

Strategies for Achieving Scale within Communities of Practice Aimed at Pedagogical Reform in Higher Education

Dr. Adrianna Kezar
University of Southern California

Dr. Sean Gehrke
Everett Community College

About 20 years ago a group of faculty in chemistry began to meet to discuss the challenge of student success and believed new teaching approaches were needed. They also read national reports about problems in STEM and wanted to address these national concerns and develop solutions. They first met at chemistry disciplinary conferences and then began to meet regionally in the mid-Atlantic. They developed a new pedagogical approach using more active and group-based learning approaches. They tested this approach and demonstrated success for students through greater learning gains, persistence, and pass rates. Several faculty submitted and obtained an NSF grant. They eventually obtained another NSF grant and branched out to other funders and began to grow as a community. They used their initial grant to start gathering faculty at workshops and an annual national meeting. They began to be a robust community of practice around this new teaching pedagogy. Over time, they realized that they wanted to enlarge their group and began to seek strategies for recruiting more individuals at their institutions and shaping the broader STEM landscape.

These are common anecdotes from most campuses, but few systemic solutions have been developed for addressing the need to improve STEM education and increase the use of evidence based teaching approaches in courses. One strategy of increased attention for scaling up curricular and pedagogical reforms has been the formation of communities of practice (CoP). A CoP is a group of people 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, 2007). What has attracted higher education leaders to CoPs is that they are a peer-based model of learning with colleagues, which works well for professionals such as faculty. Additionally, top-down mandates for change have been largely ineffective (Henderson, Beach, & Finkelstein, 2011; Kezar, 2011). A CoP draws on the natural motivation of individuals that share a common practice and connect on a similar domain, a new pedagogical approach.

While there is increasing literature calling for CoPs to be developed at the institutional level (as well as more

broadly across the profession through disciplinary societies), there is very little research about CoPs in higher education. We do not know how they form, grow, and sustain themselves (referred to as lifecycle stages); the major outcomes of participation in such groups; and how can they be designed to best foster outcomes such as improved teaching and departmental curriculum reform.

Funding agencies in the US, such as the National Science Foundation, have historically supported efforts to scale STEM reform. As a result, several CoPs dedicated to STEM reform have long-standing histories, which contain 2,000 and 7,000 faculty each, and can be studied to examine outcomes, design, and lifecycles of these entities. STEM CoPs such as these that exist at the national and regional level involve thousands of faculty. They host events; have resources such as curricular modules, journals, and newsletters; and provide on-going networking opportunities for the faculty who participate. Some aspects of the communities, such as newsletters and regional network meetings can be free, but they often charge for publications, curricular resources, and major events. We identified four long-standing CoPs and studied them with the goal of understanding how they are designed to achieve their goals; benefits of participation in them; and how they form, grow, and are sustained.

This paper focuses on the results from the third emphasis related to these CoPs' lifecycle and is framed by the literature on CoPs related to the five stage lifecycle model (Wenger, McDermott, & Snyder, 2002). We focus specifically on the third stage called maturing in which we identify some substantial variations in the higher education CoPs aimed at broadening their reach and recruiting new members. Our research question was: How do STEM reform communities grow and increase their impact on STEM reform over time? It appears that the desire for scale across a large enterprise like higher education created a series of recruitment and growth strategies that are not typically found in the traditional CoP literature. The contribution of the study is in identifying some unique features to CoP lifecycle aimed at a broad scale and enterprise-level reform in higher education. The study also helps CoPs within higher education as well as in other sectors in identifying practical strategies and challenges related to adopting these recruitment and growth strategies.

The Lifecycles of CoPs

Much of the early research on CoPs focused on how they develop or form, how they grow through stages where they bring in more members and create a more

Stage	Tension/Challenge
Potential: Start as a loose network of connections with potential for growing and developing more connections Coalescing: More connections are built, coalescing into a community	Discover/Imagine: Build on what is present or explore where potential could lead Incubate/Deliver Immediate Value: Allow connections to form and build trust slowly or immediately try to show value of the community
Maturing: Membership and depth of knowledge in community grows Stewardship: Actively share and develop knowledge formed through community	Focus/Expand: Direct energy to own interests or expand with interests of others Ownership/Openness: Balance ownership over community domain with need to bring in new ideas
Transformation: Community evolves as new members enter and/or energy wanes	Let Go/Live On: Either let the community wane or transform in order to sustain

Table 1: Stages of community development and key tensions/challenges for developing communities of practice (Wenger et al., 2002)

¹ We undertook an extensive review of the literature and found no studies directly addressing different phases of CoP lifecycles that were pertinent to this study. Therefore, we review the lifecycle model for CoPs to set the context for this inquiry.

Community	Focus	Year Est.	Size of Community	Major Work of CoP
BioQUEST Curriculum Consortium	Active learning through simulations and technology	1987	2000	On-line collections of curriculum and tools, Virtual communities and communication; Grants; Publications
The POGIL Project	Process oriented guided inquiry learning	Late 1990s, but started under formal organization in 2002	6500	Workshops; Curriculum materials; Textbooks; Implementation materials
Project Kaleidoscope (PKAL)	Active pedagogies, relevant and context based, culturally informed pedagogy – summarized as “what works”	1989	7000	Annual gatherings, Regional networks; Grants; In-person emphasis
SENCER	Civically engaged, relevant and context based STEM education	2002	2500	Annual conferences; Publications; Regional events; Assessment

Table 2: Overview of the CoPs

defined community, and how they eventually sustain themselves over time when they are often lacking in organizational structure (Stuckey, 2004; Wegner et al., 2002). The best known framework for the lifecycle of CoPs was offered by Wegner and colleagues (2002), who created a five-stage community development model based on extensive empirical research on CoPs. The model includes the following stages: 1) Potential; 2) Coalescing; 3) Maturing; 4) Stewardship, and 5) Transformation (Wegner et al., 2002). They also outline the specific challenges or tensions for each stage, which are outlined in Table 1. These challenges represent areas that might impact the viability or growth of CoPs.

We briefly review the elements of the model that guided our exploration into higher education CoPs.¹ The first phase, potential, is where an important topic attracts an informal group who are interested in beginning to work together. Wenger and colleagues (2002) note that at some point the “idea of forming a community is introduced into [a] loose network, and this prospect starts to redirect people’s attention. They start to see their own issues and interests as communal fodder and the relationships in a new light of a potential community” (p. 71). As the sense of a shared domain develops, more systemic planning and activities begin. The beginning work at the potential stage is to define the scope of the domain that brings people together, to find people who see the value in increased networking and sharing of ideas, and to identify what common knowledge is needed to further the community. Through this stage the emerging community creates a vision and sense of mission.

During the second stage, coalescing, people come together and launch the community and find value in engaging in learning activities together (Wenger et al., 2002). At this stage leaders in the community are facilitating dialogue, creating informal meetings, developing initial community support and communications, and developing organizational supports for the long-term. Within this phase the focus is to create enough interest for continued participation and involvement to establish the value of the domain. The community needs to develop

enough trust and build strong relationships to get through philosophical challenges and other issues that emerge. The community also needs to develop key avenues for sharing information and creating information rich resources.

In stage three, maturing, the community begins to take charge of activities and grows in size (Wenger et al., 2002). The community is involved in many joint activities, active learning is on-going, and the growing community is developing standards for how they will interact over the long-term. In the maturing stage, the community needs to clarify and focus its role and boundaries. As the community grows, new ideas are brought in that might expand or change the domain of its focus. The community needs to find ways to stay focused on its core purpose and mission while still including greater numbers of individuals. A key issue related to practice focuses on organizing resources and knowledge for the long haul; the community needs to systematize its practices and create a rhythm of activities that community members can count on. Also, as the community identifies gaps in knowledge, with community growth a challenge arises in creating additional resources to meet the needs of new members. The challenge of focus and expansion is palpable in this phase.

In stage four, stewardship, the community is well-established and needs to find ways to sustain energy, renew interest, and continue to gain new members. In this stewardship phase, the community is trying to sustain its momentum as continued new members join, as energies can decline over time among longtime leaders, and the ideas of the community can become stale and less intellectually interesting. Stewardship is a balance between creating ongoing ways to bring in new ideas while remaining focused, to bring in new energy as well as support to long-time leaders and to bring in new people to re-energize. Wenger and colleagues describe the maturing and stewardship phases under the same broad label of maturing and sees these two phases as hard to separate distinctly.

Lastly, the fifth stage is transformation. Wenger and

colleagues (2002) note that a tension exists between a community’s sense of ownership and its openness to new ideas that is never fully resolved and often results in crisis. As the community widens its boundaries, it risks diluting its focus. If the community stays closed it can suffocate itself. However it is natural that these events occur and sometimes the influx of new members may create a new focus for the community as it transforms. Other times the community may cease to exist because members no longer feel that its purpose is relevant or needed. This model informed our understanding of the lifecycles of the four communities in our study.

Methods

The overall study employed an exploratory mixed methods approach, including interviews, observations, document analysis, and surveys (Details about the mixed methods design can be found at: <http://www.uscrossier.org/pullias/research/projects/achieving-scale/>). The data for this paper largely draws from analyses of interviews and document analyses from our archival research. We first describe our selection of the four communities in this study, followed by data collection, analysis strategies and trustworthiness.

Sample Selection

Our interest was to focus on communities that had the following key features: 1) STEM education and reform as focus; 2) Large in scale and leading to dissemination of best practices; 3) Focused STEM reform within the context of postsecondary education; and 4) Long enough history so we could study not just formation but also outcomes and sustainability. Regarding the four communities, Project Kaleidoscope (PKAL) is a national community of STEM faculty that focuses on creating innovation among faculty so that they change their practices. The POGIL Project is a national professional development and curriculum reform effort whose mission is to connect and support educators from all disciplines interested in implementing, improving, and studying student-centered pedagogies and

learning environments. Science Education for New Civic Engagements and Responsibilities (SENCER) is a faculty development and STEM education reform initiative that approaches STEM education reform through complex, capacious, contemporary, and contested civic challenges and an interdisciplinary approach. The BioQUEST Curriculum Consortium supports undergraduate biology education reform. (For more details about the work/focus of these CoPs see Table 2, and for even more details see: <http://www.uscrossier.org/pullias/research/projects/achieving-scale/resources/>).

Data Collection

Document analysis and observation. The study began with a review of documents and a visit to each main office to conduct an archival analysis to develop a context about the four CoPs. We collected historical documents on the CoPs to trace their development over time. Items collected include: notes from meetings; planning documents; advisory board correspondence; description of their missions; philosophy and values; key correspondence between leaders; grant applications; reporting on grants; reports for advisory boards and other key groups; as well as on-going correspondence with the community via newsletters. As part of participant interviews, we also collected key documents that they noted as helpful in understanding development of the CoPs to include publications, web-blogs, or newsletters.

Interviews. After our review of the documents, we interviewed 112 people – between 26 and 30 people with each CoP to include the organization staff and faculty leaders. We asked the leadership of each CoP to help us identify key staff members, faculty leaders, and other faculty participants, using a snowball sampling technique. Each CoP is supported by current and past leaders and staff and have long-standing members and leaders that have helped with sustainability of the CoPs. We also interviewed faculty (approximately two to three from each community) who had less involvement in the CoP to get a sense of their experience as well. Interviews lasted between one and two hours and followed a common protocol informed by the communities of practice literature that asked about the formation; development, and ways the community has been sustained; challenges over time; impacts or outcomes from participating in the community; involvement; what they found most engaging in the community; and what they perceived shaped the outcomes they noted. All interviews were digitally recorded and transcribed.

Data Analysis

Data were coded and analyzed using Boyatzis' (1998) thematic approach. This approach involved first going

through the data for new or emerging inductive codes. Second, deductive codes derived from the literature on communities of practice and learning communities was then applied. Deductive codes included items reviewed in the literature related to stages of the CoP lifecycles. The qualitative data were analyzed using Hyper Research (a qualitative software program) that helps manage and analyze large amounts of qualitative data and eases the coding process. All forms of qualitative data including interview transcripts and documents were input into the software.

Trustworthiness

We utilized multiple forms of trustworthiness including outside experts and auditors, member-checks, triangulation, piloting, and multiple coders. Two advisory boards informed the study design (including all the data collection protocols and instruments) and reviewed results; one was an external board comprised of national STEM experts, and one was an internal board comprised of members from each of the four CoPs. The internal board conducted member-checks by examining whether the findings seemed to reflect their insights and experience. We piloted the interview protocols with the advisory board members who were STEM faculty reformers. Triangulation included data from multiple sources – documents, observations, and interviews. Lastly, we had three different data coders that compared their interpretation of the emerging trends and coding of deductive codes within Hyper Research. Coding was conducted separately and then compared and discrepancies discussed to fine-tune interpretation.

Findings

In the beginning phases (potential and coalescing) of the lifecycle, these higher education CoPs looked quite similar in their stages of development to the model presented by Wenger and colleagues (2002), displaying the same dynamics and challenges. We identified a departure in our data at the maturing and stewardship phases both in terms of the emphasis on wide and expansive growth (typically not described in the CoP literature) and strategies related to growth. These efforts appear tied to their goals of broadly influencing change in STEM reform nationally, whereas most CoPs studied tend to have more localized goals (e.g. a single institution) around learning. In addition, we also identify some distinctive growth strategies adopted by these four CoPs. In the potential and coalescing stages, all CoPs focused mostly on supporting individuals through the creation of workshops, conferences, and newsletters/websites.² These more individual approaches to learning are also most characteristic of

the CoP literature (Wenger et al., 2002). Thus what was unique was during the maturing stages of development, the CoPs moved into six foci areas using a plethora of strategies to spread and deepen their reforms aligned with community strengths and history.

The communities in our study adopted these six foci to spread reforms and promote growth: *disciplinary, institutional, sector-focused, constituent-based, national, and international*. Table 3 presents summary of the findings for each foci; within each foci we include information related to growth, strategies, leverage points (related to their strength, capabilities, or history), and related challenges – all detailed in the narrative.

In this article, we describe and document these various approaches to STEM reform not captured in any other study. Their stories of the maturing phase demonstrate how communities decide on strategic approaches that build on their strengths or unique strategies to which they have access, which we label leverage points. Each of these foci can be important to deepening and spreading STEM reform and are important for future STEM reform leaders to be aware of.

Each CoP mentioned that their interest in expansion was to meet the needs of STEM reform, but the communities were not aware of these foci from the onset and described how knowing about them would have been helpful to their expansion, sustainability, and success, which is why we felt it important to highlight them in this article. We highlight ways they overcame challenges when such approaches were identified. But in many instances growth strategies had challenges they never effectively addressed. Because of space limitations we highlight only a few strategies in the findings, but have the full list in Table 3. [Insert Table 3 Here]

Disciplinary Focus

Overview of characteristics and strategies. Two of the communities used disciplinary or professional societies as an approach to achieving STEM reform. The assumption within this approach is that the disciplinary societies strongly shape the teaching norms within different fields and that by working through them you can effectively alter the approaches to teaching within different fields. There were four main strategies these CoPs used within a disciplinary approach – developing textbooks, developing materials, conducting meetings at disciplinary societies, and obtaining grants that were focused on reaching new disciplines.

Leverage point. It is perhaps not a coincidence that these two communities were strongly embedded in single disciplines to begin with (POGIL with chemistry and BioQUEST with biology) and had access to disciplinary lead-

²Two of the communities had gone through the last phase of transformation, and the CoPs experience in these stages mirrored the CoP literature.

³Throughout the finding section, we attempt to list challenges after strategies. However, in some sections we embed challenges into strategies as it is easier to understand

them when discussed with the strategy. When we do so, we italicize challenges to make it clear we are discussing challenges for that strategy.

Foci	Characteristics, Strategies, & Leverage Points	Challenges
Disciplinary Used by POGIL and BioQUEST	<p>Shape overall discipline – scale through profession</p> <p>Strategies: 1. textbooks, curricular materials, 2. meetings at disciplinary societies, and, 3 obtaining grants that were focused on reaching new disciplines</p> <p>Leverage point: community has disciplinary leaders within it or access to some influential disciplinary leaders</p>	<p>Having expertise to develop materials and texts</p> <p>If discipline is a secondary strategy can strain resources if do not have link to disciplinary leaders</p> <p>Maintaining disciplinary alliances already gained as community presses into new disciplines</p> <p>Without a critical mass emerging within discipline fairly quickly absorbs too many resources</p>
Institutional Used by PKAL and SENCER	<p>Shape institutional policy and rewards – work on institutionalizing changes within institutions</p> <p>Strategies: 1. work with groups or teams from campuses, 2. institutionalized base grant projects, 3. utilizing consultancies, 4. leadership development, and 5. focus on institution-wide adoption of pedagogy</p> <p>Leverage points: 1. partnerships with organizations that had a connection to institutional leaders on college campuses; 2. institutional leaders part of network</p>	<p>Teams need support once return home</p> <p>Short term perspective of funders related to institutional change strategies</p> <p>Need faculty leadership experienced with working with administrators related to consultancies but also other strategies</p> <p>If do not have established leadership focus or program faculty may not be able to translate these skills onto campus</p>
Sector Used by PKAL, POGIL, SENCER, and BioQUEST	<p>Achieve scale by working within an entire institutional sector (e.g., liberal arts college) – must acknowledge how it requires attention to different sector needs and that sectors are influenced by different drivers</p> <p>Strategies: 1. partner with associations, consortium, or groups that represent the sector; 2. obtain grants to work with the sector; and, 3. host gatherings for individuals in that sector</p> <p>Leverage points: 1. have an entrée thru connection to leaders in a sector; 2. be leader, influential campus or role model in that sector</p>	<p>If partner with a sector may become overly identified and have trouble being seen as relevant in other sectors</p> <p>Sector grants tend to be one time and sustaining relationship within sector can become a strain</p> <p>Sector leaders change priorities all the time; hard to capture interest</p>
Constituent-Based Used by SENCER and POGIL	<p>Scale reforms by connecting to important constituent groups that enable STEM reform efforts</p> <p>Strategies: 1. partnerships with constituent groups, 2. hosting meetings, and, 3 obtaining grants to support work with constituent group</p> <p>Leverage points: 1. location in DC for policymakers; 2. active leadership of students in group; 3. a market or demand from a group – teachers</p>	<p>Lacking a clear mission to work with these groups often no tangible benefits for them – students and policymakers</p> <p>Hard to measure or no value added to these other groups</p> <p>Unable to maintain connection to or provide materials to support constituent group as not a main group within CoP</p>
National Used by PKAL, POGIL, SENCER, and BioQUEST	<p>Scale by spreading the reform across the country and embedding it within state, regional or federal/national groups</p> <p>Strategies: 1. created regional networks, 2. developed other networks or communities, 3. hosted broad stakeholder meetings, and, 4. participated in national reform efforts.</p> <p>Leverage points: 1. concentration of CoP members in a region or area; 2. connection to other networks or national efforts – facilitated by connection to Washington DC</p>	<p>Hard to replicate energy and culture of national CoP within local and regional areas</p> <p>Lack of local leadership or not as strong as can garner at national level</p> <p>Conflict with support of national partnerships/broad stakeholder meetings while maintaining support for CoP</p>
International Used by BioQUEST and POGIL	<p>Scaling by reaching out to faculty and institutions in other countries</p> <p>Strategies: 1. advisory boards; 2. accepted and encouraged national and international invitations</p> <p>Leverage point: No real evidence of potential to tap from stories</p>	<p>Having enough leadership interest to maintain international connections</p> <p>Time investment</p>

Table 3: Summary of Foci, Leverage Points, Strategies and Related Challenges

ers. While the other two communities utilize some of the strategies (e.g., textbooks) and occasionally work through disciplinary societies, this was a secondary or isolated strategy and not a focus of their attention. For example, SENCER has attempted to work with the American Association for the Advancement of Science (AAAS) and some other disciplinary societies, but given it does not have

strong roots or anchor in disciplines, they have found this strategy difficult and have not pursued it much.

Strategies. The POGIL Project created a partnership with a publisher in order to develop a series of textbooks for different disciplines that use POGIL activities. By developing textbooks, they believe they can spread POGIL by making the resources and materials readily available.

As leaders in POGIL noted: “Textbooks define the ways that people teach, and the more that we can embed our practices into textbooks, the more success will have with spreading this approach.” They also noted the importance of working with publishers that provide marketing for textbooks. Originally, POGIL was publishing its own text but could not have the same kind of reach that a publisher

can achieve with marketing lists that target faculty teaching in particular courses and publishers also have booths at almost all the disciplinary conferences. POGIL cannot afford to have booths at so many conferences nor afford the pay for travel. While the POGIL community is made up of mostly chemists (they have expanded into other fields but do not have the same concentration in biology, physics, or mathematics), by creating textbooks for other fields they are able to have a broader reach than they might through merely their workshops or website.

In order to ensure that faculty in various disciplines use these rich resources, both of these communities present regularly at disciplinary conferences and guide people to their textbooks and free online activities and materials. Over the years, they have also had booths at disciplinary conferences that describe their materials. As a BioQUEST leader noted: “we regularly had booths and presentations at NABT, ACUBE and ABLE and all of us [the main leadership group] made sure to cover the major disciplinary conferences that should be familiar with our materials.”

Challenges.³ Leadership in these two communities described the challenge of expanding into new disciplinary societies and being able to maintain a presence across various disciplines. Each had initial success within a single discipline but then struggled (being overextended in time, leadership, and resources) as they attempted to expand or even maintain their presence within that discipline over time: “Within chemistry we are really a known commodity, but in some of these other fields it’s hard to know if we can generate enough leadership or even materials to support people who want to use the POGIL approach.”

Institutional Focus

Overview of characteristics and strategies. Two of the communities decided to focus on creating STEM reform through institutions by encouraging the spread of practices across science departments within individual institutions. The assumption behind working with institutions is that they establish the reward structures and policies that faculty are responding to, and without working with institutions, reform is unlikely. The vehicles or strategies for an institutional approach included having teams of faculty and administrators attend events, institutional-base grant projects, utilizing consultancies, general or broad curriculum based projects, and leadership development.

Leverage point. The two communities that adopted an institutional focus tended to represent a multitude of disciplines and did not have strong ties to any individual disciplines in which to anchor a disciplinary strategy. In fact, both had partnerships with organizations that had a connection to institutional leaders on college campuses – PKAL through its connection to a consortium of private liberal arts colleges and SENCER was originally part

of the Association of American Colleges and Universities (AAC&U), which represents academic leaders nationally.

Strategies. Both SENCER and PKAL had a practice of inviting teams of faculty and administrators to attend their annual conferences, events, and symposium. One leader described the way teams were pivotal to their reform approach:

One of the aspects that PKAL pushed is traveling together as a team to events, and I think that that helps the local people stay together and develop relationships. You don’t hesitate to contact those people when you need advice later when back on campus.

Leaders described how changes are unlikely to occur if only individual faculty members attended events and were isolated change agents on their return to their institutions. Administrators were needed to support changes in policies and practice on campus. And the events were structured so that teams returning to campus could take action to institutionalize the changes. PKAL, for example, had everyone finish the meetings with the development of action plans for when they returned to campus. SENCER provided sessions on helping teams in thinking through the dynamics of institutionalizing change, and SENCER leaders gave consultancies to campus teams to support their return to campus. A challenge for teams is maintaining the commitment once they return to campus.

Another strategy for creating institutional changes and spreading the reform is through consultancies. PKAL obtained a grant from the Keck foundation to conduct close to 100 institutional consultancies with the goal of moving institutions further along in their reform efforts by providing expert advice from experienced performers. One PKAL leader describes the importance of these consultancies:

And then the other layer (for reform) that I think was important was the Keck Consultancy projects where you had core -- you had people that were already successful in certain areas going out to these institutions to consult on anything from curriculum, to department chairs leadership, or working or whatever.

SENCER established what it called house calls, where SENCER leaders would come out to campuses to help them think about ways to “SENCERize” their curriculum. POGIL and BioQUEST also utilized consultancies for a short period of time but eventually stopped utilizing the strategy as they lacked an understanding of how to maximize an institutional approach, which became a challenge; it appears that if a community did not have an embedded strength in a particular focus area that they did not continue their efforts in this area. PKAL and SENCER had expertise related to institutionalizing change and experience working with administration to help them in executing the strategy successfully.

Both PKAL and SENCER recognized that institutional changes required leadership, particularly leadership built among faculty who often lack the skills of persuasion,

vision setting, relationship building, and strategies for implementing change. As a result, both communities created leadership development activities and programs to help foster change agents that could institutionalize the changes they were promoting. PKAL formalized this effort within the Summer Leadership Institute (SLI) that is offered annually to approximately 60 STEM faculty. The SLI offers faculty training on how to be change agents and leaders and to institutionalize reform efforts within their campus. The SLI developed out of an earlier program called Faculty for the 21st century (F21) that brought together faculty who were nominated by institutional leaders who were seen as having the potential to be leaders and change agents. Approximately 1,500 faculty were part the F21 program, and many describe how this program was responsible for many of the changes seen nationally related to STEM reform as these leaders moved into department chair, dean, and provost positions. Similarly POGIL created opportunities for faculty to serve in leadership roles in the community as a workshop facilitator or presenter to build skills over time that might translate into being a change agent. The efficacy of these experiential approaches was not always described favorably by participants and can become a challenge, such as this participant: “Well, I think the intent was that as I played these roles in the community I would develop leadership skills, but it is not clear to me that I have or that this works.” Therefore, a challenge can be the amount of resource investment in structured leadership necessary for faculty to be capable change agents; some of these communities did not provide enough intentional support to make an institutional approach work.

Sector

Overview of characteristics and strategies. Several of these communities began their work with small liberal arts colleges; this is likely the result of much of the experimentation and STEM reform work originating within this sector. Several of the communities then used this as a base to spread across the sector utilizing their relationships. Sector-based strategies can lead to uptake across a significant number of institutions within the sector by leveraging national associations that work with these sectors and becoming part of their collective dialogues, communication avenues such as newsletters and publications, and events such as annual conferences. The assumption underlying a sector strategy is that embedding the reform into various institutional types may require attention to different sector needs and that sectors are influenced by different drivers. PKAL emerging from a consortium of small liberal arts colleges; SENCER’s affiliated with the Association of American Colleges and Universities – although it began at Rutgers a research university; and BioQUEST and POGIL were started at innovate liberal arts colleges. In terms of strategies within the sector, there were three common strategies -- partner with associations,

consortium, or groups that represent the sector; obtain grants to work with the sector; and host gatherings for individuals in that sector.

Leverage point. The communities had two main leverage points for sector: 1) entrée through connection to leaders in a sector; and/or 2) be an influential campus or role model in that sector. Because of their connection to much larger numbers of colleges, PKAL and SENCER opted to work and build across the liberal arts sector. These two reform communities could utilize the larger national organization that represented or worked with liberal arts colleges more easily. In addition, BioQUEST branched out to work with the community college sector due to interests of their leadership. While each of these communities eventually began to work across and with institutions from multiple sectors, they only had a targeted sector approach with the liberal arts sector (or for BioQUEST with the community college sector).

Strategies. The first strategy was partnering with associations, consortium, or groups that represent the sector. Because the sectors are represented by national and regional organizations, the communities partnered with these organizations to create joint publications, presented their conferences/ meetings, and provide communications about the work of the reform communities to the sector. For example, PKAL created joint publications with the Association of American Colleges and Universities, and *Liberal Education* and *Peer Review* now regularly feature articles about PKAL projects. Yet, in partnering with a group that is aligned with a sector, these CoPs can become highly affiliated with those groups and it may be difficult to reach out to other sectors. A faculty member from PKAL described this challenge:

Well, we became too affiliated with liberal arts colleges – not just LACs but east coast liberal arts colleges. We got some grant money to work with state colleges and universities, but they never really saw us as understanding their needs because we were so tied to the LAC sector.

The second strategy was obtaining grants to work in a new sector. BIOQUEST developed a grant called “C3 Cyberlearning Project” that worked directly with community colleges in creating materials for biology courses that include active learning approaches and embed the BioQUEST “3 P’s” of problem posing, problem solving, and peer persuasion. One of the leaders of BioQUEST described their work moving into the community college sector:

We realized that there were lots of faculty who have great willingness and interest in utilizing our materials but they weren’t necessarily going to the disciplinary society meetings. So we wrote grants to deal to work

more directly with biology college faculty that have an interest in our materials and approach.

Many times these groups were led to new strategies by realizing how one of their approaches (disciplinary) was making it difficult to reach another important constituent. Sector grants though tended to be temporary and sustaining the relationship can become a strain: “we have tried for years to get more grants for working with our minority serving colleges but funders seem to feel – well we gave you that money so you should be all set now.”

Constituent-Based Focus

Overview of characteristics and strategies. Two of the communities played an active role in attempting to connect important constituent groups (such as students, policymakers/legislators, informal educators, and teachers) that they felt helped enable STEM reform efforts and broaden their impact. It is important to describe this area because the CoPs felt that these groups could be instrumental in helping them reach their goals. SENCER worked to include student groups in their conferences, events, and communications. Therefore, their assumption is that reform will require outside pressures or resources to be successful. Strategies to reach out to constituent groups did not vary from the other foci areas and intended to draw upon the same strategies of partnerships, hosting meetings, or obtaining grants. Therefore below, we describe the groups and approaches taken.

Leverage point. Two of the communities were located in Washington, D.C., which provided a hub for accessing the policy constituency. While location is not the only way to be successful with this strategy among policymakers, it appeared to facilitate this focus for these two groups. Another way that a constituent group can be leveraged is if there is a market demand, which was the case for POGIL where teachers were pushing for POGIL to create materials and grant opportunities were available. Also, as is the case for several of these foci, active leadership makes this option more viable; this worked in the disciplinary strategy and was also important here as a leverage point with student leaders that emerged and were nurtured in POGIL.

Strategies. One important reform community is policymakers. SENCER created the Washington Symposium and Capitol Hill Poster Session – an annual event that brings faculty, administrators, and student leaders to Washington DC to present the individual reform efforts that were going on at particular campuses. At the event, poster sessions were provided for congressional staff to see the way campuses are changing, particularly

pertaining to solving national public policy issues related to sustainability, health care, poverty and other important policy issues. Through the event, SENCER hopes to gain greater support in terms of grant funding for STEM reform efforts and to encourage more state and local support for STEM reform.

POGIL leaders also actively worked with high school teachers and obtained several grants to bring their teaching methods into different school districts and to develop high school level POGIL materials and activities. Yet over time, POGIL struggled to maintain its commitment to teachers as it does not have a clear mission and focus related to teacher education.

Challenges. Faculty involved with reaching out to these new groups worried about whether these efforts added value to the existing community as well as to these new groups. Reaching out to new groups can diffuse the leadership, energy, and resources of the community. There were also concerns whether the community had expertise and materials to support the new community and if new members would obtain enough value to stay part of the community long-term. A faculty member captured these challenges noted by leaders in each community that adopted the constituent approach:

Given this is a new group, not faculty, it’s hard to know if we can provide a meaningful community for them. What value do we add? Will they come back? We just don’t know exactly given this is not a direction we have gone before.

National

Overview of characteristics and strategies. All of the CoPs also worked at the national level to spread the reform across the country and embed it within state, regional, and/or federal/national groups that can alter the infrastructure of support for STEM reform. Individuals, institutions, and even sectors remain individual actors, and by operating at a network level connecting actors these communities can enhance their STEM reform efforts. In terms of strategies in order to spread their efforts nationally, STEM reform community leaders created regional networks, developed other networks or communities, hosted broad stakeholder meetings, and participated in national reform efforts.

Leverage point. Regional networks were much more successful where communities had concentrations of faculty. For examples, PKAL could point to the southern or northwest region, POGIL to the mid-Atlantic, and SENCER to the northeast. These communities had some real strong regional areas that were launching points for networks

⁴ As you can see from our description here, most of the groups have not successfully engaged in an international focus in their work to the same extent as other foci, if at all. We felt it important to include here as a possible focus, highlighting the data we gathered related to this area.

⁵ It is important to underscore that Wenger et al.’s (2002) life stage development model was reflected in the stories of formation, growth, and sustaining of the four CoPs that we study. The implication of this finding is that the broader literature on CoPs can be a helpful guide for CoPs in higher education in terms of thinking about the lifecycle and the type of challenges that they will face at different points in time. A finding highlighted in another article based on this project describes the significant sustainability challenges that these CoPs face because they are not organizationally located with regular funding, and organizational structure, staffing, ongoing leadership, and other important supports that many CoPs that are located within an organization like a hospital or business would not face (Authors, forthcoming).

to bring the communities into a more national presence. In areas where they only had a few they had trouble maintaining or growing those networks. They also might leverage a powerful regional project and partnership, for example, SENCER's Greater Lakes partnership provided a regional hub to expand from.

Strategies. A strategy used by all of the CoPs to expand nationally was to establish regional networks/communities. Typically, they used a grant to establish and set up the networks and to build the regional leadership. For example, PKAL, SENCER and POGIL used grant funding to establish initial regional networks. SENCER has recently received an additional grant to build up its Western network that had proven to be operationally difficult because of the size of this region. In fact, most of the networks that were in smaller regional areas on the East Coast where institutions are more closely located have been easier to get up and running. One SENCER leader talks about the value of the regional networks:

Yeah, I was a strong advocate of the regional networks. People just don't have funding to go to national conferences, or more than one national conference. So if you went to your disciplinary conference, how do you come up with the money to go to a teaching conference? And I thought that we could do a lot more outreach and hit a lot more schools and get a lot more people on board if we stuck to regionals and we had a regional coordinator so that if a school in New Hampshire or Maine was interested in SENCER, needed somebody to go, it's probably a lot easier and cheaper for me in Massachusetts to go see them, than to have a person in D.C.

SENCER took a second approach to the regional foci by setting up place-based or thematic regional areas obtaining a grant to bring together faculty and undergraduate students at multiple colleges and universities across the greater lakes region to work on environmental stewardship on the Great Lakes Innovative Stewardship through Education Network (GLISTEN) project.

While the regional networks were clearly a strategy that all the CoPs recognized as having high potential to spread the reform efforts while maintaining costs and time, they often proved challenging. All communities felt that the regional networks either were not taking off or were very uneven in terms of progress. Many reasons were cited for this, including lack of local leadership and inability to create the energy and enthusiasm of the home organization events. For example, this quote illustrates some of the *challenges*:

Yeah, it's finding people to take over for these regionals. You know, you can't have the same five people or six people doing these regional meetings every year — they burn out, and so trying to bring in the new folks and getting them engaged, it's just been kind of a challenge, I think.

Another person commented: "Also, it hard to get the feel of the national events at the local level." But the CoPs were creating strategies they thought would help overcome these challenges such as creating guides for regional leaders, integrating regional leaders more into the national community infrastructure, and providing some funding for building the regional infrastructure in terms of seed grants.

In addition to hosting meetings of broad stakeholder groups, these communities also participated in or were included in national reform projects and used this as a lever to create change. For example, BioQUEST leaders regularly were part of national biology reform discussions hosted by the national academies and other important national groups that resulted in major recommendations such as *BIO 2010* (National Research Council, 2003). CoP leaders noted a *challenge* though in that they often invested a lot of energy in such efforts but were given little acknowledgement that would support the CoP itself. They had to balance such work with nurturing the CoP and its members. Sometimes national efforts and partnerships could come into conflict with supporting the needs of the CoP.

International⁴

The last focus for expanding their work was exploring international outreach. In terms of building an international focus, the communities utilized advisory boards and accepted and encouraged national and international invitations. There was not a well-articulated assumption about global work at the time, but there was some suggestion that other countries may have ideas that enrich us and some other countries have more energy around these reforms and their enthusiasm might actually fuel efforts back in the US. BioQUEST had the strongest international reach and exposure, and this was a result of including international individuals on their advisory boards and making international connections to teaching and learning centers and disciplinary leaders abroad. However, this was still a minor emphasis in their work. One BioQUEST leader described how this international work developed: "John [the original leader of BioQUEST] had a lot of interest in more international issues and we began to include international leaders on our advisory board and also started to get lots of invitations to travel and present our materials. So I think it really started as a result of his interest." But as John stepped down there were fewer interested international efforts and those began to dissipate over time. POGIL also has accepted invitations for international visits to Australia and New Zealand.

In terms of *challenges*, having leaders who commit to do this work was noted as problematic; as shown in the BioQUEST example, once their leader stepped down there was limited interest to continue this work. So leaders need to have succession plan for international efforts they start — especially if they are near retirement. Those trying to

reach out internationally also mentioned the time it takes to travel and the need for in-person connections to make a viable CoP connection internationally. There was discussion about whether there was a way to create branches of POGIL, SENCER, and other groups internationally versus expanding out from the U.S. For all of these groups, the international efforts were still experimental in terms of developing strategies and in terms of being able to demonstrate impact, but it was clearly an area of growth in the future.

Discussion

The findings from this article demonstrate some unique goals for these CoPs for fostering scaled and sustained STEM reform, which relate to different foci, strategies, and challenges as they move into the maturing phase.⁵ While these various communities eventually understood there were different foci they could use for expansion, it often took them years to identify new foci and only happened after much experimentation and haphazard searching for avenues to reach others. These were not obvious foci, rather, they were hard-fought-after approaches. Once identified, it took many years to fine-tune how to leverage the approach appropriately, if they even discovered how vis-à-vis their leverage points. By documenting their processes, we hope to help future groups to more easily anticipate and understand areas where they can focus their reform efforts as they work to expand and increase their impact. Rather than carefully calculating and moving into new foci — for example, institutional change through consultancies or sector strategies — these communities typically drifted into these new areas without anticipating or knowing what it might take to be successful working within this new area and with entirely new untested strategies. Our stories and descriptions of the foci and strategies make visible what has been an invisible set of assumptions for leaders engaging in change.

Our examination of their development over time demonstrates that they tend to have success with foci that build on an initial strength or assets that they have as a community, what we termed a leverage point. They had difficulty in areas where that leverage point was missing. Therefore, being able to identify these leverage points is a critical step in helping future CoPs identify how they might move forward more smoothly. It is important to note that if these communities realized they needed to develop expertise or connections (to create that leverage point) before trying a strategy, they may have been more successful. Therefore given the amount of effort it takes to embed in a particular focus, choosing to expand into other areas needs to be done with careful examination of the amount of leadership that can be generated and attention that can be given to this new foci and set of strategies. The experience and stories of these very successful communities is the importance of leveraging areas where there is

some proven assets to develop clear leadership and commitment when moving into new areas.

If the CoPs expanded into a new focus and did not have a leverage point, they threatened maintenance in the areas where they had already been successful. In other words, by moving into an institutional focus, they might threaten their disciplinary focus as they deplete resources, leadership, and energy from that focus. There is also a lesson to be learned about staying focused on areas where you develop strength before moving on to another focus and set of strategies – what might be called strategic growth. The CoP lifecycle model presented earlier highlights the importance of design principles that can be developed to help CoPs move from stage to stage. This area of strategic growth seems an important design principle to articulate from these communities that can be added to the broader CoP literature.

All of these foci are important to expansion but require significant resources to work across. Also, if the community does not attend to an area, it typically dissipates over time (examples include SENCER and PKAL with disciplines; POGIL and BioQUEST with institutions; SENCER with sector; BioQUEST with international). If the community does not have leaders that are known within disciplinary societies, it is unlikely to make progress until the CoP develops those leaders or relationships within professional societies. Therefore, in addition to the importance of strategic choices based on leverage points for expansion, CoPs also need to consider the amount of leadership, time, and resources they can allocate to expand into an area. This assessment should happen early, and if the foci/strategy is not working, leaders must understand when to pull back before it affects the overall community.

Furthermore, there are challenges that were present within these strategies that need careful attention. As noted in the literature review, articulating key challenges is a major facet in the CoP literature. Regional networks were universally difficult to launch and each group expended a great deal of thought, resources, and effort into developing them. But their experience helps to illuminate important strategies for making them more successful such as creating guides for regional leaders, integrating regional leaders more into the national community infrastructure, and providing some funding for building the regional infrastructure in terms of seed grants. Team structures at meetings will not work unless they are structured properly; team members need to build relationships if they do not already have them, they need to get advice from other individuals and teams that have undergone a similar process, and they need to be encouraged to work together once they return to their campus. While we do not have space in this paper to describe all of the lessons learned from these communities about the best ways to implement these various strategies – the larger report on this project summarizes these ideas (Authors, forthcoming).

Future research should further explore the internation-

al focus as these groups do not have enough experience to understand the range of strategies, leverage points, and challenges. Additionally more research focused on leverage points would be helpful for demonstrating additional areas and approaches to leveraging success. Our study contributes to the overall notion of strategic expansion and identifies the need for leverage points, but we imagine there are additional facets that a study aimed more specifically on leverage points might elucidate.

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Dr. Adrianna Kezar is a Professor of Higher Education and Co-Director of the Pullias Center for Higher Education at the University of Southern California.



Dr. Sean Gehrke is the Director of Institutional Research at Everett Community College.

