

Identifying and Overcoming Challenges in STEM Reform: a Study of four National STEM Reform Communities of Practice

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Abstract In this article we report on our examination of the challenges faced by four successful and long-standing national STEM reform communities. Drawing primarily on interview data from a large-scale, multi-year study informed by literature on “communities of practice” (CoPs) (Wenger et al. 2002), we describe five categories of challenges faced by the communities and the solutions employed to overcome them in order to sustain themselves and meet their goals. We chose to focus on these large and dispersed CoPs because, although on-campus CoPs have received some scholarly attention, no research has been conducted on national or regional CoPs. Based on our findings, we conclude that the solutions used to address these challenges reflected a meta-theme of flexibility in matters of design, leadership, and decision-making that contributed to the communities’ success and longevity.

Keywords STEM · Faculty · Communities of practice

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Undergraduate science, technology, engineering, and mathematics (STEM) education has been a source of concern for nearly thirty years. Countless reports have documented the need for reforms to improve student learning, persistence, and graduation rates for students in STEM majors (American Association for the Advancement of Science 2011; Association of American Medical Colleges-Howard Hughes Medical Institute 2012). Despite increasing job market demand for STEM graduates, the call for change based on report recommendations has not been widely answered (Borrego et al. 2010; Fairweather 2008; Handelsman et al. 2004; Seymour 2002).

A review of the literature shows that STEM majors have low retention rates due in large part to poor instruction (Henderson et al. 2011). Indeed, a meta-analysis conducted of recent science education research papers confirms that traditional lectures are largely considered the norm in STEM instruction (Freeman et al. 2014) despite evidence that active learning strategies positively impact student exam scores.

While we have knowledge of what works, systemic change in higher education has proven difficult. Isolated efforts (i.e., funding a short, one-time effort) have not been effective at yielding widespread organizational change because colleges and universities operate with complex reward structures and varying cultural norms and are therefore slow to change (Kezar 2011). According to Austin (2011), among the top factors that need to be addressed in order to promulgate more evidence-based teaching practices is professional development that involves communities of practice (CoPs), which “provide opportunities for faculty members to interact with others as they explore new assumptions and try out new approaches to teaching...in an environment that simultaneously provides challenge and support” (p. 13). Reports have identified communities that are focused on providing knowledge, support, and exemplary models for STEM education as important vehicles for change (American Association for the Advancement of Science 2011; Association of American Medical Colleges-Howard Hughes Medical Institute 2012), yet little systematic research has been conducted on these communities. STEM CoPs that exist at the national and regional levels involve thousands of faculty members. They host events, offer publications, and provide on-going networking opportunities for participants.

Following is our analysis of four national, faculty STEM reform communities based primarily upon interview data obtained as a result of a large-scale, multi-year, mixed methods study. The overall study was driven by research questions pertaining to the formation and sustaining of CoPs, the benefits of involvement with the communities, and the design of the communities to support faculty members. The intent of our study was to focus on the tensions and challenges faced by these communities throughout their existence and the strategies they employed to overcome these challenges in order to sustain themselves and meet their goals.

Conceptual Framework

The study was framed primarily by the literature on community-based approaches to change (Daly 2010; Kezar 2013; Kilduff and Tsai 2003; Nohria and Eccles 1992; Trowler 1998; Valente 1995). Stemming from an interest in escalating reforms in STEM teaching, we consulted literature on situated cognition theories of change, which suggest that learning and improvement occur within organizations as individuals interact and engage with one another through experience and apprenticeship (Daly 2010; Kezar 2013). This bottom-up theory of learning can be seen in social networks, communities of practice, and informal organizations, which challenge formal organizational boundaries (i.e. top-down, mandate-based reform approaches) and have a greater potential for changes at scale.

CoPs are groups of persons who share a concern or a passion for something they do and learn how to do it as they interact regularly (Allee 2000; Lave 1988; Wenger 1998; Wenger et al. 2002). For this study, we relied primarily on the CoP literature, within which the work of Lave (1988) and Wenger (1998) is foundational. In this section, we review the general design principles and lifecycles of CoPs as these can impact the type of challenges faced.

Design of CoPs

A CoP is composed generally of three elements: a *domain* of knowledge, a *community* of individuals who care about the domain, and a shared *practice* that they develop together in order to be effective in their domain (Wenger et al. 2002). The domain grounds the CoP and its members by giving it purpose, setting boundaries for learning, and guiding its evolution. The community is a supportive network of individuals who convene around a common interest in order to learn together. Practice refers to the tools, materials, ideas, and documents that the community shares in order to develop its knowledge in regards to the domain.

CoPs typically begin as organic entities and either evolve at a key point or dissolve entirely (Stuckey 2004). CoPs can be informal, but they are of great value to organizations because they allow for knowledge sharing among employees which ultimately improves organizational outcomes. As a result, typical CoPs tend to be financially supported by, or part of, a single organization. Though the specific mission of a given CoP depends on the nuances of that CoP's domain, its mission does not extend far beyond the improvement of practices for the benefit of members or the organization. Because CoPs are most often organizationally located, they rely on frequent face-to-face interactions to build rapport between members. CoPs that are “distributed” geographically do not rely on regular in-person interaction, but they can still be successful with support from an umbrella organization.

Lifecycles of CoPs

CoPs, like living things, experience lifecycles involving birth, growth, and transformation into another cycle, or sometimes, death. Wenger et al. (2002) described CoPs as having five stages in their lifecycle: “potential,” “coalescing,” “maturing,” “stewardship,” and “transformation” (Wenger et al. 2002, p. 69). CoPs typically encounter different challenges during different stages of their lifecycles due to the particular objectives of that stage. The CoP begins as an informal network of interested persons. The purpose of the *potential* stage is to determine whether there is enough common ground to recognize that the members have similar questions and similar struggles. The CoP is officially launched during the *coalescence* stage and must engage in community-building geared towards developing relationships and trust among members. The *maturation* stage is marked by a shift from proving value to the community to clarifying its mission and boundaries—a transition from sharing tips and ideas with friends to developing a formal domain requiring more structure and organization (Wenger et al. 2002). During the *stewardship* stage, CoPs strive to maintain their trajectory in spite of natural changes like the waning energy of members and new technology in the field. Finally, during *transformation*, CoPs may fade away through loss of membership or energy; or they may drastically change forms by adapting their mission to changing markets and fields. Though the CoP may effectively die during this stage, Wenger et al. (2002) state that transformation is a natural part of the CoP lifecycle.

Study Design and Methodology

Our study focused on the following research question. What challenges do leaders in national faculty STEM reform communities encounter in successfully forming and sustaining the communities, and how do the communities overcome these challenges? This question is critical because the organizations which fund these STEM reform projects have concerns about the long-term sustainability of the communities.

We gathered data from interviews, observations, document analysis, and surveys; but, as previously noted, interview data was the primary data that we utilized for this analysis. Observations and documents provided us with a context for interpreting the interview data. We interviewed community leaders and staff, observed signature community events, and analyzed key documents from all four CoPs, which allowed us to explore the stages of development, design, challenges, and sustainability.

Study Context

Unlike some CoPs, the four communities we examined were not embedded within a single organization, but distributed: community members were faculty members at institutions around the country who connected to STEM reform as a result of their work within their own institutions. We chose to focus on these large and dispersed CoPs because, although on-campus CoPs have received some scholarly attention, no research has been conducted on national or regional CoPs. We aimed to fill this gap in the literature. The fact that the four communities were distributed geographically and not tied to a particular organization meant that, unlike CoPs that benefit from continuing support of a parent-organization, these CoPs were responsible for procuring their own funding—in this case, through grants, donations, membership fees, or commercialization of materials.

Sample Selection

When researching potential communities for study we sought out those with the following four key features: (1) focused on STEM education and reform in higher education; (2) large in scale (comprised of several thousand members) and committed to disseminating best practices; (3) a long enough history so that we could study community lifecycle, challenges, and sustainability; and (4) the ability to contact members for survey. Out of a pool of approximately 20 STEM-focused communities, we selected four that met these criteria. All four formally agreed to participate in the study. The communities we examined were Project Kaleidoscope (PKAL), the POGIL Project (POGIL), Science Education for New Civic Engagements and Responsibilities (SENCER), and the BioQUEST Curriculum Consortium (BioQUEST).

Data Collection

For this study we drew upon interviews with long-standing leaders, faculty members, and staff members of the four communities. Participants were selected through purposeful sampling: We asked leaders of the communities to recommend diverse types of faculty members: those who had been very involved and those who had been less involved, and those who represented different viewpoints, institutions, and demographics. Within each such grouping we

interviewed between 26 and 30 individuals, approximately 8 leaders, 3–4 staff members, and 15–17 faculty members). The interview sample of 112 interviews consisted of 59% ($n = 66$) active community members who were faculty members, 28.5% ($n = 32$) leaders, and 12.5% ($n = 14$) staff members. Though interviews were our primary source of data, we believe that documents and observations were important for building a context with which to analyze and understand the interview data. For example, had we not attended events of the four communities and witnessed peer interactions firsthand, the importance of the communities' philosophy to its members may have been lost in interviews. For this reason, we briefly describe our process for collecting documents and conducting observations.

We began the study with a review of documents and a visit to the main offices of each community to conduct an archival analysis. We collected historical documents, notes from meetings, planning documents, advisory board correspondence, correspondence between leaders, grant applications and reports, reports for advisory boards and other key groups, as well as on-going correspondence with the community via newsletters, publications, and weblogs. Each of the communities held a "signature event," a large, annual, multi-day conference, which we attended and observed. We joined their listservs, visited their websites regularly, and attended other key events throughout the duration of the project. Observations took place from early 2012 to mid-2014, and culminated in approximately 320 h of observation data. During observations, we recorded field notes using an observation protocol guided by the literature on CoPs. Notes were typically between 30 and 35 pages long, single-spaced, for each event, and compared for accuracy. The interviews were digitally recorded and transcribed and lasted between one and two hours. Interviews followed a common protocol, informed by the CoP literature, that asked about impacts or outcomes from participating in the community and other areas related to their engagement and involvement.

Data Analysis

All qualitative data were coded and analyzed using Boyatzis' (1998) thematic approach. First, the three team members (principal investigator, and two graduate students) manually read and searched the data for new or emerging inductive codes. Second, we applied deductive codes derived from the literature on CoPs. These codes included items noted as important in the literature related to stages of CoP development, design principles, impact, and outcomes. We applied inductive codes to interview data that focused on particular challenges these communities encountered and any barriers to achieving their goal of STEM education reform. We clustered the coded language from interview transcripts and compared it to find common substantive themes. For example, language pertaining to teaching-focused "fringe faculty" (a phrase used by several participants to describe their marginalized status) was combined with language about assessments and evidence that ideas and activities work; and both were categorized under the general theme of "legitimacy." We then refined themes through diagramming and clustering (Miles and Huberman 1994) and examined them in order to determine whether they were specific to any lifecycle stages.

To assess trustworthiness, two advisory boards, an external board of national STEM experts and an internal board comprised of members from each community, informed the study design and reviewed our results: The members of the internal advisory board were able to determine whether the findings reflected their insights and experiences and to serve as a member check for added trustworthiness. The external advisory board gave feedback on our preliminary findings and helped to clarify and refine the themes and categories discovered during data

analysis. Finally, all three members of the study team gave feedback and contributed to a refinement of the final five challenge categories, thus adding to the reliability of the codes identified.

This study has one important limitation. Given that all four communities are long-standing, with histories lasting over 30 years, several of the challenges they experienced occurred many years ago; and participant memory may impact the validity of our findings. To mitigate this limitation, we examined documents and conducted archival analyses in order to triangulate what we identified in interview data.

Findings

What follows is an in-depth discussion of the five primary categories of challenges encountered by the four communities throughout their lifecycles—funding, leadership, staleness, perceived threats to legitimacy, and maintaining integrity. For each challenge, we provide a definition, which we articulated based on our interview data, and any associated subthemes as well as the solutions used by the communities to address those challenges. Our interview data revealed that all four communities exhibited each of the five identified challenges to some degree. Although some communities addressed certain challenges more successfully than others, they have all achieved success thus far in meeting their reform goals due, in large part, to the ways that they navigated obstacles. Table 1 summarizes the challenges encountered by the communities, solutions to them, and connection to the meta-strategy of flexibility that emerged.

Funding

Definition and Subthemes The funding challenge refers to the specific struggles encountered by the communities due largely to their initial reliance on short-term grants. Because all four communities were launched with soft funding from the National Science Foundation, they have all encountered financial challenges throughout their lifecycles. Funding challenges often affected the community indirectly through their impact on key events that had to be cancelled, downsized, or held in inconvenient locations. Some community members were impacted directly through the elimination of travel grants and reductions in salary, and a few project leaders continued to work without receiving salaries. According to one participant, PKAL's principal investigator never received a salary but would actively seek out funds to support its staff. Though many of the communities maintained a small staff, these groups were insufficient to manage the bulk of activities, which were handled predominantly by volunteers.

Funding struggles tended to impact the communities most by limiting their ability to hire and retain administrative staff, to recruit new members, to develop new leadership, and to train members to develop materials. Despite their grassroots beginnings, all four communities engaged in recruitment efforts to disseminate their STEM reform missions to larger audiences. These efforts included presenting at institutions across the country; hosting regional workshops and inviting new schools to attend; and more direct outreach efforts like newsletters, email, and social media. These tasks were much easier to sustain in the early days when the pool of participants was small; but, as the communities grew, grant money became insufficient to hold face-to-face events and meetings or develop new materials. One BioQUEST participant

Table 1 Summary of Challenges

Challenge	Definition & Subthemes	Solutions	Connection to Flexibility
Funding	Overcoming dependence on grants and soft funding; learning to sustain independently.	Adopting a self-sustaining mindset: <ul style="list-style-type: none"> • <i>Commercialization</i> • <i>Cutting expenditures</i> • <i>Transformation/merger with a supporting umbrella organization</i> 	Ability to adapt to new markets and financial opportunities
Leadership	Managing leadership as the community grows.	Separating the community from its key leader: <ul style="list-style-type: none"> • <i>Succession plans;</i> • <i>Leadership development programs/workshops</i> 	Flexible leaders who are willing to listen and move aside if necessary
Legitimacy	Gaining followers despite lack of recognition by dominant groups, such as the STEM faculty community.	A way to prove that practices work: <ul style="list-style-type: none"> • <i>Provide targeted evidence that practices work through self-assessment, data collection</i> 	Ability to adapt to needs of the market and the audience.
Staleness	Keeping members engaged and energized, overcoming loss of novelty or interest. Subtheme: stale leadership	Allowing for criticism and self-reflection <ul style="list-style-type: none"> • <i>Advisory boards</i> • <i>Addressing stale leadership</i> 	Flexible leadership with capacity for self-reflection to adapt to needs of community for novelty and external ideas
Maintaining Integrity	Managing tension between growing/sustaining, and staying true to community members and mission. Subtheme: Managing knowledge and materials	Reflection on purpose of the community <ul style="list-style-type: none"> • <i>Conscious evolution</i> • <i>Transparency of goals and mission among leaders and members</i> 	Self-assessment to recognize paths not in line with original mission, and the flexibility to alter the original mission if it no longer suits the needs of the community leaders

explained, “There’s lots of money set out to start things” but very little to keep things going without a commercial business model.

Solutions The communities took a variety of approaches to solving funding challenges. For example, POGIL foresaw challenges with grant funding early on; and, instead of spending down a grant, it adopted a self-supporting mindset. It began to market its activities and materials to generate income through royalties. By contrast, BioQUEST was uncomfortable with the idea of selling its materials because of its history as an open resource. Instead, it addressed funding concerns by cutting back on outreach expenses like newsletters and arranged board meetings to coincide with existing events.

Solutions to funding challenges tended to involve flexibility in goal setting and openness to new ideas and funding opportunities. For example, SENCER dropped its work with disciplinary clusters, despite it being written into the original grant, when leaders learned how fragmented some disciplines were. Instead, it adopted a regional group model, which was successful in bringing people across disciplines together on a specific topic. Uncertain financial futures forced the communities to adjust their short-term goals over time in order to secure funding and persist. For POGIL, this meant commercializing its curricula and instructional materials and transitioning to non-profit status.

Leadership

Definition and Subthemes We define the leadership challenge as the problems experienced with existing leadership as the communities evolved and grew. In the early years of SENCER, POGIL, and BioQUEST, leaders were essentially hand-picked by the principal investigators and then extended outward to those individuals' inner circles as compared to a more emergent model of leadership development like the formal mentoring system used by PKAL. Each community had one or two key leaders who were often the founders or longest-standing members and who had several important features in common. First, they were charismatic. One SENCER participant explained that "David Burns is a particularly inspiring individual... if you didn't have somebody who was quite so charismatic, I don't know that SENCER would be quite as effective." Second, the leaders embodied the mission of the community and exhibited such commitment to it that they seemed to live its philosophy. From a POGIL participant: "Rick Moog is a dynamo... very enthusiastic, very positive. I don't think he ever sleeps. So just incredible vision and hard work and enthusiasm."

The primary problem with hand-picked leadership is that it does not always suit the community *as it grows*: "The model that we worked on for 20 years was not a sustainable model because Jeanne was the force...we all had leadership roles; but the leadership was never, in a sense, dispersed, or passed on, or anything like that." Despite attempts to institute regional and local leadership, the communities suffered when it was time for their key leaders to step down or move on. When handpicked leadership steps down, communities will attempt the "routinization of charisma," as one PKAL participant called it, or the attempt to pass on the unique charm of previous leaders, which "isn't viable long-term." That same participant explained that "trying to take an organization that was created and managed charismatically and bureaucratizing it most often kills it."

Solutions Communities recognized the importance of planning for the future in order to address leadership challenges. These plans had some commonalities such as ensuring a certain number of new members every year and constantly promoting members into positions of responsibility and leadership. POGIL developed a formal succession plan, while others developed programs designed to foster leadership development. PKAL's "Faculty for the twenty-first Century" initiative, or "F21," was designed to discover early career STEM faculty and hone leadership skills through workshops and professional development. SENCER's leadership fellows program supports members who are interested in developing their own projects. Bringing in new leadership meant that older leaders needed to step aside, which was more difficult in some communities than in others. It required not only changes in personnel, but also changes to the norms and organizational structure of the communities. Since the tasks of decision-making, planning, and organizing were almost exclusively held by the communities' key leaders since their inception, it was difficult to separate the identity of the community from the leaders themselves.

Perceived Threats to Legitimacy

Definition and Subthemes We define legitimacy as acceptance by dominant institutions or cultures. For the four communities we examined, the dominant elements are the norms and values governing the mainstream academic community, which typically reward faculty research over teaching. Due to several factors all four communities to some degree perceived a

lack of acceptance from the academic community. One of the primary reasons for this was their focus on teaching and pedagogy as opposed to research. Faculty members who are particularly interested in teaching effectiveness tend to be on the periphery of dominant academic structures. For instance, one participant explained that SENCER members tended to “start out as a fringe faculty, but we believed in what we were doing.” One POGIL leader stated that he was told by early career faculty that “... if they were to try to do any of this POGIL stuff, they would not be given tenure.” These perceived threats to legitimacy tended to deter both potential members and funders.

Solutions All of the communities engaged in some degree of assessment of their practices in order to build credibility and demonstrate that their ideas and practices were legitimate and important for the STEM community. SENCER relied on the Student Assessment of Learning Gains survey for students participating in SENCER courses, while POGIL recognized that data demonstrating effectiveness required that it place boundaries around what it means to use POGIL materials. Regardless of the tactics employed, all of the communities learned early on that, in order to survive and continue to grow, they would need to demonstrate to potential funders and institutions that their practices worked and were therefore worthy of notice and attention. As with solutions to the other challenges, the communities’ success depended on their ability to adapt to the needs of funders and institutions in order to justify their importance and continued relevance to the STEM community.

Staleness

Definition and Subthemes We understand the challenge of staleness as relating to problems that resulted from a loss of novelty in all elements of the CoP: domain, community, or practice. All of the communities dealt to some extent with staleness. Whether in ideas, leadership, or materials, “changing markets, organizational structures, and technology can render the community’s domain irrelevant” (Wenger et al. 2002, p. 109). For instance, one SENCER participant complained of attending the same lecture at multiple events: “It seems like we’re still relying on the same [material for presentations]” when what was needed was “more voices from more people” rather than a single voice from a knowledgeable person. A BioQUEST participant said, “What was great in 1990 [is] not the best thing since sliced bread in 1998.” Staleness impeded the communities’ ability to evolve, and the communities struggled to remind themselves that they do not know everything.

One subset of staleness we found was stale leadership within the communities, which meant that key events were always planned by the same people or that leaders refused to acknowledge the need for change when things seemed to be functioning smoothly. “It becomes easy to not change because you have something working well, and how do you constantly stay alert to the need to change?” Fresh faces were helpful in combating staleness in leadership, but often not enough: “New people are not as powerful a force as you might think” because leaders have “to also be committed to being self-critical” in order to recognize what is not working and to give those new people a voice. We heard that leaders sometimes found it difficult to relinquish control to new members.

Solutions Solutions to staleness largely depended on whether the communities were able to make room for new ideas and to adapt to new directions based on those new ideas. Our

interview data suggests that self-reflection and criticism were effective strategies for dealing with staleness because they prevented the communities from becoming too rigid in their practices, allowing them to better adapt to the needs of community members. Because adopting new directions was the province of leadership, addressing issues of stale leadership was found to be an effective solution to overall staleness.

One community leader noted the importance of building in checks and balances to the organizational structure, such as an external advisory board which can reinforce the significance of new ideas and new voices. One SENCER leader stated that “the biggest challenge is to make sure that new leadership comes in,” but it is important that it does not stray too far from the original vision of the community because this could rattle long-standing community members.

Maintaining Integrity

Definition and Subthemes We chose the phrase “maintaining integrity” to summarize the challenges that arise when the needs of the academic community, funders, or STEM fields are not aligned with the needs of the community. All four communities struggled to stay true to their original missions while adapting to changes in their environments. This challenge often came about after a dramatic shift in focus, such as a venture into new domains or a new commercial endeavor. As an example, POGIL shifted focus when it decided to commercialize its materials by developing a curriculum that they could market and also expanded to high school, thereby generating sufficient revenue to sustain themselves. Integrity problems arose for POGIL because high school curricula did not conform to the original community mission and “wasn’t specifically written into the original grant funding it.” The challenge for the communities was to find balance between pursuit of the original cause and survival at times when those two objectives conflicted. Sometimes the challenge to integrity manifested itself as a matter of loyalty to persons instead of loyalty to a cause. For instance, PKAL’s grassroots beginning attracted a community of deeply devoted followers, but after its merger with the Association of American Colleges and Universities there were concerns that the people and traditions at the heart of PKAL would be absorbed by the larger organization.

A similar struggle was encountered by the communities which had developed regional groups. SENCER’s regional centers were successful in some regions and not others because participants struggled to feel connected to a larger purpose within their separate centers. Because the identity of the national communities was so entangled with the key leaders, it was difficult to establish a cohesive identity that would translate from the national to regional groups.

Other challenges tended to surround the management of domain and materials in the face of community growth. As all of the communities expanded from their grassroots origins, it became difficult to adapt in order to remain relevant to the members that they served. BioQUEST encountered this challenge when it was pressured to commercialize its software for the first time. From its inception, BioQUEST’s leaders were committed to open access and had always been uncomfortable with a commercial model. In order to partner with certain organizations they were required to charge for software, and it was a “hard thing to be able to walk in there, and people thought we were marketing our software when we really weren’t.”

Solutions Solutions to integrity issues depended on the origin of the particular challenge. However, because all integrity challenges touched on the fundamental purpose of the

community, successful strategies required self-awareness on the part of leadership and transparency of goals and mission. One person explained as follows.

Let's look at our mission. 'Have we been successful in the mission? If we aren't, then we need to change what we're doing. And let's look at why we are. Is it because we're doing it wrong? Did the environment change? Are our assumptions off? What's going on here?' Right? Okay. And then it's, then it's being able to ask ourselves the question, 'Is it time to pack up our chance, declare victory, and ride off into the sunset? Or is there another challenge beyond this?'

The communities overcame such challenges by reflecting on their purpose and by evolving to best serve their community given their limitations. In order for POGIL to brand its materials, it had to standardize requirements, which it accomplished through a strong central office. One POGIL leader explained that there is now a push from members for more flexibility, and the community has had to ask how it "can empower [members] to do work. And how can we do that and still maintain the integrity of what we call POGIL? And how will we manage that over time?" One PKAL participant explained that passion and self-reflection have been fundamental to the community's success: "Self-assessment is very important, too. And you find that in PKAL people. You find people who are willing to take that high-powered sense of perception and turn it inward, and that can be kinda, you know, scary." The decisions of the communities were often difficult, requiring leaders to decide between the immediate needs of the field and their members on the one hand and on the other the needs of the community itself to ensure its survival.

Meta-Theme: Flexibility to Ensure Survival

It is important to note a common feature across all five of the challenge categories. The most successful strategies reflected flexibility on the part of leaders and decision-makers and in community design. The solutions employed by the communities were not often small or easy changes, and making changes became more difficult as the communities grew. Leaders were able to recognize complacency as a threat to the diversity of ideas and to community growth, largely through self-awareness and openness to outside ideas as well as a focus on long-term usefulness. We concluded that *flexibility* was required of all communities in order to achieve success.

The theme of flexibility that we found shares similarities with Wenger et al.'s (2002) concept of "aliveness." Wenger et al. (2002) explained that CoPs can be designed for aliveness by incorporating several strategies, including opening dialogue across inside and outside perspectives, combining familiarity with excitement, and focusing on their value. CoPs that are "alive" are then able to grow organically and "reflect on and redesign elements of themselves throughout their existence" (Wenger et al. 2002, p. 53). The communities designed for evolution by facilitating interactions among members through events, workshops, and mentoring, which allowed for the organic development of new and different ideas; and they promoted discussion about differing internal and external perspectives by proactively incorporating new disciplines (from chemistry to biology for POGIL), diverse leadership (through F21 for PKAL), and rewarding members for developing their own novel projects (SENCER leadership fellows). However, the flexibility needed for success within these four communities was much more intentional than Wenger's organically developed CoPs: because of the

financial, geographic, and mission-driven differences between these communities and Wenger's CoPs. Our findings indicate that BioQUEST, POGIL, SENCER, and PKAL all anticipated and proactively tried to address future challenges through their willingness to adapt to changes in their environments. One possible reason for this intentionality is that, unlike Wenger's CoPs, which can be small and informal or organizationally located, these four communities ultimately strove for a common purpose—survival.

Discussion and Implications

This discussion focuses on two related conclusions that arose from our data. First, three of the challenges we found are not noted in the CoP literature, which suggests some important differences between institutionally-based CoPs and these four national communities. Second, because of these differences, we conclude that future leaders in STEM reform should design their communities for “aliveness,” with community growth as a foundational consideration.

Of the five challenges we discovered, only staleness and maintaining integrity were similar to Wenger et al.'s (2002) tensions. The other three challenges we encountered in this study—perceived threats to legitimacy, funding, and leadership—were not noted in the CoP literature. The appearance of these challenges reflects certain features across the four communities that do not fit neatly into a CoP classification, which is largely attributable to their uniquely distributed structures and the fact that they are not institutionally-located.

The *perceived threats to legitimacy* theme emerged as a result of the communities' desire for the respect of the larger STEM community. This challenge reflects the perception that leaders and members see themselves, to some extent, as being on the periphery of the academic community. Whether to persuade funders, recruit members, or convince faculty members to adopt their practices, these communities have only been able to achieve their goals of STEM reform by proving that their teaching approaches worked. Each community sought to change some fundamental assumptions underlying STEM education. Unlike small, institutionally based CoPs, their “practice” extends far beyond a single organization. A core mission of these four communities is the large-scale reform of STEM education. In order to accomplish this mission (e.g., to recruit members, win over department chairs, and persuade funders to finance it) they needed to demonstrate their value to the community they seek to change.

Funding was a distinct struggle for these communities for two reasons. First, unlike typical CoPs, these four large and dispersed communities are not housed within any form of parent-organization; and they were fostered independently of a supporting body. Though all four were the result of grants from the NSF, these grants were short term. As the communities grew, so did their financial needs; and they were faced with different kinds of choices than those of a typical CoP. The communities needed to support themselves in order to survive, and so they sought out commercial endeavors as a means to financial independence. Second, unlike typical CoPs, these communities are national STEM reform efforts with a national agenda: to improve the teaching practices of STEM faculty and promote large-scale institutional change. Our data reflects that growth was the most effective way for these communities to achieve change.

Finally, the *leadership* challenge was unique to these communities because of the special importance attached to these leaders by the community. The identities of the key leaders were so inextricably linked to the communities' culture that a leader's retirement or departure brought about fundamental changes. Members connected with their communities and the leaders themselves at an epistemological level. One explanation for why the message of

leaders was so compelling may be that the communities' domains of knowledge are deeply rooted in philosophies of teaching and learning that are not limited to a single skill set. The topics with which these communities engaged are intertwined with effective ways of transmitting knowledge—a topic with important and far-reaching implications for a much larger population than a single organization or academic discipline.

Our findings suggest that the most effective way of addressing the challenges we identified is in designing strategically for “aliveness” (Wenger et al. 2002). Because growth of the communities is essential to their mission, initial decisions on costs, leadership, and long-term goal-setting should be made with this growth in mind. For these communities, designing for aliveness resulted in flexibility of the communities' organizational structures, of leadership, and of goal-setting. Wenger et al.'s (2002) design principles are a good starting point for future national STEM reform communities; but because of the unique, change-oriented missions of these communities, they require more goal-based policies and more structured and sustainable leadership plans to set the direction and ensure that the community stays on course, as opposed to organic development from grassroots. This may mean that, in addition to internal and external advisory boards, the communities would benefit from subcommittees of members and leaders who deal exclusively with issues of marketing, event-planning, recruitment, and strategy.

Conclusion

In closing, in this article we identified the five primary challenges encountered by four national faculty STEM reform communities in order to explore the ways that they navigated these challenges so as to succeed in their mission of reform. We found that, while the communities are similar to Wenger et al.'s (2002) CoPs, they differ in significant ways. Based on our analysis, we concluded that the success of the communities was due in large part to their flexibility—their ability to adapt to uncertain environments, thereby, as one participant put it, “spawn[ing] ideas for mentorship, and building communities, and moving things forward that are highly adaptable in a variety of situations.” This research is important to the literature on STEM education because of its potential to contribute to the design of future STEM reform communities for longevity and effectiveness and to help achieve STEM reform at scale.

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