved in the SIIP to convey program goals and enhance the impact. Community building activities are consistent with change agent behaviors that the SIIP COP embraced to promote instructional improvement and implementation of educational innovation.

Theme 2: Community Behaviors

As Wenger (2000) pointed out, COPs form as a result of shared interests and common goals, whereas action is organized around shared responsibilities and practices. Through participation in COP activities and the quantity and quality of interactions among the program participants, certain community behaviors were recognized as significant by the research team. Participants' descriptions included three types of interactions: informal communication in two forms, verbal and written (e.g., emails), and structured communication between the innovation teams. One substantial community behavior was the concept of shared leadership. The shared leadership cluster that emerged from participant statements was further categorized based on whom the participants interacted with or types of shared governance: 1) among the innovation team's members, and 2) the SIIP COP managing or supporting the innovation teams. Overall, the participants described the dynamics among the SIIP COP members as collaborative and collegial.

The second theme of community behaviors included two clusters: *Shared Leadership* and *Teamwork and Cooperation*. We defined *Shared Leadership* as observed team dynamics that involved communal decision-making and collective accountability. *Teamwork and Cooperation*, on the other hand, was operationalized as the coordinated and collective efforts the leadership team showed to support the communities' common goals.

Shared Leadership

Being identified as the leaders of the instructional innovation program, the study participants gave an account of their experiences as part of the SIIP COP and their roles in or mentorship of the innovation teams. Participants expressed that they felt the SIIP program-built relationships and fostered respect among colleagues by emphasizing collective ownership of innovation. As Jack described the leadership,

> We're a very distributed kind of leadership…. Engineering is extremely hierarchical here. On the other hand, the SIIP team has always been very distributed. So, it's not like any of us come in with a "this is the way we're gonna do things." And we all respect everybody's knowledge.

Moreover, the SIIP COP and innovation teams encouraged shared leadership through transparency and accountability. The SIIP COP provided guidance and structure (e.g., supported defining goals, attended meetings, set expectations, and mid-year review) to the innovation teams that modeled this kind of leadership. According to Jamie,

> You really don't want to have people do work and then saying "well, you didn't do this one critical thing" because they didn't know, so it's full disclosure, everybody is working with everyone, we, the SIIP evaluation team gets a chance to figure out are the PIs really engaged…

Here, Jamie suggests that the details of implementing the instructional innovation are an important component of sharing and learning within the SIIP program. The community's collective learning can also be supported with transparent communication and shared accountability. The shared leadership approach promoted success of the innovation teams and fostered an expectation of cooperation among the members in the larger SIIP community. Jack even mentioned,

> …we come together, and we discuss things, and here's the direction, and it's been a wonderful kind of flat organization.

Our shared leadership result is consistent with the results of previous research (Kezar, 2005) and the model of shared effort, mutual learning, and on-going support (Bush et al., 2016).

To provide on-going support to the community, certain members were specifically recruited. Jack explained,

> …why we decided on various people is like [NAME] came in late because we wanted to have a very strong evaluation portion and we decided that one great way to do that was to bring [NAME] into the group and not just have her as an external person.

As leadership team members were selected purposefully for specific skills and abilities involving social interactions that support the SIIP COP, additional team members were selected based on expertise and experience with particular academic activities such as creating and executing assessment plans, building community through structure and organization of community activities, and a clear focus on accountability to promote follow-through. Team members had a shared understanding about education reform through discussions in the community and an awareness of everyone's contributions. Jack talked about building community starting with cultivating existing relationships based on common interests:

> So, I knew [NAME] and I knew he was interested in educational issues, from way back. So, yeah, the relationship, I think, has grown and I've met other people…so there you meet, other folks, who are interested in, in the same kinds of things you're interested in.

As Cynthia also recalled,

> …the essential concept actually came out of discussions…. I think that ambition came out of [member] and I discussing it before we went to this larger group. And then you know, like any team different people contribute different aspects.

Initial discussions to reform education and subsequent sharing with the larger group and other community members are part of information sharing, which is essential to promoting a shared vision and value shift from an individual's seemingly ambitious goal to a larger community effort. Succeeding discussions then transitioned to sustaining the community as Ashley noted,

> So, we started the structure of asking for multiple faculty members, instructional members from each department and asking for there to be a plan on how you're going to build this into the department culture so that improvements can persist as teaching assignments change.

Furthermore, additional community principles and activities included documenting the practice and disseminating this among SIIP COP members to promote learning. As an example of disseminating documentation of community principles and values, members of the SIIP COP communicated previous community activities, both successes and failures, to the community. The experienced EIFs shared resources with newer community members. The community behavior of sharing information to support shared leadership entailed documentation of community norms and knowledge transfer to incoming community members.

Leadership dynamics focused on program management, decision making, and the collective responsibility for the program. Participants' descriptions seemed to shift from *I* to *we,* indicating collective efforts. They no longer view their teaching as an individual task, but a collective responsibility that allows them to discuss teaching practices with colleagues and learn from other SIIP COP members' teaching practices. The shared leadership and responsibility for curriculum changes within the SIIP COP diminished the intellectual and time commitments of individual faculty.

Teamwork and Cooperation
The SIIP COP used a shared leadership approach integrating both the bottom-up and top-down approaches to optimize the SIIP COP's impact. This approach fostered teamwork, which we operationalized in the study as cooperative or coordinated effort by the members of the SIIP COP interacting with the innovation teams to support the interests of the SIIP's goals. Participants expressed how they chose to interact with the innovation teams by being clear about setting rules and assigning roles. For example, Peyton articulated interacting with innovation teams during the proposal review process:

> …it's a little unique in this way, some member of the staff is assigned to each project and they're required, or strongly encouraged, to meet weekly with their representative from the team. Meeting with them and sort of guiding them through the proposal process, hoping to ensure high-quality, final proposal, making sure it includes all things to be addressed by the RFP (i.e. request for proposals) and that sort of addresses any obstacles.

Peyton describes here the scaffolding and support the SIIP COP made available to the innovation teams from their initial introduction into the SIIP program until their full participation in the SIIP program. Jack recounts his personal experience interacting with the innovation teams as a mentor:

> Yeah, so I get to learn about different people and what, and the other thing is, we get embedded into the teams. So, I'm embedded now into the new [department] team, that's got a new SIIP … So, you get to learn about other people. Other faculty, so you interact with them, and then you sort of there all these kinds of, tentacles, tentacles that go out into the [hand gesture] and these kinda build connections.

Jack describes the interconnectedness between the members of the SIIP COP and the innovation teams. As the innovation teams continued to develop through interaction with and feedback from the SIIP COP, the functionality of both the SIIP COP and the chaperoned innovation teams were enhanced. Tim described the changes that came along with the team environment in the COP:

> …well, just the fact there was a team. I think that's sort of the biggest thing, and I think was just lots of learning about… how to work as a team…we would meet every week and we would discuss well in advance about what we planned to do, and much more deliberate about planning what was going to happen…

The increased efficiency was evident in the evolution of community activities and behaviors, including the development of a mid-year review process for the innovation teams. DeWhite described how the SIIP COP worked with the innovation teams to promote evaluation and assessment:

> We put the evaluation onus on them, but then said, "We'll help you through it." So, what I really believe, in terms of SIIP, right now, the team collaborative idea seems to be working and clicking. The mentors seem to be embedded, giving good advice, when they need help, they come back to [institutional resource] as a group, or external people, we bring them in.

Echoing Jack's experience, DeWhite indicates that leadership team members acted as embedded members on the innovation teams to provide guidance or advice. They would also pull from resources inside and outside the university to support the SIIP program. These interactions between the SIIP COP and the innovation teams exemplified teaming and cooperative community behavior. However, not all the innovation teams readily adopted the community behaviors, and some struggled as some participants noted. Overall, adopting and embracing community activities and behaviors mediated cooperation between all SIIP COP members and supported the achievement of program goals.

The cluster of teamwork and cooperation that unfolded is supported by previous research that suggests that faculty need the opportunity to interact with like-minded peers as they participate in improvement endeavors (Finelli et al., 2014). Other research findings indicate complementary skill sets are essential to collaborative pedagogical communities tasked with the challenge of impacting undergraduate education and pushing faculty who participate within COPs beyond their individual expertise (Bush et al., 2016).

The clusters under the *Community Behavior* theme are linked to interdependence, an important team characteristic defined as the condition of being mutually reliant on each other and working cooperatively to achieve the common goal (Johnson et al., 2007). Interdependence among the innovation teams was vital in the functionality of the community as each member contributed a unique set of knowledge, skills, and abilities to their respective communities. Interdependence exploited collective effort beyond what an individual faculty member could achieve in promoting educational reform to adopt RBISs.

Community behaviors/activities, such as cooperation, increase social capital and expand the network of new members of the program. Community activities are defined in the literature as faculty interacting and learning together by sharing information (Wenger, 2011) but also by engaging in joint activities and discussions to help each other (Sherer et al., 2003). SIIP COP members were responsible for orienting new members of the SIIP COP and modeling participation or in-group behaviors. For example, participants described community activities such as talking about teaching, frequent update meetings, and informal activities among the SIIP COP members. Participants noted that these informal activities often extended beyond the maintenance and sustainability of the SIIP COP.

In summary, our results are consistent with and fit within the current literature on collaborative work. Participants described three salient and highly correlated concepts about team dynamics that were relevant to developing their COP. First, developing an evaluation process was critical to accountability within the SIIP and innovation teams. The evaluation process and the modified assessment tools enhanced the quality of the SIIP COP's performance and the resultant program outcomes. The evaluation process and assessment tools became a shared resource (Sherer et al., 2003) to address

common or recurring problems among the innovation teams and provided a documentation mechanism to record SIIP COP members' experiences. Consequently, the development of the evaluation process can be interpreted as the shared or community resource of the *practice* of COPs in general as defined by Sherer et al. (2003). Second, the participants described an integrated approach combining both top-down and bottom-up practices to adopting innovative teaching practices. Third, they described the importance of members with educational expertise embedded within the smaller innovation teams. Having a peer/mentor strategically placed within each innovation team was an important structural support for positive and productive team dynamics.

Conclusions

Building a COP among STEM faculty for education reform required invested faculty (e.g., EIFs), structural support by the institution (e.g., instructional initiatives programs), and a collaborative environment with shared leadership. Our study generated three overarching observations. First, a phenomenological approach is useful in investigating organizational behavior. Our results demonstrate how the phenomenological approach revealed organizational behaviors and community themes that are context-specific yet likely translatable to other institutional contexts. Second, social capital played a key role in both themes of community building and community behaviors. For example, social capital was essential in recruiting and integrating new members into the community. Third, our results suggest a key shift in faculty beliefs around teaching, moving from an individual endeavor to a group effort that maintains a process for improvement. Finally, our results are consistent with recent research that suggest that COPs are vehicles of change by documenting how to use intentional community-building activities to initiate change (Pitterson et al., 2020).

Limitations of the Study

As with all studies, our study had a few limitations that should be acknowledged. During the course of the study, the team experienced membership attrition. Several members originally involved in data collection were not involved in the subsequent data analyses due to changes in professional duties. This unforeseen attrition, though common and inevitable, may have allowed certain nuances in the original data collection to be overlooked. Also, the data only included interviews of current SIIP COP members, not former members or students or administrators who were also stakeholders in the instructional change efforts.

In addition, the time scale of building the SIIP or innovation teams was not explicitly explored. The interviews were conducted after two years of running SIIP; however, the time scale for the SIIP COP to develop and thrive was not articulated by the study participants. Another limitation of the study was that the shift in faculty beliefs was not directly measured. However, relevant themes emerged from the analysis suggesting a shift in common faculty beliefs regarding teaching in isolation and the use of literature on the scholarship of teaching. We will systematically explore these shifts in future studies.

Recommendations and Future Work

Based on our results and experience with the program, we recommend the following to STEM and engineering education communities interested in building a culture of collaboration in their own institutional contexts:

1) Build the COP by carefully selecting community members who have the support of faculty and administration. Although our study did not include questions about prior relationships before joining the program, exploring the effects of these relationships may shed light on the matter.
2) Each member should be recruited by personal invitation to gauge their willingness to invest and engage with the focus on the community. With the focus on the community, members likely adopt a shared leadership approach where all community members are equally responsible for cooperation among members and the success of the practice.
3) Establish appropriate social and teaming behaviors within the COP. Establishing learning activities (e.g., intentional opportunities for community members to share and learn from each other) within the community is important in community building (Kezar et al., 2015).
4) Leadership should encourage all community members to engage in activities that support the sustainability of the COP such as recognizing community accomplishments, specifying the benefits to stakeholders, and effectively documenting community activities.
5) Focus on the structure of the social network that cultivates cooperation among individuals and organizations. An investigation of the quantity of contacts within the COP using social network analyses would complement the current study. We believe that instructional change happens when faculty come together with a shared vision, build a teaching-based COP, and work toward a common goal, that is, implementation of instructional innovation.

Appendix

Table 3: Full Codebook.

Codes	Operational Definition
Current Perspective on Teaching	Individual and group change in attitude and beliefs about teaching where teaching improvement is a group activity
Disposition of SOT (Scholarship of Teaching)	Exposure and awareness of SOT literature for the purpose of understanding the problem of teaching instruction issues
Entry and First Contact	Entry into program from previous professional relationship or colleagues
Identity	Self-identification as an in-group or out-group member of the COP
Leadership Team Dynamics	Shared leadership and responsibility with complementary skills
Motivation	Personal motivation to improve undergraduate education led to engaging with the COP
Peer Recognition	Combining acknowledgment by out-group members and recognition of in-group knowledge, skill, and abilities (KSA) to gain administration support
Project Team Dynamics	SIIP teams established their rules and assigned individual roles
Program Goals	Goal of program was to improve curriculum to enhance student learning and faculty satisfaction with instruction; COP focused on instructional innovation and the admin focused on sustainable change with evaluation as an important part of program
Project Goals	Removal of departmental structural barriers and collaborative curriculum revision to meet desired outcomes
Teamwork or Collaborative Skills	COP members learned to work cooperatively and collaboratively on an educational venture with both in and out group members
Working Well	COP promoting teaching as part of engineering culture with supporting resources and the objective of sustainability

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

All authors made substantial contributions to the work presented. Author KJC oversaw data collection and analysis, Authors NM and NJ-G were part of the data collection and analysis, and Author GH connected the research team to the SIIP leadership and oversaw the manuscript development. All authors agreed to be named on the author list because we contributed to the drafting of the work and the revisions. All authors provided final approval of the version to be published. All authors agreed to be named on the author list because we contributed to the drafting of the work and the revisions. All authors provided final approval of the version to be published.

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