Finding Middle Q: Sierra College's Public-Private Makerspace Partnership as a Strategy for Workforce Development

ISAM 2019 Paper No. 09

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INTRODUCTION

Sierra College in Rocklin, CA was an early leader in forming the first public-private community college partnership in the country with a commercial makerspace/coworking space as a strategy for education innovation and workforce development. The organizational structure included non-traditional, diverse partnerships to expand and accelerate the development of curriculum and pedagogy relevant to current and future workforce needs. With the experience of building and managing a dynamic and flexible network, Sierra College was uniquely positioned to serve as the statewide fiscal agent for the CCC Maker Initiative introduced by the California Community College Chancellor's Office in 2016, as well as participate as a member of the cohort of 24 colleges awarded grant funding through the initiative. This paper focuses on the structure of the partnership and its accompanying network, the challenges it has encountered, and its long-term potential to change how the College prepares students for the future of work.

BACKGROUND

Sierra College began its first education makerspace ecosystem in 2008, using "Community Collaborative" funding from the California Community College Chancellor's Office (CCCCO) to partner with eight high schools and a business advisory group to rebuild manufacturing-related programs of study. For seven years, the Sierra STEM Collaborative improved STEM supports on multiple fronts: instruction, facilities, and professional development. The Collaborative supported new and strengthened existing pathway courses serving more than 14,000 high school students. Renovations were also made to facilities, including outfitting labs with new digital design and computerized fabrication equipment. Faculty professional development began with a trip to the 2008 Bay Area Maker Faire to establish and communicate an expectation of open source and collaborative learning. The resulting teacher network was very active, logging more than 750 faculty engagements in self-directed workshops.

Following the clear success of this investment and harnessing the growing momentum of its stakeholders, Sierra College began to expand its activities to include other outside partners. In 2014, the College approached Hacker Lab, a young makerspace and coworking space business located in Sacramento, CA. Forging a partnership required engagement from many levels within the college; the Superintendent and President of the College secured executive and political support while a collaborative of deans, faculty, and staff guided internal support. These efforts led to the opening of Hacker Lab powered by Sierra College approximately one-quarter mile

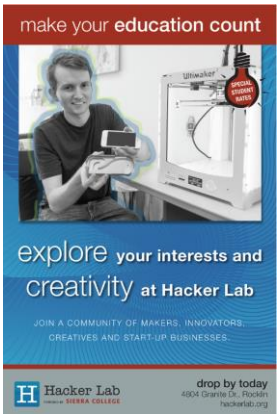

Fig. 1. Promotional materials highlight the public-private partnership

from campus in spring 2015. The College provided the first two years of rent for the 3,200 square foot retail space, as well as equipment and furniture. At the same time, the City of Rocklin committed three years of supportive funding. Hacker Lab managed the membership-driven space and provided short-term skills classes, meet ups, and other community events [Fig 1]. Eventually, the City of Rocklin partnered with Sierra College to hold the first Rocklin Mini-Maker Faire on the Rocklin campus, engaging a large slice of the community including faculty, students, community members, businesses and nonprofit groups. In spring 2017, Hacker Lab began leasing a larger (15,000 square foot) space, with Sierra College agreeing to pay one-half of the rent in exchange for significant membership discounts for students and faculty. Eventually, CCC Maker initiative funding allowed the Sierra Makerspaces initiative to be born, incorporating two additional private makerspaces in Grass Valley (36 miles east) and Truckee (79 miles east) to partner with satellite campuses in those communities.

THE SMALL WORLD QUOTIENT

The organizational ecosystem developed by the Sierra STEM Collaborative (K12) and the Sierra Makerspaces initiative (Community College) illustrates how "Small World" networks [1] can affect organizational change, particularly in preparing students for future jobs in the innovation economy. Small World networks are social structures that connect individuals or groups, allowing knowledge to circulate and be used. They are characterized by 1) the number of intermediaries between members (think: the Six Degrees of Kevin Bacon parlor game) and 2) the number of connections between groups of collaborators (as shown in the Kumu.io ecosystem maps that all CCC Maker colleges created during

the startup process [2][3][4]). Fewer and widespread connections (low Q) might mean that transference of best practice models, scalability, and replicability are low. Connections that are well defined and entrenched (high Q) might indicate high specialization and low diversity, lowering the ability to be creative and innovative. Like Goldilocks's preferences, Uzzi and Spiro argue that an intermediate level (medium Q) might be "just right" to achieve the most effective networks – systems that are simultaneously specialized, decentralized, and interdependent [Fig 2]. This paper provides evidence to suggest that Sierra College is nearing the "just right" middle ground within its own Small World network. First, it deepened its commitment to an innovative approach to training for future jobs. Next, it broadened its network by attracting like-minded, but functionally different, partners. This expanded ecosystem gave rise to culture shifts related to innovation in education throughout Sierra College. With Sierra College as an example to the rest of the growing CCC Maker network, this deepened resolution to adhere to innovative education was propagated out to other community colleges across California.

1. Avoiding a Low Q system: developing a diverse and connected ecosystem that supports a high frequency of connections.

The STEM Collaborative began moving toward middle Q as it sought to solve a problem: enrolled students were not taking advantage of Sierra College's manufacturing-related (Making) skills and knowledge training highly sought by employers. The reasons for this mismatch of offerings and enrollments were many:

- Little pipeline support—in 2008, only ten percent of high school students in eight feeder high schools took manufacturing-related courses.
- Poor communication within and between schools and employers—faculty at feeder schools were isolated from each other, and had limited connections to the College and employers.
- Limited investment in relevant resources—high school labs had outdated, broken equipment, aged infrastructure, or had shut down completely; teachers were retiring or being reassigned to non-shop classes; capital investments focused on non-mid-level-skills classes, either supporting low-wage, low-skill jobs, such as Culinary, or Engineering-specific programs designed for Baccalaureate-bound students. Meanwhile, regional employers complained they could not find enough skilled workers to fill open 'middle-skill' jobs (requiring postsecondary education, but not necessarily a Bachelor's degree).

As a result, students enrolling at Sierra College were not prepared to take advantage of Career & Technical Education offerings. High school graduates had little knowledge of or experience with opportunities to learn Welding, Construction, Machining, Computer Aided Drafting, and Mechatronics, or how these learned skills could be applied in a future job or career. Furthermore, having few options to take middle-skill courses in high school meant many enrolling students arrived underprepared for the classes at a college level; more than

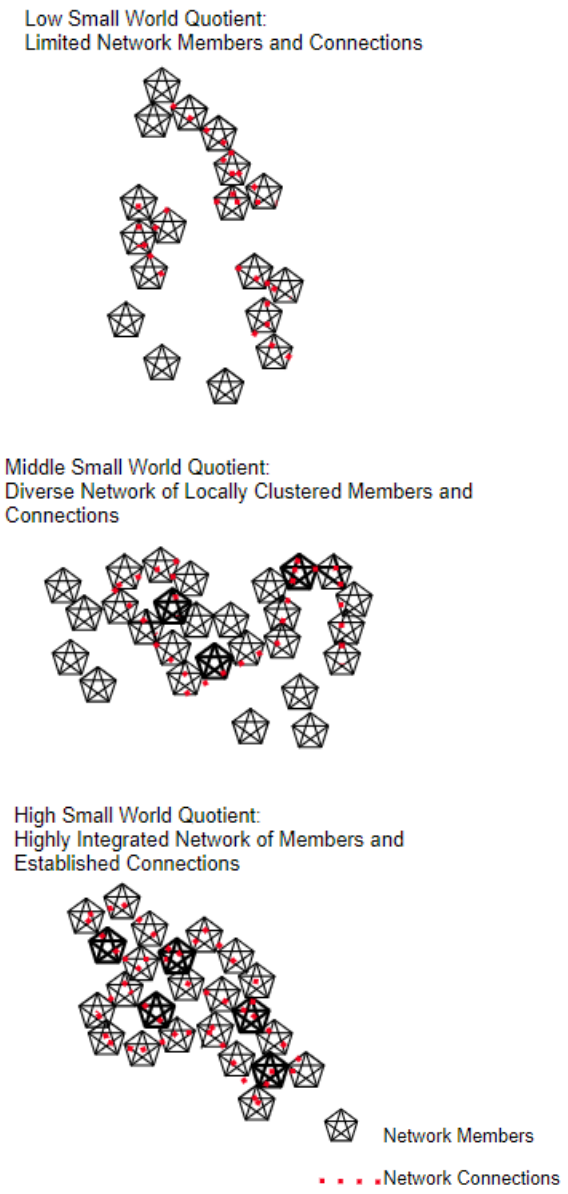

Fig. 2. Variations in Small World Network Structure (adapted from Uzzi and Spiro, 2005).

80% of first-year students were placed in remedial mathematics and English classes. Students in applied technical programs frequently left before earning their degrees or certificates as employer workforce needs were so pressing. Essentially, there was little to connect what students were learning in high school to technical education and training at Sierra College.

To address the problem of underprepared students, the Sierra STEM Collaborative, funded by the California Community College Chancellor's Office, invested $2.29 million to rebuild the high school educational infrastructure related to making and manufacturing. Whereas prior initiatives had focused on developing or adopting new curricula and teaching methodologies, this effort focused on building a community of practice amongst teachers, intentionally connecting five different school districts and 15 instructional programs. This

high school teacher network was then connected to faculty within five Sierra College instructional programs housed within three divisions. The Collaborative's first professional development event was for teachers and faculty to attend the 2008 Bay Area Maker Faire. By establishing a culture of collaboration, co-creation, and creativity, a new network was formed by a) strengthening linkages between high school and college faculty while simultaneously connecting them to larger networks established in the Maker world community and b) providing context for faculty to see themselves within a larger movement.

This supportive network of educators, connected to an external network of innovators and businesses, flourished, leading to the development of much-needed curricula to help connect students in feeder schools to what is available at Sierra College, and even helping Sierra College improve its own offerings to match incoming student expectations. For instance, one high school developed the region's first CAD/CAM digital design to fabrication program, becoming a Haas CNC shop and helping Sierra College establish their own Gene Haas Center for Advanced Manufacturing by Design soon after. Other examples of new curriculum at feeder high schools that could both connect incoming students to Sierra College's offerings and also infuse Maker elements included the development of a 9th-grade Tech Essentials class (taken by every first-year student), which incorporated design thinking and emphasized a growth mindset; and the adoption of the Design Tech International Baccalaureate program, which incorporates design thinking into product development and social benefit projects.

While teachers at schools connected to the program agreed that the infusion of funds to augment their suites of manufacturing tools—and the teacher training to use them—was needed, they emphasized that it was the Sierra STEM network that really infused innovation into their programs. The support that the Sierra STEM network offered teachers was credited with "sparking an interest in… students and preparing them to be future entrepreneurs, inventors, designers, and engineers."

Changes in instruction went the other direction, too—expanding connections between the College and the high schools also resulted in a new instructional presence within the college community. Dual enrollment agreements grew from zero to triple-digit offerings; high school teachers were hired as part-time faculty at the College; new curriculum was developed for advanced manufacturing courses; industry and community partners were connected to the post-secondary faculty network. This influx of instructional energy was further expanded by high school graduates attending Sierra College, as they became Sierra Makerspaces student leaders and peer coaches for maker-related internships, established new crucial spaces at the makerspace, engaged girls in design thinking, grew membership of student clubs, and introduced student-led events such as the "Mechatronics for Humanity" showcase.

These outcomes show the expansion and strengthening of a network encouraged by the Sierra STEM Collaborative; these growing connections transformed a 'low Q' Small World network—with isolated and weakly-connected stakeholders—to a network that expanded the ecosystem of stakeholders *and* increased the number and frequency of their associated network ties.

2. Avoiding a High Q system: increasing flow and frequent transmission of best practices, building interdependence and co-evolution.

By 2014, the Sierra STEM Collaborative ecosystem was changing to more fully engage stakeholders within the College and expand partnerships with business and government. These partnerships began with small events that radiated outward. For instance, a faculty-led Art & Innovation Day for the public that focused on shared education and creativity through hands-on activities, tours, and lectures served as proof of concept for the first Rocklin Mini-Maker Faire, which was initiated by the City of Rocklin in partnership with the College. Another opportunity to build connections arose through the combined efforts of faculty, administrators, and staff, led by high-level administrators across multiple disciplines including advanced manufacturing, business, and technology: the creation of a new model of workforce development that would respond to employer training needs and emerging occupations, and included the development of an academic makerspace in its business plan. This makerspace was given form when connections within the Sierra STEM Collaborative were engaged: the Sierra College President reached out to a previous contact about the new workforce development model and soon after (fall 2015) signed a Memorandum of Understanding that was approved by the College board of trustees to open Hacker Lab powered by Sierra College. Regular events and skills classes, guest lectures, hack-a-thons, and Meet Ups have engaged students, faculty, staff, and the community in the shared space. [Fig 3]

Taking notice of this engagement soon after the Hacker Lab powered by Sierra College opened, the Vice Chancellor of Workforce and Economic Development, California Community College Chancellor's Office, asked what it would take to replicate the College's makerspace model at other community colleges. By spring 2016, a white paper authored by the California Council on Science and Technology was published [5], followed by a $17m initiative to engage multiple colleges [3].

Fig. 3. Jointly held Meetups increased ecosystem connections

Sierra Joint Community College District applied for the role of fiscal agent and technical assistance provider for the startup project.

Sierra College's makerspace initiative proposed serving a geographic area covering two counties. As the only post-secondary institution in Placer and Nevada Counties, an area of 2,100 square miles, the College needed expanded connections to the maker communities in rural areas. Collaboration with Hacker Lab had been a critical factor in connecting the College to new individuals, companies and groups leading technical and social innovation in the Sacramento region. To expand its partner ecosystem, Sierra College created Memoranda of Understanding with two additional community makerspaces: The Curious Forge in Grass Valley and the Truckee Roundhouse in Truckee. These new partners connected the College to community creatives, entrepreneurs, artists, and makers across two counties, expanding connections both functionally and spatially/geographically.

The connection between makerspaces was made more concrete by sharing resources. Sierra Makerspaces purchased equipment to be housed at all three spaces in order to support future activities, designed and assembled the industrial textile lab at the Forge, funded a student maker in residence placed at the Truckee Roundhouse to support students and faculty using the space, and supported faculty with release time to learn new technologies and incorporate Making into curricula.

Through these partnerships and activities, student engagement began to emerge as a priority. Students used makerspace equipment to learn digital design and fabricate products in a variety of materials. For example, Making was integrated into a traditional liberal arts class - Psychology of Death and Dying (PSYC 108) [Fig 4]. An institutional culture change in student engagement emerged as a result.

Ecosystem partners began to act as co-creators, changing the College's entrepreneurial mindset. As an example, Professor Dennis Wingate developed a course in Entrepreneurship and Small Business Management (Business 140) using Mark Randall's Adobe Kickbox model. Designed to grow internal

Fig. 4. A textile project, custom designed to honor a family member or friend, was integrated into a Psycology of Death and Dying class

Fig. 5. Students completing a Sierra College Kickbox class can continue to pursue their business model by engaging with a business mentor group

R&D teams within a corporate structure, Kickbox could also be used to teach the startup process in the classroom with a few changes. Mr. Randall conducted a professional development workshop in the makerspace for faculty and administrators, and served as a co-creator on the Kickbox.edu curriculum. Students in Business 140 now learn and apply design thinking, customer validation and discovery of new market opportunities using this open source tool.

Other Small World connections opened up as a result of the Kickbox.edu work. U.S. Bank sponsored a fall and spring student showcase, and in fall 2018 Steve Ricketts, CEO of a business planning and modeling company, volunteered to lead a tri-annual 'Startup Pitch Mentor Round' event advised by a panel of high-level business mentors. At these events, Business 140 students pitch startup business concepts and receive mentor advice, and guest speakers from the startup community share their experiences [Fig 5]. More than ten student startups have emerged out of this process.

The expanded network and co-creation model became a magnet for instructional and leadership talent. As an example, Dr. Amy Schulz, representing the National Association for Community College Entrepreneurship (NACCE) on the CCC Maker advisory board, led the ecosystem mapping work with 24 colleges during the startup phase [6]. In November 2017, she was hired as the Dean of Career, Continuing and Technical Education at Sierra College. In her new role, Dr. Schulz introduced faculty to two worldwide organizations, Enactus and Ashoka, resulting in the formation of a new student Enactus team. In fall 2019, the Enactus team won first place at the U.S. Enactus Project Showcase for their presentation of an enterprise model producing gourmet chocolate using cacao beans sourced from small farmers located in six different countries.

Intra-College connections were strengthened through regional collaboration with makerspace initiatives at Sacramento City College and Folsom Lake College. For example, Sierra College issued subgrant awards to Folsom Lake College's Innovation Center to co-create a new series of courses in Fermentation Science, and to send two Innovation Center student workers to Stanford Innovation Fellows training. Sacramento City College served as the CCC Maker pilot program for a cohort-based student internship model called MakerMatic [7], and then sent faculty leads to Sierra College

to serve as trainers and mentors in an expanded pilot program. A student leader from Sacramento City makerspace developed a promotional video for Sierra Makerspaces featured at a number of regional and national events, including the 2019 Bay Area Maker Faire.

By the conclusion of the CCC Maker implementation phase (24 months), Sierra College had directly engaged many members of its growing ecosystem: 1,200 Sierra College students participated in makerspaces, 79 student interns were trained and placed, and the project conducted 41 professional development events, logged 192 faculty engagements, and supported 270 events including two Mini-Maker Faires on the College campus attended by more than 10,000 people. Ecosystem partners external to the College grew by 22 percent; internal collaboration expanded with seven additional programs of study incorporating maker and entrepreneurship elements into curriculum (Mathematics, Photography, Engineering, Advanced Manufacturing, Fashion, Applied Art & Design).

DISCUSSION

Uzzi and Spiro describe the sweet spot of collaboration and connectivity as the medium level Small World quotient (Q). Too few network members and connections (low Q) can result in silos or cliques. A highly integrated and connected network (high Q) can result in established intermediaries supporting cultural homogenization and a tendency to rely on conventional solutions or strategies. The Sierra Makerspaces network has created a structure that is both highly diverse and locally clustered (resembling Uzzi and Spiro's "middle Q"). For example, members of the Curious Forge in Nevada City have two degrees of separation to connect with Sierra College; intermediaries include the Forge's founders and College faculty and students using the makerspace. Students in the Kickstarter.edu business course have one degree of separation to connect with mentors from the business community, startup networks, and the makerspace community. Social benefit organizations, initiatives and businesses have one to two degrees of separation to connect with College faculty, students, and the makerspace community [Fig. 6]. This increase in connectivity with both internal and external ecosystem partners has translated to a deeper engagement with community and business stakeholders, not just affecting programs and curricula, but examining the deeper topic of "What and How We Teach" to meet current and future workforce needs.

	Business & Entrepreneurship Networks	Jobs & Workforce
SIERRA COLLEGE	Makerspaces Hackerspaces Coworking Networks	Startup Community
	Social Benefit Community Networks	Creative Economy

Fig 6. Degrees of Separation between the College and Selected Networks

Uzzi and Spiro's research on Small World networks is related to another body of knowledge by Henry Chesbrough: Open Innovation [8]. Chesbrough's studies concluded that business organizational structures designed to co-create with universities, connect with startups, buy and sell intellectual property, and create value statements for their customers were innovators and drivers of the tech economy. Open Innovation studies from higher education identify their primary role as knowledge creators and dispersers [9]. For community colleges, which are not research institutions, Open Innovation models might instead focus on the development of talent for high wage and high skill occupations, and the creation of a marketplace to source that talent. Understanding the future of work and then developing programs to educate, train, and connect students to future jobs will require middle Q networks for community colleges. Academic makerspaces are critical members of that network. Figure 7 illustrates an example of how community colleges might envision their role in this context.

LESSONS LEARNED

1. Understanding the Small World network model is necessary to guide ecosystem design. Both the Sierra STEM Collaborative and the Sierra Makerspaces projects were interested in achieving system-wide change, requiring a more complex system of partners than had existed before. It was the connection to the large and diverse networks of the makerspace community that moved the ecosystem toward middle Q ground.

2. Building and managing a middle Q network is challenging for a bureaucratic institution. Low Q and high Q networks are familiar and comfortable environments for colleges. For example, before the Sierra STEM Collaborative, we completed many grant-funded short-term projects that were academically siloed and limited in scope. We've also planned and implemented many projects lead by specific departments or instructional groups following well-defined roles and codes of conduct. The Open Innovation model has challenged that paradigm. Employers are seeking graduates

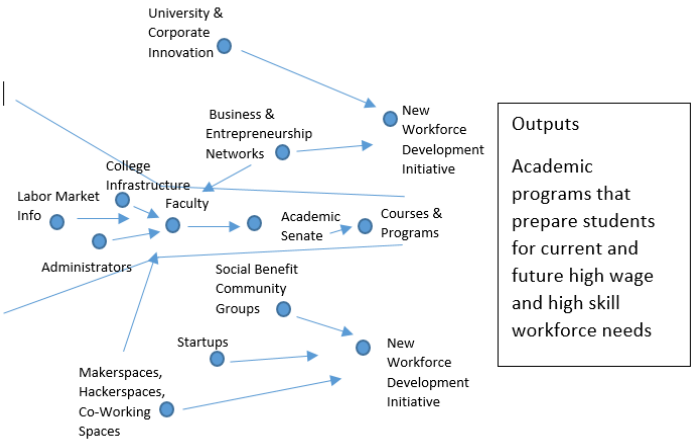

Fig 7. A Proposed Community College Open Innovation Model

with 21st century skills, the Gig Economy is transforming freelance work, and students are gaining knowledge and experience in other ways [10].

We recognize that network diversity and connectivity are necessary components for innovation. Even so, our middle Q network feels something like an arranged marriage. We may never be soul-mates to our partners, it can be challenging to collaborate or cooperate with our differing cultures, and there are definitely disagreements around process and timelines. To be successful, all groups in our network need to have some shared values and goals, such as economic equity and social well-being, and practice behaviors of inclusion, tolerance, risk-taking, communication, and empathy.

3. Community colleges need the attention of universities implementing Open Innovation education and business models so that we can translate this practice to address workforce development needs. Preparing students for future occupations, particularly for high wage and high skill middle-skill jobs, requires community colleges to build middle Q networks that look beyond static data such as Labor Market Information. Maintaining Career and Technical Education program currency (e.g. maintaining digital software and manufacturing hardware) is expensive, both in technology and human capital costs. Investing in new programs of study can be risky, especially if they are preparing students for future-focused careers.

The community college system needs support from research institutions that are designed to pose theoretical questions on the institutional value of makerspaces and middle Q networks, and conduct actionable research that can be applied and taken to scale. Community colleges need to agree on a model, and articulate the value of Open Innovation in supporting and designing workforce development programs. Makerspaces are valuable components of that model [11][12][13].

CONCLUSION

Sierra College used its public-private makerspace partnership and the open source and collaborative culture of the Maker Movement to develop a flexible and diverse ecosystem of individuals and organizations to guide workforce development services and programs. This model allowed the College to move outside the bounds of a) small, unique pilot projects that would not scale, or b) projects that 'bolted-on' to existing services and limited improvements to solve problems. The Uzzi and Spiro study on network size and structure described a flexible and diverse ecosystem as 'middle ground' within a Small World network, allowing knowledge to flow efficiently and ideas to be repurposed in new and creative ways.

Chesbrough took this concept even further to describe the characteristics of knowledge flow as "Open Innovation," a structure and mindset for adapting, surviving, and flourishing in the tech-enabled 21st Century. In Chesbrough's model, universities were identified as critical stakeholders in the open innovation process as research knowledge flows within and outside academia and businesses. Community colleges are not research institutions - however, a model of open innovation has been proposed here, based on the Sierra College experience, that uses the makerspace as a catalyst for preparing and sourcing workforce talent, especially in emerging fields of study.

Sierra College also had the unique opportunity of serving as the fiscal agent for the CCC Maker statewide initiative. This position extended the College's ecosystem to a national level, allowing members to operate at multiple levels, see more examples, and share a wider range of best practices with the College network.

When the California Community College Chancellor's Office invested in scaling makerspaces at community colleges, we did not anticipate that a structural shift to the middle ground of a Small World network would be so impactful. Sierra Makerspaces has positively affected students, faculty, businesses and the community by adopting creativity and collaboration as guiding principles for educational practices and services. Sierra Makerspaces has also suggested a new model of open innovation in the community college, guiding future efforts in workforce development and preparing students for the innovation economy.

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