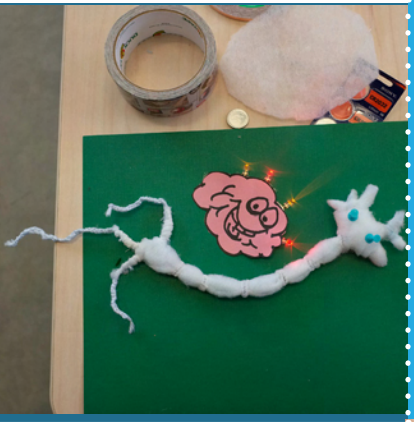

CCC MAKER SYMPOSIUM PROCEEDINGS, INTERVIEWS, AND PHOTOS

making symposium

CALIFORNIA COMMUNITY COLLEGES
ccc maker
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AUGUST 2017

CCST
CALIFORNIA COUNCIL ON SCIENCE & TECHNOLOGY

CCC Maker Symposium Proceedings, Interviews, and Photos

Prepared for the California Council on Science and Technology

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About CCST

CCST is a non-profit organization established in 1988 at the request of the California State Government and sponsored by the major public and private postsecondary institutions of California and affiliate federal laboratories in conjunction with leading private-sector firms. CCST's mission is to improve science and technology policy and application in California by proposing programs, conducting analyses, and recommending public policies and initiatives that will maintain California's technological leadership and a vigorous economy.

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CCC Maker Kickoff Symposium

The California Council on Science and Technology (CCST) hosted the California Community Colleges Maker (CCC Maker) Kickoff Symposium on August 18, 2017, at the Jacobs Institute for Design Innovation at UC Berkeley. Leading researchers and practitioners presented information to a meeting of the 24 California Community Colleges that won grants from the California Community Colleges Chancellor's Office (CCCC) to create or enhance makerspaces or maker programs on their campuses.

Registration, Coffee & Community, "Hack Your Badge" (9:30 am)

Participants got into the spirit of the event with some badge hacking, using an assortment of to make elaborate name-badge improvements.

During this activity, the **Foothill College team** (Gay Krause, Robert Pronovost, and Kyle Brumbaugh) discussed how the application process was different from other grants.

"I've written many grants," Brumbaugh said. "This process was completely different from any other grant process," he said, referring to meet-ups in both Northern and Southern California. "The activities they had us engage in prior to the actual submission were designed to create a community and a level of collegiality [among] colleges that were applying for the grants."

"We had to do an elevator pitch before we ever actually wrote the grant," Pronovost said. "It was really nice to be able to get feedback from some of the potential reviewers—the people who put together the grant process."

"They wanted people to work regionally and across the state—that's a difference as well," Krause added. "Normally, the grant process just [focuses on representing] your own group."

Now that the Foothill team is in implementation mode, they are asking themselves questions like, "Now that we have these great resources, how are we going to put them together in a way that allows us to … engage the community?" Brumbaugh said. "Because we're not just engaging with community college students, we're engaging with K-12 students … and we have a partnership with a veteran's organization to bring

recently discharged veterans into our maker space. We want to … be seen as a community resource, not just a college resource."

Van Ton-Quinlivan, Vice Chancellor for Workforce and Economic Development of California's Community Colleges, talked about her connections to maker education while she searched the maker table for a battery to power the light she'd affixed to her badge. **"**In the early days of the Maker Faire … I saw how my own sons lit up to see the combination of science and an applied [activity]," she said. "It was like a county fair combined with a STEM curriculum."

She's been tracking the Maker Movement for a while. "I saw its ability to facilitate creative skills—fungible skills that are needed regardless of how the technical aspects are retained," she said. "We wanted to invest, and connect community colleges into this in the same way that Stanford, Yale, and many other four-year institutions have…"

She sees the CCC Maker Initiative as supporting workforce outcomes in a number of ways. "For example, the internship component of the maker program is a feather in the student's cap when they interview for jobs," she said. "For the more advanced maker programs, we're supporting them to connect with employers [and] to create employment opportunities."

Jessica Parker is Director of Community and Learning at Maker Ed, an Oakland-based national nonprofit designed to help educators infuse maker education into their learning environments. She's been helping the CCC Maker Implementation Team think through critical questions by giving feedback and guidance around the grant process, including, she said, "How to make it not just equitable, but also inclusive, community-oriented, and [aligned with] what's best for the students and faculty on campus."

Parker stressed that maker education is not just about the makerspace itself. "It's also the act of thinking about how making is already part of a community, and then amplifying that," she said. "All of the colleges that completed a work plan thought about their problem statement: What are the problems they're trying to solve, and what are the assets they already have on hand?"

"That's what's exciting about making—it's not 'one size fits all,'" she added. "Every community college campus is doing something different because it depends on their community's needs…. It's really about relationship-building rather than makerspace building."

Maggie Malone-Echiburu, of Hartnell College, is site director of the Science Engineering, Mathematics and Aerospace Academy, and administrator for the school's Minority University Research and Education Program (MUREP) grant—both programs of the National Aerospace and Space Administration, or NASA. Like other maker programs, theirs encourage "everything hands-on, creative thinking, and the engineering design

process with students that are really young—K-12." Fittingly, their activities are designed as "missions."

"Every week is a different mission and we have an eight-week curriculum," Malone-Echiburu said. "NASA has been doing this for twenty years. We've had the MUREP grant for the past five. Of the nine national MUREP programs, there are three that are top-performing, and we're one of them."

Their involvement in the CCC Maker Initiative is expanding the reach of their programs. "We don't work a lot with the college students, and now we will have them coming into the aerospace educational lab, so we can use them as mentors for the K-12 students," Malone-Echiburu said. "It will encourage them to see the community college as—*not* the place that you go because you can't afford a four-year college. You go because it's leading—leading in technology, leading in workforce development."

She thinks such hands-on programs help community colleges play a role in getting every student to go to college. "I don't believe, 'Oh, some kids won't go.' They'll go … They can go to college to be a mechanic, a technician… It doesn't matter if they're artists or [other non-technical pursuits] and they think they don't belong to the educational part of going to college. I tell them, 'Yes, you do…. You can be a designer and you can design the next rockets or cars in outer space.'" She noted that in particular, her program coaches a lot of young women in this way.

Opening Remarks and Introduction (10:00 am)

After the morning badge hacking and community building, the main program began with opening remarks by CCST and the CCCCO.

"Science and technology are the way of the future, and the future of jobs in particular," said **Susan Hackwood,** executive director of CCST, as she welcomed attendees. She announced Science and Technology Week at the state capital in February 2018, when CCST will be working to align legislators, staff, and the public around science and technology. "It will be a great opportunity to highlight California Community College makerspace activities," she said.

Van Ton-Quinlivan, Vice Chancellor for Workforce and Economic Development for California's Community Colleges, personally championed InnovationMaker3, which gave rise to the CCC Maker Initiative. She began her remarks with an acknowledgement of several advisors from her office and congratulated the 24 colleges who were awarded the implementation grant.

Ton-Quinlivan said her office sees their investment in the CCC Maker program as an investment in jobs and the economy. They seek to identify the best strategies for the quickly changing job market, and the CCC Maker program is "creating transferable skills in communication, collaboration, critical thinking, and creativity," she said. "Those skills transcend any occupation or job."

Traditionally, higher education has measured itself through completion and transfer rates. The Chancellor's Office cares about workforce outcome metrics: whether students had a bump in learning; are making a living wage; and/or are being placed in jobs. That's why her office has invested in internships at many locations. The end goal across all of their grant programs is always student success and, she said**,** "moving the needle on student outcomes."

Other investments from her office support portability—both for the students and for the work of the CCC Maker community. She hopes that over time, everyone in the CCC Maker program uses the network to develop curriculum and content that can be shared throughout the state. This network means that, "When one of you develops [something], all 114 of you can get it," she said.

Other new systems will allow students to declare their marketable achievements, such as micro-credentialing and badges, through direct LinkedIn uploads. Her office supports digital infrastructure like this so community colleges don't have to "start from scratch."

Finally, Ton-Quinlivan announced a recently published article[1] with a national audience that highlights three institutions implementing maker programs: Yale, UC Berkeley, and, to much applause, the California Community Colleges.

CCC Maker Kickoff and Program Announcements (10:10 am)

Following introductions, the CCC Maker Implementation Team gave an overview of where the group has been, and where they envision the CCC Maker network going from here.

Paul DeVoe, who has been on the Implementation Team since the beginning of CCC Maker, briefly summarized a paper that will be presented at this year's International Symposium on Academic Makerspaces, which he co-authored with fellow Implementation Team member **Carol Pepper-Kittredge**.[2] "It was an easy paper to write," he told the group. "What we did was just told your story."

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[1] Maves, M. and Wilczynski, V. (2017) *Higher Education Makerspaces: Engaged Students, Hands-On Skills, Interdisciplinary Connections*. Learning By Design, Spring 2017: pp. 16-19.

[2] Pepper-Kittredge, C. and DeVoe, P. (2017) *We Are All In This Together: Building a Network of Makerspaces in California Community Colleges.* Proceedings of the 2nd Annual International Symposium on Academic Makerspaces, Case Western Reserve University, Cleveland, OH, September 24-28, 2017

The support from Van and the Chancellor's Office for both program development and eventual internships, at scale, was unique and "a big deal," he stressed. He and Pepper-Kittredge are speaking with people from all over the world about their journey into the Maker Movement. The work the CCC Maker community is doing together "compares well with anybody, anywhere in the world," he said.

The paper covers tactical issues as well as the values of being a maker in a makerspace, including a comfort with taking risks and open-source sharing. It also discusses what the team has learned about the need for each space to have its own character. "There is no such thing as a playbook for how to create maker spaces on the scale that we're doing," DeVoe said. "That hasn't been written yet."

Deborah Bird, co-founder of the FabLab at Pasadena City College, where she also teaches, began her remarks by noting that Paul and Carol's paper is a follow-up to their earlier paper, which laid out plans for the program.[3] This year's submission explains what they actually did, along with plans for what they will do next. "There's a real sense of continuity as we're growing and learning, and we're all evolving together," she said.

Bird described the maker community as including the group of educators in the room, their students, their faculties, and their broader campus communities and beyond. She explained that as the leadership group developed a strategy to get a broad swath of colleges involved in this program, they were determined to make the process as inclusive as possible. "That's why we have 24 colleges in this room—just under a quarter of the colleges in the state, " she said. "That in itself is phenomenal—it means that we're a quarter of the way there."

The seed grant process echoed the values of the community and the entrepreneurial framework of the maker movement. The goal of the early portion of the initiative was "to give you just enough money to get you into trouble," Bird said. The advisory committee knew they needed to create a culture of sharing, openness, and the resourcefulness to adapt and grow. "If we set it correctly, you'd learn more from each other than you could ever learn from a small project team," she said.

As the team developed the process, design thinking fostered a guided approach of team-building, collaborating, and sharing. The goal for the year is to have "everyone in this group contributing to our shared body of knowledge," she said. The Implementation Team is looking to grow the network of about 2,000 people to an ecosystem of over

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[3] Pepper-Kittredge, C. and DeVoe, P. (2016) *Creating a Network of Community Colleges with Makerspaces: California's InnovationMaker3 Model.* Proceedings of the 1st Annual International Symposium on Academic Makerspaces at the Massachusetts Institute of Technology, Boston, MA, November 13-16, 2016

10,000 people—a network to support a sustainable future for California's community college students.

Carol Pepper-Kittredge, the Program Manager for Training and Development for Business at Sierra College's Center of Applied Competitive, wrapped up the program remarks with a statement of the CCC Maker Initiative's goal: to encourage a "systemic" maker culture—that is, every community college student will have access to a maker space community.

The initiative is an opportunity to "redefine what it means to be well educated," Pepper-Kittredge said. "[Educators] know that students who get short-term, quick training are getting really good jobs." Such training allows colleges to "pivot quickly" in a fast-moving environment where technology, and the economy are all changing, she said. She noted that during the previous day's event, the Kumu visualization tool helped everyone understand the program's critical connection both to its internal and external ecosystems and also how those networks will drive education and jobs for community college students. This project "is going to help position community colleges to be the driver in the innovation economy for California."

The CCC Maker Initiative aims to be a statewide model for how to adapt, pivot, and scale quickly. "What's this going to look like in two years? We don't know the answer," Pepper-Kittredge said.

- PROGRAM -

After program remarks and updates, six invited speakers shared their research and experiences with the audience. [4]

Students in Maker Spaces

Lee Martin, Associate Professor in the School of Education at UC Davis, studies the making in his mobile makerspace, the Beta Lab. Making has a cool "Burning Man meets science fair vibe," he said, introducing his presentation, **Promoting Equity, Complexity, and Centrality in Maker Spaces.** But too often, creative, resourceful problem solving is depicted in the media as the territory of middle class white men. The percentages of photos and articles featuring women and in *Make Magazine* and in Maker Faire coverage are low. "But this perception is just not accurate," he said. "The most resourceful populations are often the least well resourced."

Martin presented research he conducted to understand what young people get out of maker experiences. He worked with four maker groups (ages 12 to 18), made up of

[4] See all presentations online at http://ccst.us/projects/makerspace/symposium.php

students from a diverse charter school. While he stressed that no maker activity has a uniform outcome, he did observe three key gains:

- Improvements in the specific skills students worked on (i.e. woodworking, sewing, electronics)
- Enormous shifts in identity and confidence: 93 percent of students became more confident in their ability to design new things
- Adaptive expertise (or resourcefulness)—that is, the ability to apply knowledge innovatively, to new problems. For example, a young woman he called "Olivia" tried a number of methods to solve a problem with cracking clay on her kinetic sculpture project. (He called her problem-solving effort, however frustrating, a "quintessential maker moment." In the end, "Olivia" learned to apply the "universal solvent of acceptance: that things are just not going to be perfect.")

The remainder of Martin's presentation focused on three concepts central to maker programs: equity, complexity, and centrality.

To understand *equity* issues, Martin said educators must ask: "Who's in the room? Who has opportunities and who is taking up those opportunities? Which ideas are celebrated? Are all ideas taken seriously?" To address this complex topic, he said, it's important to meet youth "where they are and as who they are—literally, cognitively, and socially-emotionally." He suggested a circle time with a slightly silly question as a good warm-up exercise. Creating the feeling of belonging is key, he said—students need that to play around, take risks, persist through challenges, and be comfortable asking questions.

Complexity is another key component to educative making: What is the nature of the work? Is it cognitively complex and intellectually challenging? Does it push students outside their comfort zones and up to a new level? Martin said creating complexity includes intellectual risk taking, a culture of drafting and feedback, seeking out other ideas, encouraging "leveling up," and an environment saturated with resources.

Finally, Martin defined *centrality* with the question: Is student work at the center of the project? "It sounds obvious," he said, "But when things get really difficult, sometimes people come in and help, and students get relegated to tasks like assembling and gluing. They need to be at the center of thinking and design work." Educators should be thinking about how to move students up and down levels of complexity, keeping them in the "Goldilocks zone" of challenged but not overwhelmed, while making sure that the complexity—design work and decision-making—remains with the student. "This can require a lot of patience," he noted.

Martin recommends conceiving of these elements as cycles. Start off grounded in something with which students are familiar; bridge this concept to maker practices, focusing on "desirable difficulties"; then build in some motivation and opportunity for an excited student "to want to learn that new thing and build their skill set." This

process can bring a shift in students' knowledge, understanding, and sense of themselves.

Zack Dowell, Director of the Folsom Lake College Innovation Center, focused on interdisciplinary collaborations in his presentation, **Making Across the Curriculum** (11:10 a.m.). His newly remodeled innovation lab is just wrapping up its soft-opening, but Dowell built his original space out of a more traditional media lab, with "old-school" technology like photo slides and floppy disks. Within five years of getting "fired up" by the 2006 Maker Faire, he'd bought a giant, $20,000 3-D printer. "It was in some sense a $20,000 colossal failure—a paper weight," he said to a round of audience laughter. "The technology was too new and not well understood. When I'd say '3-D printer,'" he recalled, "People thought, 'Star Trek?'" While the engineering department did use the tool for some interesting projects, "No one else really got it," he said.

But by cultivating interdisciplinary projects across campus, he built a case for making as a "stance"—as an approach to general education, suited to the needs of his campus. In one example he gave of a successful collaboration, geoscience students attached aerial photography rigs to kites, balloons, and quadcopters (early drone-like vehicles). Not only did students gain skills like mapping and interpreting data, but the project also led to other interesting collaborations, including a class partnership with the American River Conservancy to map their land near the south fork of the American River. Dowell said the project was a great example of "the permeability of classroom walls."

Dowell also highlighted collaborations between faculty and students. For example, a stand-out math student named Alex helped his math professor by using a 3-D printer to create manipulatives for a Calculus class. A history teacher heard about the project, and worked with the same student to create a 3-D printing system to synthesize pieces for a game she does with her students. The lab built connections with two different departments, both teachers got a sophisticated teaching tool, and the student got experience and portfolio pieces that, in his case, led to a paid internship.

Dowell used numerous photos to illustrate other successful collaborations across campus, including between teachers of young children, and the chemistry and biology departments. Theater Arts students used the Innovation Center to design a room-scale interactive installation for the school's library. One project involved building loaded dice and then graphing the outcomes of repeated rolls; another involved using fiber arts projects to understand the role of women in archeological history.

To help faculty cultivate ideas for collaborations like these, his lab has held professional development trainings for faculty from departments across campus, including skills training, such as how to use the laser cutter. Dowell also emphasized the importance of a supportive co-working space, with many students all working on prototypes for their classes. "It was so important to have people occupying space together and doing their thing," Dowell said. "So many rich conversations emerge from that."

Some lessons Dowell shared with the group were:

- "Your mileage may vary." There are many ways different colleges are going about this work, and outcomes are not uniform. This is good!
- "Find the others." This is a big ecosystem that includes the college, artists, entrepreneurs, and others in the community—with the students right at the center.
- Make sure spaces are accessible and equitable. Use the "IEIC" model: For every decision, process or program, ask: Who is **I**ncluded, who is **E**xcluded, who is **I**mpacted by it, and who is **C**onnected to it?
- Always be prototyping—version 1 will never be right. Spend time with an object or a process or an idea.
- Sustainability: What happens after this grant is spent? At Folsom Lake College, they have tried to build making into the curriculum wherever possible, including creating the designator "MAKR" that can be attached to a variety of courses to indicate a making component. For example, an established entrepreneur course now has a prototype component. "Before, they were just writing a business plan," he said. "Now they're writing a business plan and making the object."

In a follow-up interview, Dowell noted that his newly redesigned space has been in a soft-opening phase for a year, and will just be starting regular hours this fall. The space has been remade using current digital technologies, many of which will provide quantitative data on the space. For example, they are adopting technology that enables students to log into a machine by scanning a card, which allows them to track which machines are used the most, and how much time users spent with a machine. ID scanners at the entrance will not just count the students coming into the lab, but also can collect data such as user departments and majors.

Qualitatively, Dowell will be looking to improve the lab's understanding of student learning outcomes. He is working on improving pre- and post-participation questionnaires probing hard-to-measure areas like empowerment: Do students feel like they can do things? Do they feel better about themselves, their abilities, and about their school?

Paulo Blikstein, of FabLearn Labs at Stanford University, presented to the group from Europe via Skype. (10:40 a.m.) Event organizer Brie Lindsey (CCST) had the opportunity to "hack" the presentation after technical problems arose with the connection. As Blikstein's screen sharing would not work, and he could not hear the Berkeley side of the communication, Lindsey controlled slide advancement in Berkeley, while reflecting the slides on the wall back via Skype, and typed in written cues and questions from Berkeley. At the conclusion, the audience showed their appreciation by using the American Sign Language signal for applause: waving hands in the air.

Blikstein opened his talk, **Assessing Learning in Complex Learning Environments,** with a comment on equity. “We have this idea that through uniformity—by giving people the same content at the same time—we give people the same opportunities to advance their education. “ he said. “We’ve been trying this approach for a hundred years…. It just hasn’t worked.”

Exploration Technologies (ET) within maker culture—such as robotics, 3-D design, computer technology—had been deemed expensive, unrealistic, and impossible to implement in the classroom, Blikstein said. But he enumerated changes in the last 15 years that have prompted us all to revisit the promise of ETs:

- ETs entered mainstream education as “21st century skills.” They became part of the discourse of large government organizations.
- The cost went down by a factor of 10 up to 100. For example, a robotics kit went from $5,000 20 years ago, to $300 10 years, to $30 today.
- Public awareness of coding and making has increased: national and statewide coding initiatives, White House Maker Faire—have helped bring niche activities to the mainstream.
- Better research is being conducted and presented at conferences and in journals aiming to understand how learning environments that incorporate ETs work.

Blikstein said his lab pushes against idea that gains from maker education cannot be assessed or measured. They’ve developed several tools to do just that:

- Eye-tracking and bio-sensing: Where are kids looking when they are building something? Are they looking at the same thing when they are collaborating?
- Tracking where objects are and students are in the makerspace. Observations can be plotted on heat maps and used to determine where they spend their time.
- Tracking student roles: Are people idea ambassadors? Question askers?

In addition to these cutting-edge assessment technologies, his team has studied the value of exploration by flipping the “flipped classroom.” They found that students learned 25 percent more when they started with exploration and then moved to lecture, compared with the other way around. When the lecture came first, researchers observed that the information was “coming into a void.” Putting exploration first helped students develop curiosity and questions, so they paid more attention and learned more.

To explore learning in collaborative environments, researchers in Blikstein’s lab observed performance by groups of students paired in one of three ways: two high-GPA, two low-GPA, or one high- with one low-GPA student. They found that with mixed pairs, “very interesting things happen,” he said. While pairs of two low-GPA students demonstrated the least amount of learning, the outcomes for the other pair types were better, and nearly equivalent—a low-GPA student paired with a high-GPA student was

tasked with “driving” the pair’s learning, these pairs did just abut as well as pairs with two high-GPA students. These results suggest that social engineering in the maker classroom can be used to make the most of learning opportunities.

In another assessment study, students were given a task, such as fixing a broken object, and gesture-detection sensors were used to measure the student’s activity. Not surprisingly, active students learned more than idle students. But, Blikstein said, the most interesting result came from analyzing how many times students alternate between active and passive states: “Experts alternate between active and passive. They build things, stop, evaluate, and go back,” he said, recommending that instructors can make sure their students employ these cycles of action and reflection.

Summing up, Blikstein said that these tools allow more precise measurements of the kinds of learning that take place in maker environments. “This provides the opportunity to have equity without uniformity,” he said. “Such gains are measureable, low-cost, and scalable.”

Maker Spaces at Work – Afternoon Session

Marlo Kohn is the Associate Director Stanford’s Product Realization Lab (PRL) at Stanford, where she also runs the teaching assistant (TA) program. Her presentation, **Teaching Assistant Coaches and Campus Collaboration** (1 p.m.), described the PRL’s staffing model. “We think of these teaching assistants as our main product,” she said in her opening remarks.

Kohn helped set up PRL: “What it should be, what goes into it, how to get people to come—all the challenges many of you are facing,” she noted. It’s open to all Stanford students, regardless of a departmental or class affiliation, but it’s a competitive application process.

The lab has 18 to 20 TAs each year, usually about half male and half female. They receive intensive training on the space and the equipment and work 20 hours per week. Their role is to staff the lab, but Kohn stresses that it’s not just minding a desk—they have specific tasks and help any students that come into the lab, training individuals on equipment, spreading a culture of safety, and learning not to just give answers—what she describes as “being shop Google”—but rather to help students find information. This role can be especially challenging for highly skilled individuals, who, she has observed, often like to show off their knowledge. But, she said, “It’s a great learning opportunity to help them work through that.” The program supports learning how to think, not just be given ideas to work with.

The lab is open in four-hour blocks. It offers its own classes and tangentially supports other classes. TAs teach students how to use tools like manual mills, lathes, and welding equipment—all in the context of structured labs. Each TA designs his/her own project

and their skill levels vary, generally between very opposite ends of the spectrum, Kohn observes—they may have taken robotics or never have touched a screwdriver.

Kohn says teaching TAs to become better coaches is an important part of the program. TAs work with small groups of students on projects, helping them scope project choices according to individual abilities and available tools. TAs support the whole process: sketches, prototyping, remodeling, and learning technical processes.

TAs are rewarded for their work with financial support during their master's degree studies and off-hours use of the lab. Additionally, the technology, leadership skills, and especially people skills they learn at PRL are sought after in the job market. A rich and active alumni network continually shares resources and opportunities. This network, along with industry recognition of PRL coaches' skillset, is among the most valuable products of the coaching program.

PRL is housed in the Department of Mechanical Engineering and has built relationships with faculty across campus, half from outside Engineering. Kohn provided several examples of collaborations arising from these cross-campus relationships. A writing teacher had students build a project that illustrated the students' writing projects; a history teacher had students throw, glaze, and fire pots to understand the importance of the Japanese tea ceremony. Kohn notes that none of the collaborations were planned—they all arose organically as a result of having the space and resources available.

Björn Hartmann, an associate professor of Electrical Engineering and Computer Science at UC Berkeley, is the faculty director of Berkeley's Jacobs Institute for Design Innovation, and host of the event. His talk, **Design Innovation Course: Design Interactive Devices & Campus Collaboration** (1:30), presented the programs run by the institute along with some history of the space. Tours of the facility were offered in the morning and after the final presentation.

The lab is a project of the College of Engineering, but is open to the entire campus. The vision behind the institute: It's not enough to give students technical skills; they must understand how to work in interdisciplinary teams; how to design, prototype, and iterate; how to construct in a sustainable way; and how to combine art, design, and engineering perspectives—all in a global context.

"California's rich history of combining design and technology inspired the institute," Hartmann said. He provided two iconic examples: To create the now-classic wood curves of Eames chair, the makers needed not just to understand design, but to understand how to mold plywood into organic shapes. He also cited Steve Jobs' well known quote: "It's in Apple's DNA that technology alone is not enough. It's technology married with the liberal arts, married with the humanities, that yields us the result that makes our hearts sing."

"Here in Silicon Valley," he said, referring to the entire Bay Area as the "bleeding edge" of innovation, "technology alone is not enough—it must be combined with an understanding of user need and how products fit into people's lives." The Jacobs Institute teaches this through a "design thinking and design doing" curriculum.

Jacobs Hall is a 24,000 square feet over three-and-a-half floors. Having both making (first floor) and teaching (second and third floors) in the same building is important to the program. They coordinate with engineering and entrepreneurship, but the institute's focus is on design and making. They have relationships across campus. The institute's place in the campus ecosystem is "in the center of making, emerging technology, and design," Hartmann said.

Their most critical tools are:

- Powerful design software—with functionality like analysis and simulation that allows students to express their intent
- Digital fabrication and hand tools
- Programmable electronics

Each semester, 10 departments teach 20 courses to about 1,200 enrolled students. The maker space had about 900 members last year and is headed toward its 1,000-member capacity. The next challenge for the program will be to collaborate with other departments and spaces across campus, like welding and civil engineering. The faculty is mostly engineering, but they bring in lectures in areas like industrial engineering that

don't have departments on campus. They have five FTE technical staff and also run a student-supervisor program, mainly for undergraduates. (By contrast, Marlo Kohn's program at Stanford is designed for graduate students.)

Hartmann defines two main student audiences: The "Basecamp" group is the broad base of students who gain exposure to prototyping and design thinking for one semester, then move on to a variety of majors. The "Peak" group is smaller. "If we let them, they would live in this building," Hartmann said, to knowing amusement from the audience. The institute looks at programmatic ways to give peak students a pathway to exciting careers in design and technology. They also offer design and innovation courses, co-curricular courses, and student-led courses, and they now have an interdisciplinary minor. Maker passes are available to access the space. In their most popular class, Design and Prototyping, half of the students come from outside engineering.

Hartmann recommends attending the International Symposium on Academic Maker Spaces, which is coming up soon at Case-Western University. He and Stanford's Kohn are helping to organize it.

After the presentations, Hartmann addressed a query: How is maker culture different from the traditional engineering education and its "capstone project" culture?

"The traditional model of engineering education model was: 'Welcome to college. Take your math and your physics and then we start at fundamentals, work our way up, and then right before you graduate, you get to do a project,'" he answered succinctly.

"We believe that open-ended projects, where students really feel ownership of the project direction, are really important *throughout* their undergraduate education. Because being motivated by their own open-ended projects also creates a pull for conceptual knowledge. If you're really motivated to figure something out and the first solution doesn't work, what do you do? You look at, 'What engineering principles or other domain principles do I need to learn about to have a better version two?' We wanted students to have those experience freshman year, sophomore year, junior year—not just at the end."

Ghigo DiTommaso is the director of UC Berkeley's **Design and Innovation for Sustainable Cities Summer Program** (2 p.m.), also the title of his presentation. The program is run Berkeley's College of Environmental Design (CED), where DiTommaso is a lecturer. His presentation describes the college's introductory five-week undergraduate summer class on the problems that cities face, including resource management, sustainability, and innovation and design. The program started in 2014 with 18 students from all over the world, and has grown to 43 students as of this past summer. While they are no longer nimble enough to go visit numerous small design studios around the city, they have maintained a very tight-knit community while accommodating growth.

The program incorporates “old-school lectures followed by and Q&A” led by various professionals and CED faculty; presentations by students, starting with their home cities; and field experience. The class engages a wide variety of observational techniques to explore the Bay Area as an urban center, including sketching, photographing, counting pedestrians, counting cars, and identifying where people sit and don’t sit. “Understanding what’s happening in an urban space is one of the fundamentals of the program,” DiTommaso said.

The students’ field notes come together into a physical collage on a pin-up board, then they “move into the digital world,” with tools like GIS and Rhino, a 3D modeling program. For their culminating project, students design a board game to understand all the players in an urban environment. “The components of the board game are loaded with the forces at play—economic powers, stakeholders, the local community…” he said.

Students use tools like laser cutters and 3D printers to fabricate the board and the pieces by hand, and they develop their game’s logic and rules. They refine and iterate game design, incorporating feedback from the studio review and can use the fabrication lab “to refine the design of the game as an artifact itself,” he said. For 85 to 90 percent of the students, it’s their first experience in a fabrication lab.

“We use the metaphor of the game not only as a way to expose them to complexity of urban process, but also as a way to introduce the students to topics related to design,” DiTommaso said. “The game becomes almost a piece of industrial design.” The process also introduces the different workforce entry points for student interested in some form of urban studies, from architecture to planning to academia.

Developing a design proposal is another key component of the process. “By playing the game with their peers, they can start to identify a series of design solutions that think they could be addressed at [their urban] site.” DiTommaso said. In week three, students develop proposals for site-specific design solutions such as relocating a freeway, creating a levee, or fortifying housing along a shoreline. The proposal is an opportunity to integrate their increased knowledge of the issues into more sketching and problem-solving.

The course culminates in a final review that gives students the excitement of studio review—they gain presentation skills by formally present both their game and design proposal to the class and invited guests. Finally, they spend a day presenting their games at San Francisco’s Exploratorium science museum. This setting creates interesting interactions between the college students, and young museum visitors as they play the games together.

When asked about the cost of the program, DiTommaso replied that it's an expensive course, but the teaching methods and pedagogy would be transferable to other programs.

Report-out and end (3:15 pm)

The event closed with an invitation to reflect on how materials and tools in a makerspace relate to equity and inclusion. Participants were asked to consider how the layout of the maker table impacted the choices they made about accessing materials; whether the tools provided were a welcoming invitation to making; and what changes might have made for an even better making experience. CCC Makers were invited to take any consumable materials from the maker table home to their respective colleges.

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