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LEVERAGING THE POWER of a Community of Practice to Improve Teaching and Learning about the Earth

By Kim Kastens and Cathryn Manduca

Communities of Practice and Why They Matter

As you reflect on your personal and professional life, perhaps you can recall times when you were part of a sustained group of people whose interactions sparked each other's learning around something that you all cared passionately about. When with the group, you felt appreciated by people who shared your priorities and goals. Group members provided you with both practical resources and emotional support, and in return you were willing to reciprocate generously with your time and ideas. The group felt like more than the sum of its parts, accomplishing far more together toward their shared goals than they could have as individuals.

And then, on the other hand, you may have been part of groups that fell flat, that left you feeling drained rather than energized, groups that sucked up your ideas and effort and gave you little in return. Why do some groups work so well, while others struggle?

Anthropologists recognize a social structure called a "Community of Practice" (Lave & Wenger, 1991). Such communities share a concern or passion for something they do (Wenger-Taylor & Wenger-Taylor, 2015) and interact regularly to learn to improve their practice; through these

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interactions they develop an overlapping knowledge base, set of values, history, and experiences (Barab, et al, 2004). On a larger scale are "Communities of Transformation," which seek to create a new practice or transform an old one, rather than merely build capacity for the practice among the community (Kezar & Gehrke, 2015). As word of communities of practice and transformation has spread in discussions of education, leaders have set out to construct such communities in both K–12 and higher education. Some have failed outright, many stumble along, and a few have thrived.

In this article, we describe one such thriving community, the U.S. geoscience education community (GeoEd CoP). We share observations and hypotheses about what makes the GeoEd CoP work and propose an explanatory model in which interconnected reinforcing feedback loops move the CoP toward higher levels of capacity and accomplishment. Finally, we share lessons learned and ideas about what it would take to replicate this success in other domains and disciplines.

The Geoscience Education Community

For the last two decades, the Geoscience Education profession in the United States has been pursuing a community-based strategy for improving undergraduate geoscience education. An engaged group of colleagues now identifies as geoscience educators as well as geoscientists and interact regularly for the purpose of improving their teaching effectiveness. The GeoEd community interacts through workshops, webinars, email listservs, journal clubs, sessions at professional society meetings, and a dedicated journal.

Leadership of the community emerges from interactions among the leaders of national grant-funded professional development programs, the National Association of Geoscience Teachers (NAGT) and other geoscience professional societies, and the Science Education Resource Center (SERC). SERC provides supporting services that integrate the online resources produced by many of the projects. NAGT publishes the journal, markets the programs, collaborates with educational leaders from other professional societies, and provides sustained community management for successful programs that began as grant-funded projects. These interactions, combined with a value system that supports collaboration, create sufficient cohesion for the community to function.

This community has staged hundreds of events where the overarching agenda is about coming together with peers to improve teaching and learning about the Earth (Manduca et al, 2010). Events range from brief webinars, to half-day conference sessions, to 2–3 day workshops dedicated to specific pedagogical challenges or disciplinary topics, up to the week-long Earth Educators' Rendezvous. More than 4000 faculty have attended one or more geoscience education workshops (Manduca et al, 2017, and unpublished data). Colleagues who are unable to attend in person can tap into associated web-based resources (SERC, 2017b) or participate in Travelling Workshops held on their own campuses (NAGT, 2017c). Colleagues who have experienced and benefited from the GeoEd community are now purposefully trying to replicate the model to build a Geoscience Education Research Community of Practice (St John et al., 2016).

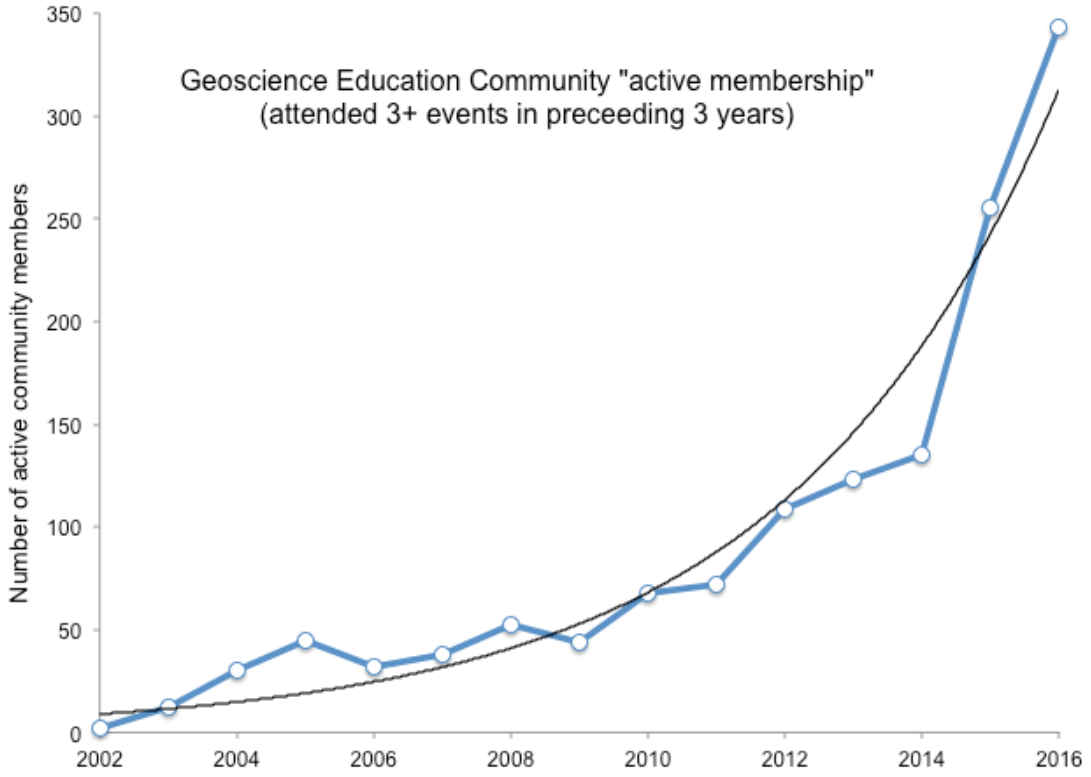
Beginning in 2016, the NAGT national online surveys of college geoscience faculty (Manduca et al., 2017) asked, "To what extent do you consider yourself part of a community of geoscience educators that shares your goals, philosophy, and values for geoscience education?" The survey sampled 2,408 educators, or approximately one quarter of the faculty teaching undergraduate geoscience nationwide. Sixty-two percent of respondents replied that they consider themselves to be part of such a community "to some extent" or "to a great extent." The more GeoEd workshops respondents had attended, the stronger their sense of belonging to the GeoEd community.

Growth of the community is strong. Using data from the Science Education Resource Center's (SERC, 2016) database of workshop participants, we defined "active community members" as individuals who had participated in at least three workshops during the preceding three years. From 2002 until the present, this number has grown exponentially (Figure 1). Over this time, the community increased

In Short

- Faculty Communities of Practice have been promoted as a way to improve education in both K–12 and higher education.
- Over the last two decades, faculty who teach undergraduate geoscience in the United States have built a thriving nationwide community of practice, characterized by individual learning, supportive colleagues, group accomplishments, and effective infrastructure.
- A systems dynamic model reproduces three essential characteristics of the GeoEd community of practice: rapidly increased capacity of the community; mutual reinforcement of individuals and the community; rewarding and energizing participation for community members.
- The model is driven by a set of intertwined reinforcing feedback loops in which an initial change causes a change in something else which then loops around and causes a further change.
- This model can be used by educational leaders to diagnose problems in existing communities of practice or to catalyze new communities of practice.

Figure 1. "Active community members" for any year were defined as individuals who had attended a total of three or more SERC workshops in that year plus the two preceding years. The observed pattern of community growth over time (blue line with dots) is close to an exponential curve (solid black line). Exponential growth is characteristic of systems driven by reinforcing feedback loops.



its capacity to stage and lead strong community activities. People who had experienced one workshop continued to come back for more, and funded professional development projects engaged in active outreach and recruiting of new participants.

What Energizes and Enables this Community of Practice?

What provides the motivation or inspiration to keep CoP members coming back for more? In the case of the GeoEd CoP, important factors have been individual learning, supportive colleagues, and group accomplishments, all enabled by strong underpinning infrastructure, management, and funding.

Individual Learning: When asked what they value in a GeoEd workshop, participants give high marks to ideas and tools that they can use immediately (McLaughlin et al., 2005). GeoEd community activities are designed with individual learning as a central outcome. To ease the transfer of new learning into practice, professional development events are characterized by faculty learning from one another. This works because faculty peers are viewed as trusted sources for information and ideas, since their advice is grounded in their experience teaching similar students about similar topics. Experts from outside the field are brought in strategically to ensure that the community engages with significant new ideas from research, policy, or other relevant domains.

As individuals learn from one another, the collective level of the conversation rises. Individuals can come back to the community, even to address the same topic, with the expectation that the discussion will be at a higher level with new ideas. For example, early GeoEd workshops included basic discussions of the importance of articulating learning goals and the value of assessment in understanding student learning. But today these concepts are being leveraged to address more challenging problems, such as teaching systems thinking or supporting diverse students. The ability of the GeoEd Community to routinely provide high quality learning opportunities leading to new, practical ideas keeps people participating and encourages them to contribute to making future events happen.

Supportive Colleagues: Participants also see as valuable the opportunity for productive networking and interaction with their colleagues (McLaughlin, 2005; Rockman et al., 2013; Manduca et al., 2017). The nationwide GeoEd community is formed of like-minded individuals who share a common interest in improving undergraduate geoscience education, either in general or on some particular topic (such as introductory courses or the sequence of courses that

prepares students for a particular subfield). Without access to a broader community, it can be difficult to find colleagues who share these values (Shulman, 1993), particularly for faculty who are isolated in a department uninterested in educational reform or who are the only geoscientists on their campus.

In addition to the practical value of networking, faculty report interactions with their peers to be empowering, energizing, and motivating (Rockman, 2013; Manduca et al., 2017). They leave community events feeling that more work is worthwhile, that they can do it, and that change will come. As noted above, the more workshops survey respondents had attended, the stronger their self-reported sense of belonging to a community of like-minded educators. Based on interviews and discussions, we think that causality runs both directions in a virtuous circle; participating in substantial interactions with fellow practitioners makes an individual identify more with the community, while feeling like a welcome member of a community of kindred souls encourages an individual to return for more interactions.

Group Accomplishments*:* GeoEd events are rarely planned simply as opportunities for those who know less to come and learn from those who know more. Instead, there is often an ambitious task of co-constructing an entity or structure or mechanism that will help to overcome a challenge or solve a problem that is felt throughout the community. Products created in this way include syntheses of current practice around particular teaching challenges (e.g., Mogk & Bruckner, 2007); digital libraries of instructional resources (Manduca & Mogk, 2000; Manduca, Fox & Iverson, 2006); sets of guiding principles for climate, ocean, atmosphere, and solid Earth literacy (NAGT, 2017a); and an agenda for the emerging field of Geoscience Education Research (Manduca, Mogk & Stillings, 2004; St. John et al., 2017).

Building valuable things together leaves participants with both a useful new tool and a satisfying sense of accomplishment. For example, developing a community review system and collaboratively reviewing over 2000 teaching activities (NAGT, 2017b) resulted in both a tool to find the highest quality activities and a mechanism to offer peer-review recognition to the contributing colleagues. Co-constructing a successful product strengthens collegial ties within the group (Kezar, 2013).

Underpinnings: Behind the scenes, a technical and business/management infrastructure is needed to keep events and communications running smoothly, support leadership and decision-making functions, and manage group resources. For the GeoEd community, the Teach the Earth website (SERC, 2017b) provides an online venue to collect and disseminate educational resources. The Serckit web-based infrastructure (Fox et al., 2005; SERC, 2017a) enables regular online communication and collaboration, and can be adapted to support distributed co-development projects.

This business and management infrastructure must orchestrate efficient use of both cash and in-kind resources. Grants to a number of PI's from the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), and others have been important in the establishment and growth of the GeoEd CoP. NAGT provides an overarching, community based management structure through its leadership, committee structure, and executive office that is used to sustain and coordinate efforts. The GeoEd CoP business model also depends on departments willing to contribute financial support and faculty who are able to participate because their institutions allow them to spend professional time in this way. Without this support from institutions of higher education, motivated by their recognition that learning about teaching is of value, the system would grind to a halt.

The final underpinnings are attitudinal: a high level of trust and a relatively low level of competition. Early on, the GeoEd community created a culture that valued sharing of pedagogical expertise and teaching resources. This was possible because faculty doing similar work at different

Faculty from three different institutions collaborate to develop a module on Major Storms and Community Resilience (Doner et al., 2017), adding to the community's toolkit. Photo credit: Katie Lauer

institutions do not view each other as competitors in their teaching practice. Moreover, pedagogical strategies and digital educational resources are not consumed or dissipated through use; they can be contributed by one and used by many. Faculty were not previously rewarded for publishing teaching activities—so peer recognition was a plus in an arena where there was little to be lost.

Systems Dynamics Model for Community of Practice

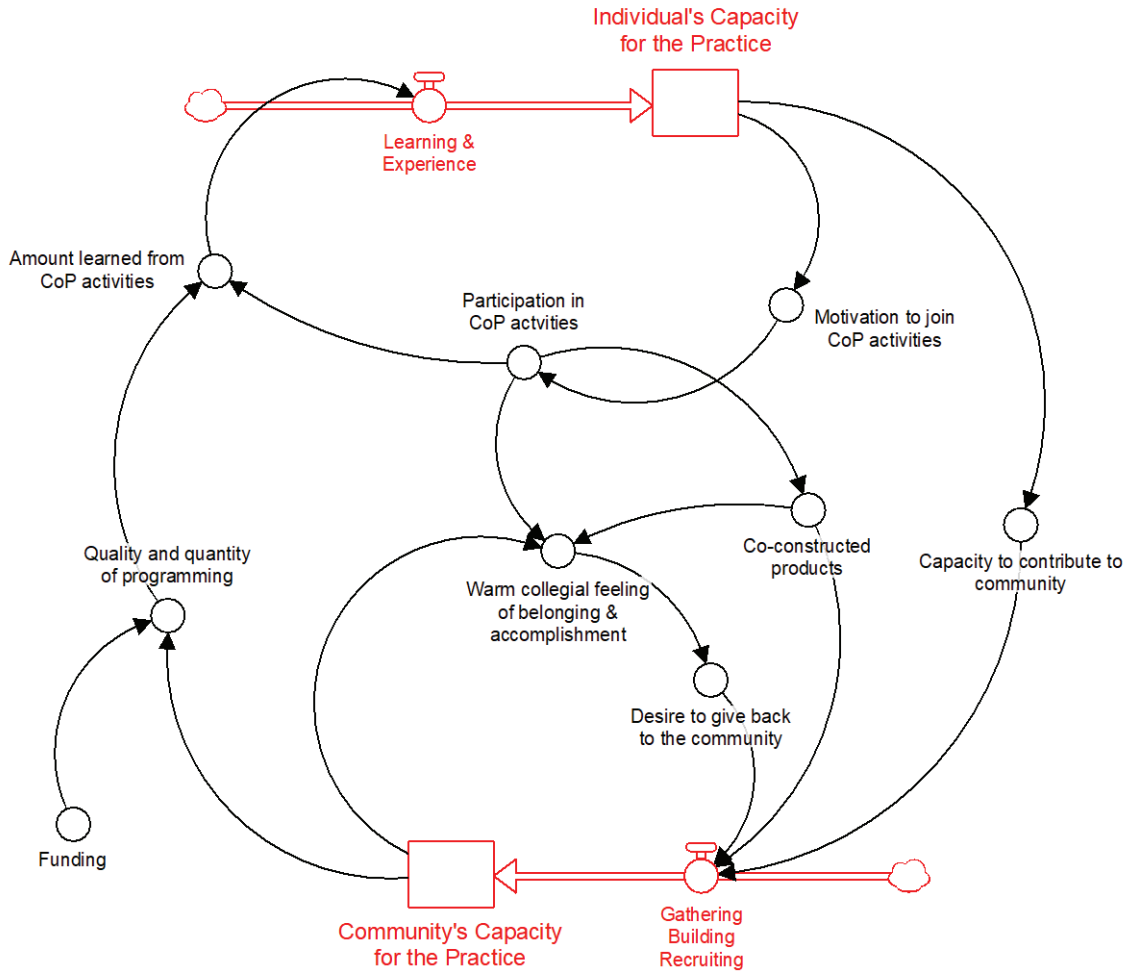
We can weave together the elements described in the previous section into a conceptual model that captures our ideas about key drivers of effective communities of practice. Like all models, ours is a simplification of a more complex reality. However, if we can create and validate such a model, it should be helpful for building new CoPs, for diagnosing CoPs that are failing to thrive, and for framing a research agenda to probe more deeply into the dynamics of this powerful social structure.

Our model seeks to reproduce three essential behaviors: First, effective CoPs improve both the individual's capacity and the community's capacity for the practice. Communities of practice manage to be more than a zero-sum game. Value is traded and shared, but both parties end up ahead of where they would have been without the interaction. Second, the capacity of the community ratchets upward toward higher levels of competence or capacity over time. During a CoP's most vital phase it seems that growth enables more growth, leading to exponential increase in capacity such as that shown in Figure 1. Finally, effective communities make participants feel good, alive, effective, appreciated.

Figure 2 sketches our conceptual model. (More detail is available at Kastens (2016)).

The two red boxes of Figure 2 represent an **Individual's Capacity for the Practice** of GeoEd, and the **Community's Collective Capacity for the Practice**. The first essential behavior that the model must produce is to increase both of these capacities over time. The individual's capacity can be increased through learning and through experience (Figure 2, upper red arrow). The community's capacity can be increased through gathering, archiving, and sharing resources; through building or inventing new resources;

Figure 2. Schematic model of the underlying dynamics that we think help to propel effective communities of practice. Elements from the model are indicated by bold face where they are cited in the text.



and through recruiting new members (Figure 2, lower red arrow).

The second essential behavior that the model seeks to reproduce is exponential or self-reinforcing growth. Scholars of complex systems have found that such exponential growth is often a consequence of one or more "reinforcing feedback loops" (Meadows, 2008). A reinforcing feedback loop is a situation where a change in something causes a change in something else, which then loops around to cause a further change in the first thing, pushing the system further in the direction of the original impetus.

For example, a student does some good work, which leads to praise from the instructor. The praise causes an increase in the student's sense of self-efficacy and motivation, which in turn leads the student to do even better work. This kind of feedback loop is called "reinforcing" because each pass around the cycle pushes the system further in the same direction (at least to a point). In the student example, the student is nudged toward more praise, more self-efficacy, more quality work, in a continually reinforcing cycle. In our CoP model, we sought to build into the model reinforcing loops that would nudge both the individual's capacity and the group's collective capacity upward in ways such that earlier successes enabled and catalyzed later successes.

To achieve the desired exponential behavior, our model contains three reinforcing feedback loops. The first deals with individual learning. The second deals with affect, the role of positive emotions in generating individuals' willingness to contribute to the collective. The third and most complex loop embodies the reciprocal relationship between individual's capacity and the community's capacity. Each loop and the interrelationships among them are depicted in Figure 2 and described below.

Individual learning loop: Envision an individual who develops a bit of capacity and interest in practice X. As her capacity and commitment increase, she may be motivated to join activities staged by an appropriate community of practice. Motivation increases the likelihood of participation. Participation, in turn, enables learning, which leads to a further increase in her capacity.

This sequence of events and influences is represented by the small loop at the top of Figure 2, where **Motivation to join CoP activities** feeds into **Participation in CoP activities**, which feeds into **Amount learned from CoP activities**, which increases the **Individual's Capacity for the Practice**. This form of reinforcement (the more you learn about something the more you want to learn) is not specific to CoP's. However, **Amount learned** is mediated by the **Quality and quantity of programming** provided by the CoP; thus, the vigor of the individual learning loop can be increased by increasing the capacity of the CoP.

The affective loop: The affective loop is where we have incorporated into the model the observed behavior that effective CoP's make members feel good, alive, effective, and appreciated. Community members with this set of feelings are motivated to give back to the community and thus further build the community's capacity.

"In our CoP model, we sought to build into the model reinforcing loops that would nudge both the individual's capacity and the group's collective capacity upward in ways such that earlier successes enabled and catalyzed later successes.

The affective feedback is represented by the small loop at the bottom of Figure 2. Note that in the center of Figure 2, **Participation in CoP activities** leads not only to learning, but also to **Warm collegial feeling of belonging and accomplishment**. That, in turn, leads to **Desire to give back to the community**. "Giving back" could take the form of contributing materials, working to organize or lead events, teaching novices, or other contributions that feed into the community's capacity. The final part of the affective feedback loop comes about because the increase of **Warm collegial feeling of belonging and accomplishment** is influenced by the robustness of the **Community's Capacity for the Practice**.

The reciprocal benefits loop: A third feedback mechanism captures the behavior that individual capacity and community capacity ratchet up together so that when individuals benefit the group benefits, and vice versa. As the community's capacity grows, it is better able to serve individuals' needs and support individuals along their own varied learning trajectories. As an individual's capacity grows, so does his/her capacity to share insights, resources, and skills, and thus contribute to the community.

In Figure 2, the reciprocal benefits loop runs around the perimeter of the diagram. Reading up the left side of the diagram, the **Community's Capacity for the Practice** enables **Quality & Quantity of Programming** which supports **Amount learned from CoP activities**, which feeds the inflow into the **Individual's Capacity for the Practice**. Conversely, reading down the right-hand side of the diagram, **Capacity to Contribute** combines with **Desire to Contribute** (from the Affective loop) to speed up the inflow into the **Community's capacity for the practice**.

There is a second pathway by which **Individuals' Capacity** feeds into **Community Capacity. Participation in CoP** activities (which we met earlier in the Individual learning loop) has multiple benefits in the model, one of which is the creation or invention of **Co-constructed products**. In the case of the GeoEd community, **Co-constructed products** include a digital library, instructional modules, white papers, and an observation-based evaluation system for classroom instruction. Each of these **Co-constructed products** increases the **Community's Capacity for the Practice** of geoscience education.

Most of the "underpinnings" described in the previous section (leadership ability, faculty time, technical infrastructure, etc.) are not shown in the model because they are present throughout the entire system. We have, however, shown **Funding** as a strong and direct influence on the **Quality and Quantity of Programming** (lower left corner of Figure 2). If **Funding** stops or declines drastically, the functioning of the outer **Reciprocal Benefits** loop, and thus the entire intertwined system, is at risk. But funding alone, in the absence of the rest of the reinforcing feedback mechanisms, cannot drive the ratcheting upward behavior.

> That 'warm collegial feeling of belonging and accomplishment' needs to be nurtured and fostered. It's not just a lovely side benefit; it's at the heart of what makes the CoP tick. Activities that allow participants to get to know one another, share experiences, celebrate each other's accomplishments, and work together on substantive projects are as important as the amount of skills and knowledge that are developed.

There are many other influences that come into play outside of and within these three loops. We offer this as an "appropriately minimalist model," (Larsen et al., 2014), a model comprising the fewest elements and interactions that seem capable of reproducing essential behaviors of the system. The model is in need of testing and is open to many researchable questions: Can the workings of the feedback loops be demonstrated with observations? What is the relative importance, quantitatively, of the three major loops and additional influencers? How do these interactions change over the lifetime of a CoP, from its embryonic stages through maturation and into decline? How do affective factors (motivation, desire, feeling of belonging and accomplishment) transform into action? Since co-constructed products play two roles in the model—creating entities or processes that are inherently useful in advancing the community's practice and strengthening collegial bonds among the creators—what are the attributes of collaborative creation projects that maximize each of these two roles?

Lessons learned

This model carries two lessons of importance to Community of Practice builders regardless of field. First, both the individual and the collective need to benefit from CoP activities; both need to be continually building up capacity for the practice. If individuals are not benefiting, they won't come back, and they won't contribute. If the collective is not benefitting, the practice won't move forward, and the CoP will have nothing new to offer to individuals.

Second, that "warm collegial feeling of belonging and accomplishment" needs to be nurtured and fostered. It's not just a lovely side benefit; it's at the heart of what makes the CoP tick. Activities that allow participants to get to know one another, share experiences, celebrate each other's accomplishments, and work together on substantive projects are as important as the amount of skills and knowledge that are developed.

These ideas can benefit CoPs no matter their level of activity or success. For CoPs that are humming along, consideration of this model can help foreground activities that may appear peripheral but are in fact playing a critical role.

For CoPs that are struggling, the model may provide ideas for how to re-energize the system. Are all the loops complete, or is there a missing or weak element? Does the programming provide sufficient individual learning? Is the community's increasing capacity translating into new programming, so that individuals continue to find new things to learn and achieve? Are community members developing collegial relationships that endure? Are members recruiting new members? Is the group methodically building individuals' capacity to contribute the community, for example by offering leadership opportunities to new people? Is the community producing products that are well used and advancing the community's goals?

Challenges might also be arising from a problem with the underpinnings, such as a squeeze on funding or faculty

time, or a technical infrastructure that intimidates rather than supports. CoPs should scrutinize both feedback loops and underpinnings as they try to diagnose problems.

If you want to create a Community of Practice from scratch, where should you start? A crucial early step is to establish the community/individual value proposition, the elements of your Reciprocal Benefits Loop. How will individuals benefit from participating? What added value will the community be able to accomplish by working collaboratively rather than continuing as individuals? A compelling founding vision that captures a goal that many individuals will want to work toward may be an integral part of the answers to these questions (Kezar & Gehrke, 2015). Similarly, you should plan programming with both individual and collective benefits in mind and then evaluate the programming for its effectiveness in ratcheting up both individuals' and the group's capacity for the practice.

Look for activities that have multiple beneficial outcomes (Kastens & Manduca, 2017). For example, peer learning and co-construction of products simultaneously enhance the feeling of belonging and accomplishment while increasing the capacity of the individual (peer learning) or the capacity of the community (co-construction of products). Build underpinnings that will enable the community to create useful products through collaborative work. Start with the minimal set of underpinnings and develop them as your tasks grow.

Finally, attend purposefully to the Affective Loop. "Interact frequently." Plan for lunch. Find meaningful roles for newcomers. Tell stories about the heroes and pioneers of your practice. Make sure that credit is distributed between the individuals and the group. Institute rituals and events to recognize each other's accomplishments. Smile, and laugh together. And when an event ends with the warm collegial feeling of belonging and accomplishment hanging thick in air, enjoy a moment of self-congratulation and achievement, and then recruit co-leaders to do it again. C

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