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A New Liberal Art

How systems thinking prepares students for a complex world

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Noah Berger for The Chronicle

The shipboard training provided at Cal State Maritime gives students "a bigger sense of how the world works," one alumnus says.

In the eight years that Gladys Wiggins has worked at Yuma International Airport, her job has grown increasingly complex.

She has managed operating budgets in the millions, dealt with a raft of state and federal rules, inspected safety equipment, negotiated with local unions, submitted grant applications, conducted environmental studies, and glad-handed local politicians and businesspeople for support. She earned her bachelor's degree in engineering in 2001, became the airport's director of operations and resident engineer in 2009, and was running the place by 2013.

Today, she credits her success to a learning environment vastly different from the deserts sprawling across southern Arizona. When she was 21, she boarded the *Golden Bear,* a ship owned by the California State University Maritime Academy, and spent 96 days on the ocean. That meant not only long hours of wrestling with the boat's mechanical components to keep the generators and diesel engines humming, but also interacting with a chain of command among her fellow students, and in tight quarters, no less. It meant seeing, up close, the logistics of the global economy, her peers' unfamiliarity with (and sometimes hostility to) foreign cultures, and the government regulations that ruled everything.

The *Golden Bear* is not simply a ship, but an amalgam of technical and human systems. It is the kind of hands-on laboratory that other institutions might consider creating, in their own ways, to prepare students for a complex, interconnected world.

"One thing I realized is that you can understand a systematic approach of every working part," she says, "but if you can't create that culture, that bond, that trust in learning about the individuals you're working with, then your projects are going to come to a halt."

What Ms. Wiggins received, perhaps without knowing it, was an introduction to systems thinking. The term refers to a discipline that examines the relationships between essential parts of an organization or a problem, and determines how to manage those relationships to get better outcomes. At Cal Maritime, professors frequently talk about the ship as a "system of systems": The captain, engineers, and able-bodied seamen work on the systems in navigation, engines, potable water, ballast water, sewage, and more to make the whole thing churn across the ocean. If those students are thinking really broadly, they are also considering the impacts of systems off the ship: fuel prices, climate, or international boundaries.

This kind of broad thinking is a key to success in the workplace of the future.

The most valued workers, observers say, will understand and incorporate systems thinking into their jobs and lives. Philip D. Gardner, one of the leading scholars of the connections between college and career, has said that systems thinking is a key attribute

of the "T-shaped professional" — the employee who has depth of knowledge in a particular expertise as well as the ability to work and communicate across disciplines.

Joseph E. Aoun, president of Northeastern University, writes in his new book, *Robot-Proof: Higher Education in the Age of Artificial Intelligence,* that systems thinking will be a "higher-order mental skill" that could help human workers compete with machine learning. Consider, he says, Koen Olthuis, a Dutch architect who designs floating buildings because he sees how architecture and urban planning intersect with climate change, materials science, and engineering. "Computers could be programmed to think across a variety of silos, enabling them to engage in systems thinking of a sort, but the big creative leaps that occur when humans engage in it are as yet unreachable by machines," Mr. Aoun writes. "Systems thinking is a critical cognitive capacity for anyone in a position of leadership but also for anyone attempting to discover new knowledge, launch a business, or create something original."

Although systems thinking is touted as a critical skill for the future, its roots go back several decades, to computer science. David Peter Stroh, author of *Systems Thinking for Social Change,* notes that systems thinking grew out of system dynamics, a discipline invented 60 years ago by Jay Wright Forrester, a computer engineer and professor of management at the Massachusetts Institute of Technology. Forrester noticed striking parallels between engineering and information systems and social systems. He saw the ways that relationships in all complex dynamic systems can have amplifying or balancing effects, which result in conditions that increase, decrease, or stabilize over time. The models that he and his students built were highly technical, but the underlying ideas were adopted by scholars in other disciplines — notably, environmentalists who saw the connections between human systems and ecological systems. Donella Meadows, one of the authors of *The Limits to Growth*, a 1972 book that examined how resource shortages could lead to economic and social collapse, became a prominent figure in systems thinking.

While systems thinking as a discipline is not as rigorous as Forrester's method, which relies on mathematical models to track changing relationships, it is much more accessible and more focused on human interactions.

"The world is becoming increasingly interdependent," Mr. Stroh says. Linear thinkers believe that problems have direct causes and that you can optimize the whole by optimizing each of the parts. Systems thinkers know that problems can have hidden, indirect causes. It is the relationships among the parts that matter most. Moreover, because there can be long time delays between when a problem arises and manifests, problems and their solutions are also examined on a longer timeline in systems thinking.

Mr. Stroh highlights a difference between linear thinkers and systems thinkers with an example in his book: To stop a rising crime rate, policy makers might adopt a "get tough" policy in arrests and sentencing. A conventional thinker would assume that if you "optimize" the punishment for crime, you would reduce it. But the systems thinker would see that widespread arrests and longer prison sentences damage the relationship between the police and communities, introduce more people to criminal life through prison, and deprive young children of their parents, extending the problem into the next generation. As a result, get-tough policies lead to more crime, not less. A systems thinker would take a step back and consider how poverty, education, urban planning, and community cohesion are the real factors in play and would seek to put leverage on those elements.

Much of systems thinking relies on the soft skills that employers ask for these days: communication, problem solving, collaboration, adaptability. People trained in systems thinking see the gaps where complications or opportunities can arise, and conceive of how that system connects to others within and outside of their industries. They will have their heads up, looking around, not just buried in a discrete task or duty. Those skills are also some of the hardest for employers to find among recent graduates, surveys suggest.

To remain relevant, Cal Maritime has had to expand and change its curriculum to focus on systems thinking and large-scale problem solving. Shipping, much like any industry, has been affected by mechanization and offshoring. In the 1950s, there were 1,200 American-flagged ships in the U.S. merchant marine; today, there are about 180.

The sailing life also has limited appeal. Many Cal Maritime graduates who get a job as a sailor or engineer on an ocean vessel stay for only about five years. Being isolated at sea, away from home and family, leads them to seek a job on shore. Often those jobs are in shipping-related industries, but sometimes they are in something totally different: managing investment portfolios, running power plants and oil refineries, working for Tesla or Google, or designing rides for Disneyland.

New opportunities are emerging in maritime cybersecurity, navigation, and autonomous ships, says Thomas A. Cropper, Cal Maritime's president, and those disciplines might have applications in seemingly unrelated industries, like banking or finance. His students "have to have an understanding of systems, because they are operating not just in an international economic system, but an international financial system or international logistics systems, and they all come together in maritime," he says. "An understanding of systems will help someone be agile and have some portability."

Gerald Spencer, who graduated from Cal Maritime in 2014, uses his training today at 3Scan, a company that uses advanced imaging technology to perform biopsies.

He thinks of his job as an extension of his training in the engine room on the boat. The *Golden Bear*'s pipes of fluid are now thick strands of fiber running from San Francisco to supercomputers in Oregon. The lessons he learned interacting with his fellow sailors — in communication, problem solving, and division of labor — have now transferred to this team of Bay Area entrepreneurs.

"If the only thing you're taking away from that education is how to look at a force diagram and running an equation and get an answer, you're not really getting the full picture," he says. "What you should get is a bigger sense of how the world works and operates."

We're entering a labor market where many people will change jobs half a dozen times or more before retirement, and graduates will have to be flexible thinkers who can adapt to new careers and new challenges. In response, academic programs should look beyond their disciplinary walls at the connections between people and problems.

This kind of approach could apply to a range of disciplines — music, journalism, public health, agriculture, theater — that offer vocationally oriented majors. But those programs would need to slightly tweak what they are teaching. Thomas Fisher, the director of the Minnesota Design Center and former dean of the architecture school at the University of Minnesota-Twin Cities, leads students to use their training in architecture and design to tackle intractable problems in fields far from urban planning or buildings. The students in his program have been recruited to work on the challenges embedded in big systems, like public health. His students might ponder how the rising cost of health care interacts with growing poverty, car-oriented city planning, and government support for sugar, corn, and junk food. A systems approach spirals out from one problem to touch many.

Some of his older colleagues, raised in an academic world defined by ever-narrowing specialization, think this approach is nuts. "But the younger people flock here," he says. "They recognize this gives them a lot of adaptability in the marketplace. There will always be people who can design buildings. Now, what the world really needs are people who can help with these bigger systemic failures."

For now, colleges are still organized around siloed disciplines, with educators assuming that students will figure out — on their own and in the future — how to make the broader connections to other subject areas. "To me, it's about just being more explicit and acknowledging the fact that our students are going to end up doing a much wider range of things than what our degree programs assume," Mr. Fisher says. "I don't think it's a radical shift. It's more of a mind-set shift, being more explicit about things that we now are basically teaching implicitly."

While liberal education was pilloried as useless in the years following the recession, the reputation of the liberal arts — and, specifically, the humanities — has recently been revamped as the generalist training favored by Silicon Valley start-ups and high-end consulting firms. By discussing Plato or reading American history, the story goes, a student will learn how to see, communicate, and think broadly in the workplace, not to mention in the quiet moments of private life. With a liberal-arts degree, "you can do anything," proclaims George Anders, a *Forbes* writer. Meanwhile, Randall Stross, a Silicon Valley historian and *New York Times* writer, touts the liberal arts as the new "practical education."

By contrast, real practical training — directed at specific careers — is derided by intellectuals. Training for one job or one industry, they say, is perilous in an era when the economy and technology will eliminate many careers and create entirely new ones.

ut reading Plato or studying American history doesn't automatically give a student an introduction to systems. Practical, career-oriented education could be just as valuable — perhaps even more so.

Consider the Culinary Institute of America, one of the best-known colleges for tomorrow's head chefs, sommeliers, and other food specialists. The cooking school, as it turns out, shares some remarkable similarities with Cal Maritime: The skills that produce a beef Wellington dinner for two — much like those that keep a ship cruising on the ocean — might seem very specific and difficult to transfer to other kinds of careers. But like the ship, the kitchen functions as a teaching device — a laboratory where students learn how to confront unexpected problems, try a hand at leadership, and start to see the interlocking human and technical systems, the scaffolding of any workplace.

Phil Mansfield, CIA

Students at the Culinary Institute of America's Napa Valley campus learn to work closely with one another. "Being a chef requires a global vision," says one expert.

One recent morning at the Culinary Institute of America at Greystone, one of the institution's two California branches, first-semester students decked out in white coats and tall white hats had been divided into teams, set at stations, and assigned to make beef with spätzle for lunch. They organized their teams according to the amount of time or space that a task, like reducing broth or chopping vegetables, might take. They had to be aware of peers moving around them with sharp knives or hot pans. They were accountable for delivering the right ingredients, at the right times, to their various stations. A screwup — which eventually happened when one student delivered liquid broth, rather than a more viscous beef reduction for the demi-glace — meant that the students were an hour or more late getting lunch to the table.

All of this serves as an introduction to *mise en place* — French for "everything in its place" — an organizational framework that allows chefs to manage the various ingredients coming into the kitchen and the food coming off the stovetop. For many chefs, it's a guiding principle and a way to see how systems — human, financial, environmental — interact with a menu, a restaurant, or even a life. One young cook here has the words tattooed on his arm.

"The culinarians have a saying: A cook sees his station, and a chef sees the whole kitchen," says Dan Charnas, a New York University journalism professor and author of *Work Clean: The Life-Changing Power of Mise-En-Place to Organize Your Life, Work and Mind*. "Being a chef requires a global vision — the ability to see systems, to see how everything fits together." The greatest chefs are not just thinking about when to broil the fish, but how the fish relates to the pasta cooking at another station, the food delivery that evening, the fishermen working on the ocean, the changing climate's impact on their fisheries, and so on.

"If you've ever seen some of the chefs graduate and go on to do other things — whether it's run their own businesses or run consumer-products companies — they take their *mise en place* with them, because it's now ingrained in them," Mr. Charnas says.

While observing students working at their stations, one of the chef instructors says that perhaps only 20 percent of culinary-institute students will eventually work in restaurant kitchens. Among the rest, many might work as restaurant managers or in food-related corporations. Others will go into journalism, education, marketing, or research and development. The chef at CIA said that one of his best students of the past few years graduated and went to work in a top restaurant, but eventually left to work in real estate.

Christine Flanagan, a consultant known for her work on competency-based education and career preparation, got a bachelor's degree in English from the University at Albany, then in her late 20s went to culinary school at Johnson & Wales University, thinking she wanted to be a chef.

Near the end of her time at Johnson & Wales, she decided that the kitchen wasn't for her, and she left one semester before getting her culinary degree. "I still walked away with probably more value from that experience, in being able to apply it to the real world, than I did from getting a B.A. in English," she says. The English degree gave her some critical-thinking and writing skills.

"But it did not give me what the culinary arts did in terms of a process within a system that can be applied to other places," she says.

In training students to think about systems and develop crucial soft skills, hands-on learning is key. Real-world problems that are unscripted and consequential force students to consider their place within a system, as they work alongside peers, usually for some tangible outcome.

A college doesn't need a ship or a kitchen to create this learning environment. Programs that incorporate concepts of sustainability — which consider an activity's environmental, social, and financial impacts — inherently place a student's work in a systems frame. The Sustainable Cities Initiative at the University of Oregon marshals the work of hundreds of students in dozens of courses to solve problems in a selected Oregon city or government agency every year. Projects in one course inevitably interact with the work of other courses, and in the process students start to see the relationships between components of a problem. (Students also frequently say that the hands-on work is among the most rewarding of their college experiences.)

The programs at the nation's various work colleges — which can range from office work to farm work to janitorial services — can have a similar effect. That work is designed to teach students about teamwork, responsibility, communication, and problem solving on the job. But at places like Berea College or Warren Wilson College, where sustainability and service learning have been integrated with the work, students are more likely to connect their job on, say, the college farm with the health of the land, the changing climate, the work of farms around the college, poverty and hunger in Appalachia, and the financial footing of the college farm itself.

Susan Opp, the provost at Cal Maritime and an entomologist, finds an analogy for hands-on experiences by contrasting them with cookbook experiments, the traditional method of teaching science: "You would give students a canned lab that you had already figured out, and they were just going to replicate what you had done before to show that they can do it, too," she says. Hands-on, open-ended learning environments, she says, help students learn "to solve problems and think more holistically."

Her students, too, talk about the lessons of the ship in terms of metaphors. Logan Kent, a senior and a marine-engineering-technology major at Cal Maritime, has developed a more global view of his studies through hands-on work. He tells stories about the times he has worked long shifts, tuning up pipes and pumps, fixing broken couplings, transferring fuel into the ship, or standing watch in the middle of the night, to secure the boat.

"If I can get in there and I can physically hold a pipe, run my hand along that pipe, and know which way the flow is going through it, it helps me visualize the whole thing," he says. Professors at Cal Maritime commonly refer to the boat as a city, he says, so you have to know how all the parts work together. But Mr. Kent thinks of it as more like a human body.

"Systems are very much like anatomy," he says. "I've talked to people in the medical field and told them that they would understand what I do, just because it's so similar."

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