Navigating Institutional Change for Student Success in STEM
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In a 2007 issue of Liberal Education that centered on faculty leadership and institutional change, editor David Tritelli wrote, “Institutions whose mission it is to prepare students to meet the challenges of the twenty-first century are not always well served by the persistence of traditional boundaries among disciplines and departments or between the curriculum and the cocurriculum, academic affairs and student affairs, or the liberal arts and the professional fields. In fact, the primarily vertical organization of colleges and universities can create structural impediments to achieving the goals of a twenty-first-century liberal education.”

However, achieving the level of change that builds institutional capacity to ensure that all students have the opportunity to do inquiry-oriented, hands-on, and integrative work requires moving campus constituents out of their comfort zones. Mark Twain got it right when he quipped, “The only person who likes change is a wet baby.” This is as true for reform of undergraduate science, technology, engineering, and mathematics (STEM) learning as for any other significant curricular change effort.

To determine which elements are necessary for a successful STEM reform, Project Kaleidoscope (PKAL) launched the STEM education effectiveness framework project, led by Susan Elrod, former executive director of PKAL and now interim provost and vice president of academic affairs at California State University–Chico. That project aimed to develop a comprehensive institutional change model to help campus leaders plan and implement evidence-based student learning and success in STEM reforms into scalable and sustainable actions. The project was funded by the W. M. Keck Foundation and engaged eleven colleges and universities in California to test evidence-based strategies that would lead to program, departmental, and eventually, institutional transformation. The project leveraged PKAL’s twenty years of STEM education research and reform experience in creating more effective curricular, teaching, and program strategies. The participating institutions developed their own campus projects and, through their work, helped shape the model.

This issue of Peer Review, also sponsored by the W. M. Keck Foundation, tells the stories of six participating institutions that developed and field tested the project’s comprehensive institutional model for facilitating strategic change in STEM education. Instead of using our traditional practice article format, this issue features case study excerpts from the Keck/PKAL project that give a sense of each campus's progression toward institutional transformation as they negotiate the model’s eight steps: (1) establish vision, (2) examine landscape and conduct capacity analysis, (3) identify and analyze challenges and opportunities, (4) choose strategies/interventions/opportunities, (5) determine and build readiness for action, (6) begin implementation, (7) measure results, and (8) disseminate results and plan next steps.

This fall, AAC&U will publish Increasing Student Success in STEM: A Guide to Systemic Institutional Change, a guidebook by Susan Elrod and Adrianna Kezar that expands upon information presented in this issue. This forthcoming publication includes detailed information about each element of the institutional change model accompanied by an explanation, key questions to consider, and highlights from campus case studies. It also frames the key questions that should be asked during each phase of program development and includes a rubric to help campus teams gauge their progress through the phases of the process. The book also reflects efforts based within the STEM disciplines but that are applicable to all, providing an organizational framework to help campus leaders anticipate and address the infrastructural issues that can impede long-term interdisciplinary program sustainability.

Navigating campus reform efforts can be tricky, complicated, and sometimes frustrating, but the outcomes make all of the work worthwhile. As Elrod and Kezar point out in the forthcoming report: “We appreciate the efforts of our pioneering campuses that explored new territory—literally going where few colleges have gone before. Campuses that are open to a broader vision for student success and that allow themselves to engage in what can be a messy process of change can create high-value, sustained, and scaled efforts at STEM reform.”

—SHELLEY JOHNSON CAREY
or the past twenty years, countless reports have been issued calling for change and reform of undergraduate education to improve student learning, persistence, and graduation rates for students in STEM; however, few recommendations in these reports have been widely implemented (Seymour 2002; Handelsman et al. 2004; Fairweather 2008; Borrego, Froyd, and Hall 2010). Aspirational student success goals in STEM have been set most recently by the President’s Office of Science and Technology 2012 report, Engage to Excel: Producing One Million Additional College Graduates in Science, Engineering, Technology and Mathematics (2011). This report states that STEM graduation rates will have to increase annually by 34 percent to meet this goal. On most campuses, the persistence and graduation rates of underrepresented minority (URM) and first-generation students still lag behind those of their majority counterparts. Thus, in order to reach the aspirational graduation rates called for in national reports, a focus on URM and first-generation student success is imperative.

While many change efforts have been initiated, almost always at the departmental level, few have reached the institutional level of entire programs, departments, or colleges in the STEM disciplines, described as necessary in these recent reports. There is growing recognition that reform in STEM is an institutional imperative rather than only a departmental one. Student advising, faculty professional development, student research mentoring, academic support programs, clear STEM-focused institutional articulation agreements, external partnerships with business and industry related to internships and other research experiences, and many other critical programs and areas that have been identified as central to student success are often overlooked within reform efforts. New research demonstrates the importance of a broader vision of STEM reform for student success—moving from programs and departments to an institution-wide effort. For example, institution-wide implementation of high-impact practices has been shown to dramatically improve the graduation rates of URM students (Kuh and O’Donnell 2013). The Meyerhoff Scholars Program at the University of Maryland Baltimore County epitomizes this type of institution-wide effort and combines specific academic, social, and research support interventions that have resulted in dramatic improvements in graduation of minority STEM students (Lee and Harmon 2013).

The Keck/Project Kaleidoscope (PKAL) STEM Education Effectiveness Framework project, funded by the W. M. Keck Foundation, aimed to develop a comprehensive, institutional model to help campus leaders plan and implement evidence-based reforms geared toward improving student learning and success in STEM into scalable and sustainable actions. The project engaged eleven California-based colleges and universities (see box, below) to test evidence-based strategies that will lead to program, departmental, and eventually, institutional transformation.

The systemic institutional change model that came out of this project, outlined in this article and brought to life by the case studies in this issue, is a valuable tool to help campuses work on this broader vision. This model provides both a process and a con-

### Participating Institutions in the Keck/PKAL Project

- California State University–East Bay
- California State University–Fullerton
- California State University–Long Beach
- California State University–Los Angeles
- San Diego State University
- San Francisco State University
- W.M. Keck Science Department of Claremont McKenna, Pitzer, and Scripps Colleges
- University of San Diego
- University of La Verne
- The California State University Chancellor’s Office
- University of California–Davis
tent scaffold for campus leaders to plan, implement, assess, and evaluate change efforts in undergraduate STEM education in a way that goes beyond redesign of a single course or isolated program. Further details regarding the model have been written in a guidebook for campus leaders who have convened (or will convene) teams comprising faculty members, department-level leaders, student affairs staff, appropriate central administration officers, institutional researchers, and undergraduate studies officers. We have learned from our own work as both researchers and practitioners that institutional change is best executed by a cross-functional team working together. Institutional change depends on the support of leaders across campus—including grassroots faculty leadership, mid-level leadership among department chairs and deans, and support from senior leaders in the administration.

This issue of Peer Review, produced with generous support from the W. M. Keck Foundation, provides an overview and case studies from six of the project campus teams describing their STEM reform journeys. Each case study highlights the elements of the Keck/PKAL model for effective institutional change to increase student success in STEM that was developed during this three-year project. We appreciate the efforts of our pioneering campuses to explore new territory, often going where few colleges have gone before. We are convinced that campuses that are open to a broader vision for student success and that allow themselves to engage in what can be a messy process of change can create sustained and scaled efforts at STEM reform.

**THE KECK/PKAL MODEL**

The Keck/PKAL model for effective institutional change outlines both a process and content that will lead to increased student success in STEM. Although focused on STEM, it is applicable to any change process that is focused on improving student learning and success. The elements of the model are illustrated in figure 1 and described in table 1.

The model is shown in the context of a river because the flowing nature of a river represents the flowing nature of change as well as the dynamic and powerful process of change. The flow (change process) encounters obstacles (challenges presented by certain aspects

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### TABLE 1. MODEL ELEMENTS

<table>
<thead>
<tr>
<th>MODEL ELEMENT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Establish Vision</strong></td>
<td>The vision represents the direction in which the campus is aimed in terms of altering its STEM experience to support student success. We encourage a vision that is clear, shared, and aligned with institutional priorities.</td>
</tr>
<tr>
<td><strong>Examine Landscape and Conduct Capacity Analysis</strong></td>
<td>A direction forward is typically best created through an analysis of the existing landscape (internal campus data as well as external reports on STEM reform) as well as a review of current capacity to engage in change generally—such as history of reform, leadership, and buy-in and ownership among faculty. This stage focuses on collecting data and information to conduct analysis.</td>
</tr>
<tr>
<td><strong>Identify and Analyze Challenges and Opportunities</strong></td>
<td>The landscape and capacity information needs to be analyzed in order to identify both challenges and opportunities for the campus. This phase often brings in politics and culture that might be sources of both opportunities and challenges.</td>
</tr>
<tr>
<td><strong>Choose Strategies/ Interventions/ Opportunities</strong></td>
<td>Campuses need to familiarize themselves with a host of possible strategies or interventions to address the challenges identified and leverage the opportunities. They can examine these strategies in light of the capacity of the campus as well as opportunities identified earlier.</td>
</tr>
<tr>
<td><strong>Determine Readiness for Action</strong></td>
<td>In addition to reviewing capacity and opportunities, there are key issues that emerge when implementing specific strategies such as resources, workload, institutional commitment, facilities, timeline, and other areas that campuses should review in order to effectively implement the strategy and to ensure that the campus is ready to move forward with that particular strategy. Campuses will be able to take advantage of opportunities, such as a newly established special campus projects fund, or a new faculty hire with appropriate expertise, that can be leveraged in support of effective implementation. This phase also involves further exploring campus politics and culture.</td>
</tr>
<tr>
<td><strong>Begin Implementation</strong></td>
<td>Implementation involves drafting a plan for putting the intervention or strategies in place. The plan builds off of the ideas from the readiness for action, capacity of the campus, and opportunities identified. All of these will be built into the plan, as well as a process for understanding challenges as they emerge. In addition to creating a well-laid-out plan, campuses may decide to pilot an initiative first and then consider how to modify and scale it after an initial trial.</td>
</tr>
<tr>
<td><strong>Measure Results</strong></td>
<td>Campuses will also create an assessment plan to determine whether the intervention is working and ways they can be changed over time to work better.</td>
</tr>
<tr>
<td><strong>Disseminate Results and Plan Next Steps</strong></td>
<td>In order to prevent the continued “silobization” of work, it is important for campuses to think about dissemination opportunities on campus as well as off campus, either regionally, statewide, or nationally. Also, keeping the momentum going will require deliberate planning for next steps.</td>
</tr>
</tbody>
</table>
of the change process) represented by rocks in the figure that may result in an eddy where the flow circles around the obstacle until it can break free. The resulting eddy motion is an apt analogy for the circular swirl, or iterative process, that campus teams experience when they encounter resistance and challenges along their path toward reform. They must work through the issue, determine the nature of the challenge, and figure out how to get the flow going again in the desired direction. Travelers on the river may enter at various points or “put out” at certain locations to rest and regroup. New travelers may enter and join a party already on a journey down the river. Indeed, teams working on systemic change initiative may start at different points, alter membership, or even stop for periods of time because other campus priorities emerge, team members take on other duties, campus leadership changes, etc. Teams may also enter the river at different points, depending on where they are in terms of understanding of the problem, existing expertise, campus leadership capacity, etc. Teams can also paddle up or downstream, although ultimately the general flow will be to go downstream toward action and success. The case studies in this issue highlight campus experiences using the model as they worked toward their own STEM education reform goals.

INFORMATION GATHERING AND DATA ANALYSIS

Our approach to change and to this project is based on practices of organizational learning. Within this approach to change, information gathering and data analysis play a central role in helping individuals to identify directions and appropriate interventions for making strategic forward progress. Participants in any organizational learning/planning process foreground the data, reflection, dialogue, and nonhierarchical teams learning and developing innovative approaches. This means having campus teams look at data related to student success in order to determine the specific challenges and problems and to orient themselves toward a vision for change. But an organizational learning model also focuses on learning throughout the change process. The model is focused on facilitating organizational learning, but it also incorporates key ideas from other research on change such as the need to address politics, developing buy-in and a shared vision, understanding the power of organizational culture, and helping campus leaders unearth underlying assumptions and values that might create resistance to change.

During our work with campuses, we discovered common challenges and barriers they encountered. The most common obstacle was that campus leaders wanted to start by immediately implementing a strategy that they read about in a report or publication. While news of a successful program may motivate change, it is important to check in with campus vision and landscape analysis before jumping into implementation of the latest published student success strategy. It may or may not fit your campus situation, student population, faculty expertise, or resources. Campuses that jumped right into a strategy found that, while they made some progress, they struggled with defining purpose, specifying outcomes, implementation, and measuring impact. They ended up going back to their vision, refining it and doing more landscape analyses, which ultimately slowed progress but improved success in the long run. Another common barrier we identified was that campus team members held implicit theories of how change happens that were contradictory and often contrary to the project’s vision and goals (Kezar, Gehrke, and Elrod, forthcoming).

For example, a common assumption among STEM faculty is that meaningful change can only happen in departments.
If faculty hold this belief, they will resist examining potential levers outside the department that are important to address, such as mathematics preparation, success in a prerequisite course in another department, level of study skills, advising, or institutional support, which is critical for sustaining long-term change. Implicit biases can only be revealed through conversations about beliefs, values, and practices. Therefore, we encourage teams to make their first meeting a discussion about how change occurs in order to make their implicit theories explicit. What makes this process hard is that implicit theories are often unconsciously held. Many people may not be able to articulate a theory of change or understand why the model is hard for them to work with. It can help just to have the candid discussion among your team members: “What do you think it will take to start an undergraduate research program here?”

Other common barriers encountered were:

- faculty beliefs about their roles as “gatekeepers” or as the “sage on the stage” as opposed to “gateways” or as “guides on the side”;
- the lack of faculty expertise in evidence-based STEM education teaching and assessment methods;
- a misguided belief that all faculty and staff share the same vision;
- failure to examine all the implicit assumptions about the problem, possible solutions, and approaches; team members’ implicit theories of change that may prevent them from engaging in aspects of the work;
- a lack of capacity for data collection and analysis in terms of support from centralized offices of institutional research;
- inadequate incentives and rewards for faculty participation in STEM reform projects;
- inadequate planning to secure appropriate buy-in, approval, or support from relevant units, committees, or administrators;
- inadequate resource identification or realization;
- unforeseen political challenges, such as tension regarding department “turf” or resource and faculty workload allocation;
- shifts in upper-level leadership leading to stalled support or redirection of efforts to new campus initiatives (e.g., quarter to semester conversion);
- changes in team membership because of sabbatical leaves or other assignments;
- failure to connect STEM reform vision at the departmental level to institutional priorities to secure support and resources; and
- lack of consideration about how students will be affected by and/or made aware of the changes, including the rationale for them. In order for students to fully participate, they need to understand how they will benefit from the changes or new opportunities.

MORE ON THE SYSTEMIC INSTITUTIONAL CHANGE MODEL

The full details of the model will be published in a forthcoming PKAL report, Increasing Student Success in STEM: A Guide to Systemic Institutional Change. The guidebook includes detailed information about each element of the model accompanied by an explanation, key questions to consider, highlights from campus case studies, challenge alerts (mistakes to avoid or pitfalls to be aware of), and timeline considerations. The guidebook also contains specific tools to help campus leaders and teams plan and manage change initiatives, such as:

- tools to help campus leaders and teams determine how to get started in the process;
- a readiness survey to help teams determine whether they are prepared to move forward with implementation of their chosen strategies and interventions;
- a rubric to help campus teams gauge their progress in the model phases;
- examples of data analyses to conduct as well as examples of implementation strategies to address common challenges facing STEM programs; and
- suggestions for how to build effective teams, develop leadership capacity, and sustain change.

These tools are also included in a practical workbook intended for use by teams to actively work through the elements of the model. This workbook and the full-length case studies are available on the project website: http://www.aacu.org/pkal/educationframework.

REFERENCES


Kezar, Adrianna, Sean Gehrike, and Susan L. Elrod. (Forthcoming.) “Implicit Theories of Change as a Barrier to Change on College Campuses: An Examination of STEM Reform.” Review of Higher Education.


Framing Leadership for Sustainable Interdisciplinary Programs

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Susan Elrod, interim provost and vice president for academic affairs, California State University–Chico

Interdisciplinary learning is a twenty-first-century imperative. We are continually faced with societal and global challenges that require interdisciplinary thinking to identify suitable solutions, such as finding new energy sources, dealing with the effects of our changing climate, and ensuring populations across the globe have adequate food and healthful living environments. In addition, research in the science, technology, engineering, and mathematics (STEM) disciplines is increasingly crossing traditional disciplinary lines with scientists and engineers collaborating with other disciplines, including the humanities and social sciences, in both basic and applied research projects.

In *A New Biology for the 21st Century* (National Academies 2009), the interdisciplinary and integrative nature of the biological sciences is described with respect to issues related to global food, health, environment, and energy challenges. *Innovation with Impact* (American Society for Engineering Education 2012) argues for educational innovations that address the increasingly collaborative, multidisciplinary, entrepreneurial, and global nature of problems, and the need for curricular initiatives that facilitate interdisciplinary breadth, communication, teamwork, critical thinking, ingenuity, creativity, leadership, and an understanding of global economic, environmental, and societal contexts. These reports followed on the heels of the National Academies report (2004) *Facilitating Interdisciplinary Research*, which outlined specific strategies for making research environments more conducive to collaboration.

This article emerged from work done in the national Keck/Project Kaleidoscope (PKAL) *Facilitating Interdisciplinary Learning* project, funded by the W. M. Keck Foundation. The primary aim of this project was to identify specific strategies for facilitating interdisciplinary college learning that significantly involved the STEM disciplines. The project involved teams from twenty-eight colleges and universities—representing the diversity of four-year institutions in this country. Teams were chosen based on their vision for and commitment to undergraduate interdisciplinary learning; most teams were at the beginning of a process for creating a new or significantly revised interdisciplinary program. All programs involved STEM disciplines either entirely or in concert with disciplines outside of STEM. Figure 1 shows the distribution of the types of interdisciplinary work in which campuses were involved. During the course of the project, more than three hundred faculty and campus leaders were engaged, participating in five national meetings, including two roundtables focused on assessment and leadership. Teams submitted annual reports and were surveyed at the beginning and the end of the project regarding institutional structures, barriers, climate, and other issues. Five key recommendations were distilled from the work of campuses in this project; they are summarized in *What Works in Facilitating Interdisciplinary Learning in Science and Mathematics Summary Report* (AAC&U 2011). While the project had a deliberate focus on interdisciplinary STEM programs, we believe the project findings are applicable to any type of undergraduate interdisciplinary program.

To further assist campus leaders in answering the question, “How can I shepherd a fledgling interdisciplinary curricular initiative to become a mature, stable interdisciplinary program?” we took the five project recommendations and aligned them with a process flow that outlines key issues to address when planning, implementing, and institutionalizing innova-
tive, interdisciplinary programs. Details of this process flow are published in Leadership for Interdisciplinary Learning: A Practical Guide to Mobilizing, Implementing, and Sustaining Campus Efforts (AAC&U 2012), as well as on an interactive website developed to assist campus leaders of interdisciplinary initiatives (http://www.aacu.org/pkal/interdisciplinarylearning/guide.cfm). This article focuses on the final stage of the process—creating programs that last—because through this project, we have come to understand that long-term sustainability may be the most critical issue for the establishment of successful interdisciplinary programs.

In particular, we apply the “four frames” model of organizational theory (Bolman and Deal 2008; Bolman and Gallos 2011) to the issue of long-term sustainability. This approach identifies four frames, or lenses, through which organizational issues can be viewed: (1) the human resource frame, (2) the structural frame, (3) the political frame, and (4) the symbolic frame. We found that program leaders often encounter issues that fall within the context of one or more of these four frames and that impede program growth and stability (Kezar and Elrod 2012).

Our rationale in taking the frames approach was to help institutional leaders view these challenges from multiple perspectives in order to identify practical pathways for overcoming them. We believe that attention to the issues identified by this organizational model early in the process of developing interdisciplinary programs will improve the likelihood of long-term success. This approach is likely to be useful for new curricular innovations, whether interdisciplinary or not, if they share the common theme of creating new structures, bringing people together in new ways, requiring creative allocation of resources, and encouraging teamwork across disciplinary or departmental lines.

THE CHALLENGES TO SUSTAINING INTERDISCIPLINARY PROGRAMS

New interdisciplinary courses and programs are generally easy to start. They often begin with a spark of interest by colleagues or students based on current research interests or societal issues involving interdisciplinary themes. Designated as experimental courses or special programs with temporary funding, they can be successfully launched. However, finding support beyond this pilot level is often the point when interdisciplinary programs fall apart. When the early adopters run out of steam or bump up against other departmental teaching commitments, or the program exhausts its initial special funding, the program ends. However, if during program planning and implementation stages strategies have been put in place, or can be developed based on the multiple perspectives described in the four frames model, the likelihood that the program can be sustained by the institution is high. Thus, we chose to focus here on leadership strategies that support sustainable interdisciplinary programs.

THE FOUR FRAMES APPROACH

If you study any program that has been successfully introduced and sustained at an institution, you will see that the program has the necessary people (positions and specific individuals), supportive structures (policies and incentive structures), and alignment with mission and governance of the institution (political structures). In addition, the achievements of a sustainable program are recognized and celebrated regularly (symbolic indications of a successful program). The human resources, structures, politics, and symbolic elements represent four key factors that are required for a program to be sustainable and represent four frames through which a leader at any level can view a fledgling initiative to determine what strategies could be applied to move the initiative toward sustainability. This four frames model was developed by Bolman and Deal (2008) as an approach for evaluating issues, developing a more complete picture of what is happening, and making

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**FIGURE 1. THE DISTRIBUTION OF THE TYPES OF INTERDISCIPLINARY WORK IN WHICH CAMPUSES WERE INVOLVED, BASED ON POST-PROGRAM SURVEY DATA.**

One program was a campus-wide initiative (green), four projects involved many (more than three) STEM disciplines (blue), six projects involved a few (two or three) STEM disciplines (orange), eight programs involved many disciplines beyond STEM (red), and nine programs involved a few disciplines beyond STEM (purple).
decisions about what to do next. Bolman and Gallos (2011) took the initial four frames model and demonstrated its usefulness in the academic environment.

In our work with leaders at all levels, we have found that when leaders truly take on the questions posed by all four frames, they often arrive at powerful insights regarding issues that threaten the sustainability of their initiatives. Leaders may also identify new approaches they have never before considered when looking at the issue from these multiple organizational perspectives.

In the sections below, questions are posed reflecting each of the four frames as they apply to interdisciplinary initiatives. Each question is followed by a list of the most common or impactful campus strategies that have been synthesized from the project and from workshops and conversations with a variety of academic leaders around the country.

**Human Resources Frame:** *Do you have (and can you keep) the right people?* For an interdisciplinary initiative to be successful, the campus environment must attract talented individuals and find ways to channel their talents and support their work in the program. To sustain an interdisciplinary initiative, programs need (1) people with appropriate interdisciplinary and programmatic expertise, (2) appropriate incentives to encourage participation of faculty and students, and (3) faculty development opportunities that support teaching and assessment strategies appropriate to interdisciplinary learning.

Strategies in this frame include those that relate to hiring, cultivating, and rewarding faculty and staff with appropriate expertise, such as the following:

- Create a clearinghouse list of faculty within the institution whose training, teaching, or research expertise overlaps with interdisciplinary program focus areas.
- Institute hiring procedures that permit the hiring of faculty who are not affiliated with a single department but are instead affiliated with multiple departments and/or an interdisciplinary program.
- Consider using the Council of Environmental Deans and Directors recommendations on hiring, promotion, and tenure (RPT) policies that are supportive of interdisciplinary teaching and learning; problem-based learning, or case study analysis).
- Create and participate in regional networks of campuses or colleagues that leverage experience and expertise to create collaborations around interdisciplinary research and learning environments.

**Structural Frame:** *Do you have enabling structures?*

The structural frame refers to the rules, policies, procedures, and reporting structures that programs and individuals must navigate in order to accomplish their missions and goals. Leaders need to pay attention to these issues; according to Bolman and Gallos, “[a]cademic leaders succeed when they create an appropriate set of campus arrangements and reporting relationships that offer clarity to key constituents and facilitate the work of faculty, students, staff, and volunteers” (2011, 11). Therefore, to have a sustainable interdisciplinary initiative, a program will need strategies for (1) creating workload policies that support interdisciplinary course offerings; (2) developing review, promotion, and tenure (RPT) policies that are supportive of interdisciplinary teaching and learning; (3) establishing appropriate formal and informal spaces for interdisciplinary programs and projects; (4) funding interdisciplinary programs and projects; and (5) communicating to stakeholder communities both internal and external to the institution. In this framework, strategies pertain to policies, facilities, funding models, and communication processes that will enable the innovations to last beyond experimental pilot testing, such as the following:

- Develop co-teaching models appropriate to campus resources; use these
models as temporary mechanisms in the initial phases of program piloting to develop a cadre of experienced interdisciplinary instructors.

- Create mechanisms that allow linked courses to be scheduled at the same time, enabling the classes to meet together periodically to have cross-disciplinary discussions.
- Review RPT policies for mechanisms that support interdisciplinary course or program involvement.
- Consider mechanisms for ensuring that interdisciplinary program leaders have input in tenure and promotion decisions as they relate to interdisciplinary program needs.
- Use memoranda of understanding to clarify roles and responsibilities of interdisciplinary faculty and how RPT decisions will be made (committee membership, departments involved in the review and their role in the review process).
- Integrate efforts to find space for new interdisciplinary learning with the decision-making process concerning institutional priorities and budgets.
- Repurpose existing spaces to creatively address needs for interdisciplinary learning in ways that aren’t new or additive, but that ensure more complete integration of the interdisciplinary program into the institutional culture.
- Create/renovate spaces and facilities to promote and facilitate interdisciplinary learning.
- Align budgetary structures, allocation, and reallocation procedures to support interdisciplinary programs, faculty, students, and spaces.
- Align institutional fundraising initiatives, including the search for funding from federal agencies and private organizations, with support for programmatic and institutional goals regarding interdisciplinary learning.

- Include development staff in planning meetings, or meet with them separately, to ensure interdisciplinary learning and program goals are on the fundraising agenda.
- Seek external funding for projects that will help the campus develop and launch new interdisciplinary courses or programs.
- Develop websites for interdisciplinary programs to serve both internal and external audiences.
- Leverage campus conferences, such as student research conferences, to ensure interdisciplinary program-related presentations are included.
- Use relevant student organizations to publicize interdisciplinary program outcomes, events, and accomplishments.

**Political Frame: Have you created alignment with campus politics and shared governance?**

One of the greatest perceived barriers to sustaining interdisciplinary programs is the seeming competition between departmental needs and interdisciplinary program needs—particularly conflicts that are associated with competition for scarce resources (money, students, faculty time, and space). Most institutions are organized in a departmental or college structure that can create islands (or silos) where it may be difficult to build the bridges necessary to support interdisciplinary initiatives. This is particularly true where budget models or curriculum approval processes favor traditional departmental line reporting or college structures. According to Bolman and Gallos, “Skilled academic administrators are compassionate politicians who respect differences, manage them productively, and respond ethically and responsibly to the needs of multiple constituencies without losing sight of institutional goals and priorities” (2011, 12). However, departmental boundaries and complicated political terrain don’t have to be barriers. To sustain an interdisciplinary initiative, programs need strategies for (1) engaging departments in the conversation, (2) including interdisciplinary faculty in decision-making processes, and (3) establishing curricular review and approval procedures that are inclusive of interdisciplinary programs/projects. Strategies to achieve this goal include the following:
Include department leadership in early conversations regarding new interdisciplinary programs to identify concerns that need to be addressed or opportunities to leverage department resources or program offerings.

- Identify disciplinary or general education requirements that might be met by new interdisciplinary initiatives or existing courses that may help new interdisciplinary programs reach their goals.
- Establish formal administrative structures and leadership positions in support of interdisciplinary programs (e.g., Center for Interdisciplinary Studies, dean of Interdisciplinary Studies, Center for Materials Science).
- Work to ensure interdisciplinary programs have the same rights and responsibilities as disciplinary programs in governance decisions (representation on senate committees, curriculum committees, etc.)
- Ensure campus curricular approval and review processes enable the development of interdisciplinary learning courses and programs.
- Check that the curriculum processes allow courses and programs to be identified as interdisciplinary, and provide space for various department-level approvals and comments.

**Symbolic Frame:** Do you celebrate faculty and student achievements with respect to the interdisciplinary initiative?

Stories, symbols, and celebrations shape and convey the meaning and goals of an interdisciplinary initiative to a wide range of constituencies and can make the initiative visible and a part of the institution’s culture. Particularly important is the need to recognize and celebrate the achievements of the individuals—students, faculty, and staff—in the program. As Bolman and Gallos point out, “Good theater fuels the moral imagination, and successful campus leaders infuse everyday efforts with energy and soul” (2011, 12). To sustain an interdisciplinary initiative, programs need strategies for celebrating student and faculty work in interdisciplinary areas. Strategies to achieve this goal include the following:
- Celebrate achievement of key interdisciplinary milestones and successes, including student achievements and alumni news, as well as program events and faculty research accomplishments.
- Host and publicize speaker series on topics related to the goals of interdisciplinary programs.
- Disseminate key programmatic achievements via campus websites and news outlets and through alumni news, as well as external venues such as conferences.

**CONCLUSION**

There is a growing demand for interdisciplinary programs and learning. The bellwether reports published by the American Society for Engineering Education and the National Academies provide key indicators of where undergraduate programs should be focused—on creating more interdisciplinary experiences where students can gain the knowledge and skills they need to address the complex challenges facing our society. However, it is a leadership challenge to plan, implement, and sustain these types of programs over the long haul. This article focuses on an approach that we hope will help campus leaders “reframe” the challenges, clarify their thinking, and test assumptions in order to create sustainable programs. While the Keck/PKAL project engaged campus teams around programs in undergraduate STEM learning, we believe that leaders working on any type of interdisciplinary or innovative program will benefit from this approach.

The four frames provide lenses through which key issues challenging sustainable program can be viewed and help leaders develop creative solutions to those overcoming the barriers.

**ACKNOWLEDGMENTS**

The authors wish to thank the W. M. Keck Foundation for its generous support of the Keck/PKAL Facilitating Interdisciplinary Learning project, as well as the more than three hundred faculty members at twenty-eight campuses that participated in the project. Their dedication and commitment to innovative student-centered undergraduate programs resulted in the recommendations presented here. Many, many thanks for their vision, energy, and creativity.

**REFERENCES**


The University of California–Davis (UCD) is a large research institution with over 26,000 undergraduate students. Nearly 60 percent of students are pursuing a major in STEM (science, technology, engineering, or mathematics). UCD has a long history of initiatives for improving retention of specific student populations and within specific STEM fields.

**EXAMINE LANDSCAPE AND CONDUCT CAPACITY ANALYSIS**

The iAMSTEM (integrated agriculture, medicine, science, technology, engineering, and mathematics) Hub, established in 2012 by the provost and housed in the Office of Undergraduate Education, is the first unit dedicated to comprehensive undergraduate STEM student success across the campus.

The founding of iAMSTEM coincided with the launch of the UCD 2020 Plan, an effort to increase enrollment by 5,000 undergraduate students by 2020. One of iAMSTEM’s first directives was to investigate STEM student factors that might impact or result from planned university growth (e.g., impaction, time to degree, retention, etc.).

**IDENTIFY AND ANALYZE CHALLENGES AND OPPORTUNITIES**

Several concerns emerged from our analyses. For example, average time to degree was consistently greater for STEM students than for non-STEM students. Average retention in STEM majors was only 55 percent. Among underrepresented minority (URM) and first-generation (FG) STEM student populations, performance gaps emerged from the very first quarter and persisted until graduation or transfer out of STEM. Retention of URM and FG in STEM majors averaged just 35 percent.

The pattern and magnitude of losses was distressing and suggested that at least some of our students were leaving STEM majors for reasons other than personal preference. Growth of the student population would likely further strain instructional capacity and resources, which in turn could threaten the goals of the 2020 Plan. iAMSTEM set out to better understand STEM student success and if or how we could impact it.

Local conventional wisdom attributed STEM student losses primarily to students’ lack of ability, interest and/or willingness to work hard (i.e., innate traits over which we have little influence). Our examination of the data suggested a more complex story. Students from every academic level and from every demographic were leaving STEM in high numbers. Based on this data and the findings of decades of retention research, we hypothesized that quality of instruction was a critical yet underexamined part of our student success equation (Seymour 1995). If true, then by improving instruction, we could improve student outcomes. Our mission was clear.

**DETERMINE READINESS FOR ACTION**

Most of our students who left STEM did so by their fifth quarter (middle of second year) while still enrolled in large introductory courses (100–500 students per section). Large lecture classes dominate the early part of our STEM students’ careers and pose unique challenges for student learning. Given the importance of introductory courses for later success, we focused our attention on understanding the outcomes and dynamics of our largest introductory STEM classrooms. UCD Institutional Research surveys and departmental program review studies offered insights into campus morale and the self-assessed approaches to teaching used by the average instructor. But there was little data available that informed what was or was not actually happening day-to-day in
classrooms. It quickly became apparent that if we wanted to better understand the role of instruction in student success, we first needed to improve our ability to see and measure it.

In response, we created UCON (Undergraduate Classroom Observation Network), a team of highly trained undergraduate observers that used an iAMSTEM designed app based on the COPUS observation protocol (Smith et al. 2013) to quantify instructor and student behaviors in the classroom. With the permission of instructors, the UCON team enabled iAMSTEM to characterize instruction across all introductory STEM courses. To paraphrase Sir William Thomson, you cannot improve what you cannot measure. We could now measure instruction and relate it to student outcomes.

CHOOSE STRATEGIES AND BEGIN IMPLEMENTATION

While iAMSTEM was ramping up its ability to gather, analyze, and make sense of instructional data, we were also embedding ourselves in small-scale collaborative efforts on the ground. We looked for places where we could be useful. When we first came on the scene, only a few communities of STEM faculty were interested or engaged in transforming their own instruction. However, we were repeatedly approached by graduate teaching assistants (TAs) eager to advance their teaching skills, as few comprehensive TA training programs or resources were available. One of iAMSTEM’s first efforts on the ground was helping the instructors and coordinator running BIS2A—the first gateway course in the introductory biology series—to systematize and improve the quality of their TA training program. Early successes with that team established trust, and opened the door to discuss more ambitious and impactful instructional approaches for helping students learn. Full-scale implementation of the team’s ideas would require resources, so we looked to outside organizations for support.

In late 2012, iAMSTEM became part of the Bay View Alliance, an international coalition of research universities focused on understanding cultural change related to instruction. In 2013, we submitted a successful proposal to the Association of American Universities (AAU) to support development of active learning practices across introductory STEM courses. That same year, we received additional support from the Bill & Melinda Gates Foundation for transformation of introductory biology and began our participation in the Keck/PKAL project. These awards and collaborations supplied much needed resources and expertise, allowing us to secure the commitment of our new colleagues and collaborators to take things to the next level.

By the 2013–14 academic year, we were finally ready for a full-scale test of our hypothesis: intentional design of instruction, based on our best understanding of learning and teaching, can increase success of all students. We piloted TA-led highly structured discussion sections in BIS2A (supported by grants from AAU and the Bill & Melinda Gates Foundation). Students attended three one-hour large lectures and one two-hour discussion section per week. The same faculty instructor led all lecture sections. Control discussion sections were taught using the conventional curricula and activities. Treatment discussion sections integrated active learning instruction with adaptive online material developed at Carnegie Mellon (Thille 2013). Active learning TAs were trained to use formative student data from the online activities to inform and adapt instruction and curricula each week to meet their students’ specific needs. Weekly TA training meetings permitted active learning TAs to review student data together with peers and to brainstorm ways to address student weaknesses and misconceptions.

The team put enormous thought and effort into design and implementation, fueled by the passion and progress of the TAs. We knew, however, that expecting TAs to significantly improve student performance in a course, whatever their training, was asking a lot. Not surprisingly, detractors were numerous. It was a long shot, but a worthy one that, if successful, would demonstrate the merit of our hypothesis in a way that no one could ignore.

MEASURE RESULTS

Classroom observation data collected from lecture and discussion treatments revealed that discussion sections incorporated significantly greater active-learning instruction over lecture and that active learning TAs required significantly greater engagement and accountability from their students than either the lecturer or the control TAs. After controlling for covariates, Spring 2014 students in the active learning discussions were 66 percent more likely to pass the course (based on total exam scores) than students in control sections.

The positive outcomes realized by the TAs encouraged three of the four BIS2A faculty to begin integrating active learning instruction and practices into their own lecture sections during the 2014–15 academic year. The impact of those changes were measured through comparison of each faculty member’s student performance on standardized pre- and post-exams and exams from previous quarters using statistical analysis techniques such as propensity score matching and performance prediction modeling. Additional faculty from the BIS series learned of the BIS2A results and are now working with iAMSTEM to integrate active learning practices into their courses as well.

Using similar strategies, iAMSTEM’s chemistry team has developed and tested a variety of teaching methods and strategies, including online alternatives to textbooks, online homework software with instructor dashboards, active learning and group tasks in lecture and discussion sections, and implementation of pre–post learning assessments across most sections of the introductory chemistry course series. Outcomes from these efforts have secured the backing of the department chair and informed new discus-
tion by chemistry faculty and lecturers about greater integration across the introductory series. iAMSTEM also helped to launch two course transformation committees, Chemistry Innovation and Chemistry for Life Science, that are actively engaged in instructional improvement and alignment of course and series student learning goals. More instructional experiments are planned for the 2015–16 academic year, along with development of formalized active learning TA training and professional development of faculty and lecturers.

**DISSEMINATE RESULTS AND PLAN NEXT STEPS**

We are still in the beginning stages of change. It takes time, footwork, and plenty of coffee and coaching sessions to figure out what people need and help fully realize solutions. As with great teaching, we’ve learned that great innovating requires more listening than telling. From students to instructors to the provost and chancellor, each person we work with has unique concerns, capabilities, and questions. Each sees value in what we do in direct proportion to our alignment with their goals. Understanding collaborators’ needs (and ensuring that they know we understand their needs) requires real listening and empathy. We have found no shortcuts.

To scale the successes of our collaborators, we are working to bring together all campus communities focused on student learning to share ideas, results, and challenges and find ways to extend their efforts into the larger community.

**National Dissemination**

We are very fortunate to be part of multiple active communities working to promote evidence-based instructional strategies for STEM instruction. As previously mentioned, these include (1) the AAU STEM pilot initiative, (2) the Bay View Alliance, (3) the Bill & Melinda Gates Foundation Adaptive Learning Acceleration initiative, and (4) the Keck/PKAL project. Between these four projects, we are involved in ten or more multi-institutional gatherings each year. These community interactions provide tremendous opportunities for sharing findings and learning valuable lessons from others. Through the iAMSTEM Tools for Evidence-Based Actions project, we share iAMSTEM developed apps (e.g., student pathway ribbon tool and the GORP classroom observation platform) as well as tools and research from fellow community members. We’re working on several articles for submission to journals and hope to share our experiences and findings at national education association and disciplinary group meetings and universities across the country.

In late 2014, the chancellor and provost were informed of our work through discussions with others outside of our university, including the leadership of AAU and the Association of Public and Land-grant Universities, and through articles in the *New York Times* and *Inside Higher Ed* blog posts. Sometimes the right voices from the outside can be compelling allies on the inside.

**REFLECTIONS**

Three years into the work, we still love the job and the amazing people we regularly interact with. As a group, we strongly believe in maximizing the effectiveness and quality of instruction to help students achieve their best. Some of our key lessons learned include:

- **Student success is the product of a system.** To improve a system, it is important to understand all the parts and the relationships that connect them. Not everyone working in a system can see all the parts. For example, program- and department-level workers cannot always see or anticipate higher-level barriers that can disrupt or block innovation (financial issues, student flow, resource limitations, etc.). A big part of facilitating systemic change involves helping others understand how the system works and how they can be most impactful.

- **Change is hard and often risky. Resistance to change is logical.** Logic, data, and good ideas by themselves rarely convince people to take a risk and do something hard. People convince people. Trust convinces people.

- **Graduate Teaching Assistants matter.** Despite their significant role in undergraduate education, TAs are vastly underutilized and underdeveloped as educators and mentors. Our work has demonstrated that TAs can have a significant impact on student learning and success if given proper training and support. Yet so few are. TAs can also influence campus instructional culture through modeling, mentoring, and some friendly peer competition. It’s time to value and cultivate their potential as educators and innovators.

**REFERENCES**


STEM Success through System-Wide Coordination

The California State University (CSU), with twenty-three campuses, 447,000 students, and 45,000 faculty and staff, is the largest, the most diverse, and one of the most affordable university systems in the country. CSU’s mission is to provide affordable, high-quality education to the top third of the state’s high school graduates, offering degrees at the master’s and bachelor’s level, with some professional doctorates added in the last few years. Campuses small and large serve diverse regional communities—rural and urban—from Arcata in the north to San Diego in the south. CSU is the engine of economic prosperity, civic health, and upward mobility in the state. In the 2011–2012 academic year, all of the CSU campuses graduated 76,427 baccalaureates; 10,651 of them were science, technology, engineering and math (STEM) students. The CSU system educates more Hispanic, African American, and American Indian undergraduates than all other institutions in the state combined. But six-year graduation rates are near 50 percent and lower for students of color. Overall graduation rates in STEM are even lower: 33 percent of all students who entered as first-time, full-time, first-year students in 2008 and declared a STEM major graduated in STEM, and drop-offs are steeper for underrepresented minority students.

Relying on the “birds of a feather” effect, faculty said they greatly valued system office-hosted discussions, deliberations, and learning and sharing with others facing similar challenges and issues.

ESTABLISH VISION
We hypothesized that a collaborative community of university leaders could aggregate and coordinate efforts to facilitate and support the layering of inquiry-based, experiential, or participatory learning throughout campus STEM degree programs. We were familiar with evidence showing that engaging, “high-impact practices” (Kuh 2008) deepen learning, improve student persistence, and close achievement gaps. Our initial vision incorporated our desire to see STEM students take risks, make discoveries, and address big questions as engaged scholars over the course of their degree attainment at CSU campuses. In the longer term, we wanted to permanently improve the ability of CSU to graduate all students interested in STEM majors.
At the start, team members recognized that they did not share an administrative organizational structure, nor did they report to a common organizational point of contact. Team members had not previously collaborated around a strategic change initiative. Like change agents in departmental settings, individual Keck/PKAL team members were driving evidence-based STEM-related initiatives, but their efforts were not strategically coordinated. In hindsight, the accidental design of the Keck/PKAL team turned out to be a happy coincidence, unintentionally mirroring a “collaborative academic leadership” team (Humphreys 2013). It is important to note that the team brought together CSU experts on student engagement and success, high-impact practices, evidence-based STEM instructional practices, and communities of learning and practice. In this way the team represented a broad range of views of the student experience on our campuses. However, as one team member commented, “We never really delved into whether each member of the team saw a need for system-wide coordination.” The team scheduled recurring teleconferences and began to share data and perspectives on effective STEM education.

**EXAMINE LANDSCAPE AND CONDUCT CAPACITY ANALYSIS**

In 2009, CSU joined Access to Success—a consortium of state systems organized by the National Association of System Heads and funded by the Education Trust—to boost graduation rates and close achievement gaps. As a result, most Keck/PKAL team members were familiar with the goals, objectives, and campus efforts associated with the CSU Graduation Initiative. However, while the Graduation Initiative focused on support for high-impact practices and encouraged campuses to use evidence- and data-based strategies, we quickly discovered team members did not have a shared vision regarding high-impact practices and their role in effective STEM education.

The most common finding was that some team members regarded high-impact practices as extracurricular activities, not part of or integrated with classrooms, instructional practices, or desired student learning outcomes. In fact, as our discussions progressed, we noted a separation or lack of coordination between student success efforts and instructional practices in the STEM curriculum. As a result, we spent significant time during the fall of 2012 on a deliberative learning process. We discussed the national call for undergraduate STEM education reform, what barriers to reform STEM departments might be facing, what evidence-based practices were adopted across the system, and what gaps the Keck/PKAL team might help fill. We spent significant time discussing high-impact practices and sharing discipline-based education research. The team became familiar with system-wide data on STEM student persistence, “switching” (out of STEM) rates, and graduation rates using new data systems developed as part of the CSU Graduation Initiative.

Team members visited CSU universities to interview campus-based Keck/PKAL teams. Campus-based faculty and administrators consistently expressed the need for a centralized “voice” or resource to raise awareness of evidence-based practices and their impacts on STEM student success. Campus-based experts suggested that our initial strategy of aggregating and coordinating system-wide STEM-related initiatives was not enough. Deeper integration of evidence-based practices within the curriculum was needed system-wide. Campus advisors suggested visible, centralized advocacy was needed to scale and embed evidence-based practices into the STEM curriculum. Faculty and administrators interviewed and surveyed agreed that the most important role for the system office would be as convener. Relying on the “birds of a feather” effect, faculty said they greatly valued system-office-hosted discussions, deliberations, and learning and sharing with others facing similar challenges and issues. Campus teams said they wanted a centralized Effective STEM Education Initiative to rely upon and refer to as campus STEM education initiatives took root.

**IDENTIFY AND ANALYZE CHALLENGES AND OPPORTUNITIES**

As a team, we decided to bring in a facilitator to help pull our team together, get focused, and get ready to move forward. We planned an all-day, facilitated, face-to-face retreat and included other stakeholders and leaders from the system office. We agreed upon tactics grounded in work by Kezar (2012) that recommends focusing on three key components: (1) deliberation and discussion, (2) networks, and (3) external support and incentives. A refined vision was formed: Our diverse pool of STEM graduates, with their unique qualifications and talent, will be prepared to meet the challenges and opportunities in our global society. Evidence of the success would be (1) increased resources and partnerships for advancing effective STEM education; (2) increased support and rewards for implementing effective high-impact practices; (3) a highly visible, system-wide entity to coordinate, convene, advise, and act as an effective STEM education resource; (4) a CSU STEM education universally enhanced by improved articulation of evidence-based practices and curriculum; and (5) stronger connections among system-wide programs and initiatives that all together lead to (6) STEM graduates and faculty that better reflect the state’s demographics.

**CHOOSE STRATEGIES AND DETERMINE READINESS FOR ACTION**

During the team retreat, we also decided to focus on two strategies: (1) increasing resources and partnerships for advancing STEM educational effectiveness system-wide and (2) developing a highly visible,
system-wide entity to coordinate, convene, advise, and advocate for effective STEM education. We identified a number of grant opportunities offered by external funding agencies and went into action writing proposals to support these strategies. By winter 2014, we successfully garnered two new external grants totaling more than $5 million in support for effective STEM education efforts across CSU. Together, the two grants provide resources, personnel, and financial support for campus-wide efforts to improve undergraduate STEM education. The Keck/PKAL team continues to work together to execute the two new grant-funded initiatives, including plans to organize annual system-wide Effective STEM Education Summits. These summits will gather not only grant-supported campus teams but also other campus teams funded by system-wide programs and initiatives, as well as other faculty and administrators interested in learning how to improve STEM education and STEM faculty development.

A reflection of our process indicates that the Keck/PKAL team continually encountered challenges and opportunities related to our system-wide perspective. Our team agreed early in the process that organizational and cultural change across a system as large as the California State University would not be accomplished using top-down directives. Chancellor’s office or system-wide administrators typically have earlier career experience on university campuses working directly with students and faculty. Thus, the first instinct of a system-wide administrator is to defer to campus expertise. All members of the Keck/PKAL team were surprised by campus feedback asking for greater centralized advocacy and leadership around effective STEM education initiatives. We are pleased we were able to find external grants and partners to support and pilot strategic initiatives around effective STEM education system-wide. However, it will take campus commitment, intentional cross-divisional partnerships, and creativity to institutionalize new evidence-based practices in STEM education within public higher education budgets. Ongoing advocacy for effective STEM education from the CSU Office of the Chancellor, along with data to drive evidence-based policy and decision making, will be of pivotal importance.

REFERENCES


Implementing a Summer STEM Bridge Program

Bidushi Bhattacharya, director of sponsored research and science liaison, W. M. Keck Science Department, Claremont McKenna, Pitzer, and Scripps Colleges
David E. Hansen, Weinberg Family Dean of Science and professor of chemistry, W. M. Keck Science Department, Claremont McKenna, Pitzer, and Scripps Colleges

The W. M. Keck Science Department is the interdisciplinary home to the biology, chemistry, environmental science, and physics faculty for Claremont McKenna, Pitzer, and Scripps Colleges (3C). The department, located at the intersection of the 3C campuses, is administered cooperatively. Keck Science offers more than a dozen discrete majors and provides comprehensive, interdisciplinary instruction in small-class settings and numerous opportunities for students to conduct research. Because of increased interest in science as a major among 3C students, departmental enrollments have grown appreciably during the past ten years. Increased student engagement has led the 3C presidents to examine the long-term needs of the department; in turn, the department has worked to develop numerous initiatives to promote student success.

ESTABLISH VISION
In 2011, the five undergraduate Claremont Colleges (5C), which include Pomona and Harvey Mudd in addition to Claremont McKenna (CMC), Pitzer, and Scripps, had the opportunity to develop a shared STEM (science, technology, engineering, and mathematics) retention program with support from the Howard Hughes Medical Institute (HHMI). The principal goal of the HHMI award is to prepare undergraduates to become leaders in science research and medicine. When considering the exceptional resources the Claremont consortium can offer, community building was identified as a key component to retaining STEM majors. Also central to the program is enhanced support of a diverse range of students—including those from groups traditionally underrepresented in science—through summer bridge programs.

EXAMINE LANDSCAPE AND CONDUCT CAPACITY ANALYSIS
When developing the Summer Science Immersion Program (SScIP), the Keck Science Department drew on its own experience with STEM recruitment and retention and also examined other campus models. A number of successful science immersion programs have been implemented throughout the country, and a particular inspiration to the department was the Louisiana State University (LSU) Biology Intensive Orientation for Students (BIOS) program. This program, which focuses on the expectations of college-level biology courses and the skills required for academic success, has been thoroughly evaluated and found to be effective in increasing the success of students in LSU’s biology curriculum and their retention in the major.

This program, which focuses on the expectations of college-level biology courses and the skills required for academic success, has been thoroughly evaluated and found to be effective in increasing the success of students in LSU’s biology curriculum and their retention in the major.

To further understand the needs of Keck students, the department conducted a retention study in 2011 on every matriculating...
student at all three of the department’s sponsor colleges during the years 2005–10. Demographic, financial aid, test score, and academic data were collected for 5,363 students, and a database of more than 200,000 cells was created. The study revealed that 19 percent of students on need-based financial aid major in a science field, compared with 15 percent of students not on aid. The study also found that 13 percent of Caucasian, African-American, and Hispanic/Latino students major in a science, as do 23 percent of Asian and Asian American students. Significantly, the study found that the math SAT is an effective predictor of success in the department’s gateway course in introductory chemistry (16.8 percent of the variance in grade in the first semester, 19.6 percent in the second) but far less so in introductory biology.

IDENTIFY AND ANALYZE

CHALLENGES AND OPPORTUNITIES

Because the retention study suggested that there was no one group of students uniquely at risk, the department’s SScIP has been broadly targeted to first-generation students; to students from underrepresented groups in science, including women; and to students who attended underresourced high schools.

CHOOSE STRATEGIES

In August 2013, Keck Science launched the one-week SScIP session for incoming, first-year 3C students; the program was again run in August 2014. The theme of the SScIP curriculum was the Chemistry of Life, and a philosophy of acculturation—not remediation—was employed to introduce the participants to the excitement of science and to the expectations and demands of college-level science coursework. Departmental faculty served as instructors for the program, and returning students as peer mentors.

BEGIN IMPLEMENTATION

In both summer 2013 and 2014, the SScIP students participated in interactive seminars on core science topics in biochemistry, molecular biology, and astronomy. A full day was devoted to issues faced by underrepresented groups in science, and as a part of this module, the students and faculty traveled to California State University–Los Angeles to meet with Patrick Sharp, chair of the Department of Liberal Studies and an expert on race and gender in science and science fiction. To introduce the students to the department’s teaching laboratories, the students performed two hands-on experiments from the introductory chemistry curriculum. A module on the search for life on exoplanets included a visit to the Griffith Observatory in Los Angeles. The week culminated with an analysis of the genome and proteome of the protozoan Tetrahymena thermophila, and the students were invited to contribute their results to an international genomic database (http://ciliate.org/index.php/home/welcome).

During the planning process, the department was fully aware that the immersion program would provide many students with their first experience living away from home and that asking these students to arrive one week early for the SScIP could mean sacrificing time with family, time away from paid employment, or both. Consequently, on the first evening of the program, the department hosted a welcoming dinner for all of the participating students and their families. The department also engaged other stakeholders, including prospective and current students, parents, and alumni. In addition, the creation of the SScIP highlighted to the 3C deans, presidents, and boards of trustees the department’s commitment to STEM student success. The 3C offices of public communication were provided links to a Keck Science publicity video (http://www.jsd.claremont.edu/News/Keck%20Edit%20Final.mov) that included scenes from the SScIP and to an online article (https://www.jsd.claremont.edu/News/ssip.asp) that included student interviews and detailed descriptions of the curriculum and activities.

MEASURE RESULTS

Assessment of both the summer 2013 and 2014 SScIP cohorts is being conducted by CMC’s director of academic planning, Dianna Graves. Several times each semester, reports that provide course enrollment data, grades in both science and nonscience courses, and the current declared major, if any, for each SScIP student are being generated through the 5C enrollment management system. Outcomes measured to date are positive—for example, in the first year of college for the 2013 SScIP students, the thirty-eight participants collectively enrolled in 305 full-credit academic courses. Just nine courses were dropped, a completion rate of 97 percent. The completion rate in STEM courses was also impressive, 96 percent overall in the first year of college.

REFLECTION

The Keck Science Department believes that the Summer Science Immersion Program has been an extremely important addition to its curriculum, and the website and video noted above were created to help describe the program to prospective students and to the larger community. Keys to the success of the program have been a clear articulation of the department’s commitment to the success of all of its students, the assessment of outcomes, and the engagement of multiple stakeholders.
First-Year STEM Retention Strategies at the University of La Verne

Kathleen F. Weaver, associate professor of biology, University of La Verne
Jerome V. Garcia, professor of biology, University of La Verne
Christine Broussard, professor of biology, University of La Verne

The University of La Verne, a private Hispanic-Serving Institution located in eastern Los Angeles County, promotes a positive and rewarding life for its students through four core values: ethical reasoning, diversity and inclusivity, lifelong learning, and civic and community engagement. Within the Natural Science Division in the College of Arts and Sciences (CAS), one of the primary and shared pedagogical methods to promote lifelong learning has been to emphasize experiential techniques and problem solving and to provide our students with the skills needed to be successful in graduate studies and industry. For example, all students in the biology department conduct a capstone research project, which provides the opportunity for one-on-one work with a faculty mentor/advisor to address a contemporary research question. In addition, our courses utilize high-impact practices (HIPs) that teach scientific inquiry and writing skills and use inquiry-based laboratory learning modules developed to provide opportunities to design, conduct, analyze, and present outcomes of experiments.

From 2006 to 2012, just prior to our participation in the Keck/PKAL project, the biology department grew from 28 to 103 incoming majors. The rapid rise in incoming students brought retention and preparedness in the first and second year to the forefront. Faculty teaching upper-division courses felt that as class size increased, under preparedness, both in content and skills, became a larger issue; student feedback on course evaluations supported faculty impressions. One of our main challenges was that the biology department didn’t have a unified set of learning outcomes for students or a way to assess their learning. This meant that the content in the first-year series did not align with upper-division coursework. Moreover, while the department was a collective of passionate faculty, we lacked a shared vision, and several members were hesitant to change.

The Keck/PKAL project provided an opportunity to structure the kind of institutional change we realized was necessary for the department. The project provided a model and goals that were supported by our new campus leaders—a new president and a new CAS dean—as well as the structure needed to help faculty leaders institutionalize departmental change. The team for the Keck/PKAL project was Jonathan Reed, current provost and former CAS dean, and biology faculty members Kat Weaver, director of the La Verne Experience; Christine Broussard, Natural Science Division chair; and Jerome Garcia, chair of biology.

ESTABLISH VISION
La Verne has been recognized as an exemplar in Latina/o STEM education. Given the national dialogue around the increased need for diverse STEM graduates, we were well positioned to contribute to fulfilling this need and to share our strategies to help other institutions. The desire to improve STEM education at La Verne came from the mission of the institution to serve the community, including better serving our own students. Even with our accomplishments, we felt more could be done to further their success.

To increase student success, faculty gravitated toward science process skills and writing as two primary areas of development that could be scaffolded into the curriculum. In addition, the faculty consensus was that students needed to learn how to ask questions, formulate hypotheses, carry out experimentation, analyze data, and present research in lower-stakes environments beginning in the first year. Our goal for the project was to effectively scaffold these skills to improve retention and help prepare our students for the capstone and beyond. To accomplish these goals, we needed to leverage
university-level administrative and curricular changes and generate department-level discussions about learning outcomes and the curriculum in the first-year biology series.

**EXAMINE LANDSCAPE AND CONDUCT CAPACITY ANALYSIS**

In 2011, at the beginning of the Keck/PKAL project, the biology department identified growth and retention as our major challenges. Data showed that retention was just over 40 percent after one year and 25–40 percent after two years (figure 1). We had made previous attempts to address these issues based on information from senior exit surveys, one-on-one student interviews with the department chair, and other conversations with students. In 2008, we changed the beginning three-course/twelve-unit series (Principles of Biology, Plant Biology, and Animal Biology) to a two-course/ten-unit series (Plant Biology and Animal Biology) because of student complaints that the three semester-long series was too time consuming and not transfer friendly. However, these changes were implemented without a model or structure, and student complaints actually increased while retention rates declined. This made the department wary of further changes.

At the same time, La Verne was in the midst of leadership change. The College of Arts and Sciences hired a new dean, Jonathan Reed, who was willing to bring experts to campus, help faculty apply for grants, and send faculty to conferences (AAC&U, PKAL, and others) to learn more about science pedagogy. In addition, a new president, Devorah Lieberman, arrived in 2011 and was able to work with the CAS dean to scaffold HIPs into a shared La Verne Experience—including the start of a first-year learning community (FLEX) and a shared learning experience (One Book, One University). All departments in the university were requested to offer a FLEX general education course, tied with another general education and a writing course, which strengthened the learning community and provided students an opportunity to reflect on their learning.

**FIGURE 1. RETENTION RATE FOR INCOMING BIOLOGY STUDENTS FROM 2006–2012 BROKEN DOWN BY YEAR (DATA INCLUDES THE INCOMING CLASS)**

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**FIGURE 2. STRATEGIES ADOPTED BY THE BIOLOGY DEPARTMENT WITHIN THE KECK/PKAL PROJECT**

- **STRATEGY 1:** Utilize Administrative Support
  - Professional Development
  - FLEX Initiative, Leverage
  - External Help, Facilitator

- **STRATEGY 2:** Gain Faculty Buy-in
  - National Context
  - FLEX 1st Edition
IDENTIFY AND ANALYZE CHALLENGES AND OPPORTUNITIES

Initial attempts in 2008 to improve retention after the first year did more harm than good; therefore, it was important to the process to gain community buy-in. A major change to the first-year curriculum and departmental learning outcomes could not be decided by a few faculty. We felt that it was extremely important to get everyone’s input into the process, to make changes that would lead to improvements in retention, and to nurture the collaborative work environment that we all value.

Going through the Keck/PKAL process required that we gather data and critically analyze our past decision-making strategies. As a group, we tended to rely heavily on student feedback, whereas this process required us to look at the data and at national trends in pedagogy before making decisions. We also realized that we needed an outside facilitator to lead the change discussion. Many of the faculty felt that our retention numbers were well within the national norm and that first-generation students need more time to complete their degree because they are under-prepared. In addition, because many of the faculty calling for change were junior faculty, it was important to have an outside expert providing context to our campus issues and potential pathways to change.

DETERMINE READINESS

Overall, the biology department was filled with passionate faculty who wanted the best for students. All faculty wanted to be actively involved in the development of departmental learning outcomes and participated in their mapping across the first-year and upper-division coursework. In order to implement change into the first-year series, we needed to examine faculty workload and schedule times to meet with course groups to outline and refine themes and develop new laboratories and assignments for students. As our student numbers were increasing at all levels, the shifting of loads meant that some upper division courses needed to be covered by adjuncts. Two faculty volunteered to take an overload the first year so they could teach in the first-year series and not have to give up their other courses. However, overloads are not a sustainable solution, and the department chair was able to negotiate for a new faculty line.

Another factor for readiness was the increased communication required to create a seamless transition for students. Faculty felt extremely overloaded by the university initiatives and departmental changes when the process began. We also struggled with getting appropriate data from institutional research. We had to learn what questions to ask, and their staff had limited resources with which to process each of our requests. As an institution, we are moving toward evaluating baccalaureate goals within the e-portfolio, which may alleviate (allowing more data to be assessed within departments) or exacerbate (generating more requests to collate data on student success) data access issues. To compensate, we collected data ourselves by comparing rosters between courses to see if students stayed in the major, until we were able to get the official data. In addition, we selected signature assignments that we will evaluate annually to look at student progress on our departmental learning outcomes.

CHOOSE/IMPLEMENT STRATEGIES

We chose a strategy, implemented, evaluated more data, and then moved forward; in this way, our own process was cyclical and required multiple strategies (figure 2). Our overall goals were to capitalize on institution-level changes and the La Verne Experience platform to increase retention to 70 percent after one year and at least 60 percent after two years. Because we wanted to have community buy-in throughout the change process, our strategies and implementation came in pieces. We did not expect to have complete consensus, but we moved forward with the process and worked to gain input and guidance.

Our first strategy was to utilize administrative support and university-wide changes to facilitate change at the department level. The

GOAL: Improve Retention and Student Preparedness

STRATEGY 3: Curriculum Change (FLEX 2nd Edition)

Examine Data
General Biology
Scientific Inquiry
Science Writing
Interdisciplinary (One Book)
began to mentor newer faculty, going together to meetings and participating in the FLEX initiative. FLEX courses were required to be covered by full-time faculty, and university-wide planning sessions were held to support the connection of content between FLEX courses.

Our second strategy was to gain faculty buy-in for change. We held a two-day departmental retreat led by PKAL facilitator Susan Elrod, who asked us to look at data together, read publications related to science vision and pedagogy, and decide on a departmental vision. In addition, she helped us to develop our introductory-level learning outcomes, which would later be the foundation of a new general biology series. We also examined our departmental retention and graduation data and then split the faculty into working groups to examine departmental coursework and research other general biology series outside of La Verne. Faculty teaching Plant Biology (part of the FLEX first edition) and Animal Biology assessed whether first-year learning outcomes were met within existing coursework. Other faculty examined the General Biology I and II series curricula from several other campuses, including community colleges and four-year private and public institutions. Faculty also examined the graduate prerequisites from several health programs and graduate institutions as well as new MCAT guidelines to compare student needs.

Our final strategy was to implement curricular changes in the first-year series, FLEX second edition. In fall 2013, the department, with encouragement from the dean, decided to change the series from Plant and Animal Biology to General Biology 1 and 2. In addition to identifying our learning outcomes and creating a new structure for their implementation, several additional changes were made to the curriculum in an effort to implement HIPs at this early and formative stage, including the participation in the One Book, One University program, reading primary research, writing and peer critiquing, and presenting an original research grant.

MEASURE RESULTS
Institutional research and the department faculty examined retention of biology students after one semester and one year for both the 2012 and 2013 FLEX courses. For the 2012 FLEX first edition, we retained a total of 60 percent of the incoming biology majors after one year. For the fall 2013 FLEX second edition, we retained 62 percent of biology majors after one year. Retention data for subsequent years will give us more information about our success at increasing student preparedness.

In addition to looking at retention, in the spring General Biology II course we administered the Classroom Undergraduate Research Experience (CURE) survey, a pretest–posttest survey developed by faculty from Grinnell College, Hope College, Harvey Mudd College, and Wellesley College and funded by Howard Hughes Medical Institute. The CURE survey allowed us to examine student attitudes toward science and their learning gains in the second semester course. In preliminary data, students demonstrated three postcourse trends: (1) gains in skills of science process such as ability to analyze data, to read and understand primary literature, and to learn laboratory techniques; (2) gains in understanding the scientific process (such as scientific habits of mind, ethical conduct, and the understanding that scientific assertions require evidence); and (3) clarification of career path, including greater interest in pursuing master’s or doctoral degrees. Interestingly, data revealed that University of La Verne student gains surpassed national averages, in many areas, of the gains of students who had participated in a summer undergraduate research experience (assessed by the SURE), and all students who took the CURE survey at the same time (spring 2014, n=8,700).

DISSEMINATE RESULTS AND PLAN NEXT STEPS
We have presented results from our project at the AAC&U Transforming STEM Higher Education Conference and the AAC&U Annual Meeting as well as at on-campus venues. Based on the many lessons we learned from the framework project, we have revised the four-year biology program curriculum, to be implemented in fall 2015, and we are working on a manuscript for CBE Life Sciences for summer 2015 that will summarize all of our inquiry curriculum work.

In conclusion, the Keck/PKAL model itself was a critical piece for us. As stated, past decisions were sometimes made with little to no cumulative data. Many faculty have emphasized high-impact practices and worked hard to help our students succeed. However, much of our work had been done in parallel with each other, without a real united or solid communication between department members. The process of looking at data and seeing opportunities for growth was important for us.

In many ways, we had a bit of a “perfect storm,” with many events converging to propel us toward major curriculum reform. Without the external events (new administrators, new professional development opportunities, FLEX academic initiatives, external interventions such as the Keck/PKAL guide for systemic institutional change and Susan Elrod’s guidance), we would have made progress much more slowly. The question of readiness was the most complex for us. Some of us were ready to embrace the changes and took advantage of the opportunities presented. Others were not ready but got swept up in the university-wide momentum. However, once we got past the initial difficult evaluation, we easily worked together to develop learning outcomes for the first-year series. Overall, we feel like the change process is continuous but that the first time through it gave us the tools and language we needed to understand each other and what it would take to move forward.
STEM Student Success through the CSUF Catalyst Center

Robert A. Koch, special assistant to the provost, California State University–Fullerton
Michael Loverude, associate professor of physics, California State University–Fullerton

California State University–Fullerton (CSUF), especially within the university’s College of Natural Sciences and Mathematics (CNSM), has a history of supporting STEM (science, technology, engineering, and mathematics) education and innovation in instruction. Even the most recent efforts trace back to CSUF’s National Science Foundation-funded Undergraduate Reform Initiative (URI), which proposed to retain greater numbers of beginning science and engineering majors by providing these students with knowledge and experience essential in the modern workplace; ensuring that future teachers have the understanding, skills, and attitudes necessary to promote student success; and educating a citizenry more literate in science and engineering.

Two important outcomes of this project were (1) the planting of the seed of active learning in the classroom in STEM instruction and (2) the hiring of discipline-based educators to complement the math educators who were already members of the department of mathematics. Through this project, three science education faculty members were hired to bring discipline-based science education research to the college and what was known as the Center for Enhancing Science and Mathematics Education. Several years later, a restructuring of the program led to the re-envisioning of the center, now known simply as the Catalyst Center. These centers fostered many innovative curriculum change projects over time, including the adoption of supplemental instruction (SI). SI sessions were added to several courses in math, biology, chemistry, and physics that had a high percentage of DFW grades and impact all STEM majors. Data collected since the inception of the program in 2005 indicate that attending five or more SI sessions during the semester increased persistence and improved graduation rates for all participants and narrowed—or, in some classes, closed—the achievement gap for underrepresented minorities and women.

**ESTABLISH VISION**

Despite many efforts, by 2012 there appeared to be a waning of the campus push of the late 1990s and early 2000s to introduce active learning to the science classrooms. At issue were the high stakes for faculty experimenting with active learning modes—some faculty receive lower student evaluations in active learning classes, despite data indicating that students learn more. And because developing the skills to offer and manage effective active learning experiences is a long-term process that requires support, many faculty, especially untenured and part-time faculty, abandon the effort before becoming proficient. Following several meetings with vigorous discussion of the state of active learning in the CNSM classroom, the Keck/PKAL Framework Change project team arrived at a vision for their work: to develop a culture in CNSM in which instructors—tenure-track faculty (TTF), non-TTF, and teaching associates—use evidence-based, scientific approaches to teaching.

The goal was to establish a program that could be institutionalized to provide professional development for the CNSM faculty to engage in scientific teaching.
and student learning in classroom, online, and laboratory instruction in courses across the curriculum. The goal was to establish a program that could be institutionalized to provide professional development for the CNSM faculty to engage in scientific teaching.

EXAMINE LANDSCAPE AND CONDUCT CAPACITY ANALYSIS
However, the newly convened project team found that there was a lack of consensus on the existing state of affairs regarding scientific teaching in CNSM. While they had excellent support from the office of institutional research, the data collected by the institution did not include any information about faculty teaching practices, attitudes, or aspirations. Because the question “What percentage of the CNSM faculty members were using evidence-based, scientific approaches to teaching and student learning in classroom, online, and laboratory instruction in courses across the curriculum?” remained unanswered, the team decided to administer two surveys: one based on Trigwell and Prosser’s Approaches to Teaching Inventory (2004) and a survey adapted from Henderson (2008) and Tanner (2013).

IDENTIFY AND ANALYZE CHALLENGES AND OPPORTUNITIES
Results from these surveys suggested that faculty wanted the opportunity to be creative, have agency in adopting research-based instructional strategies, and have mini-grant support that allowed them to pilot various approaches and gave them flexibility to adopt strategies that made sense for their particular circumstances. Also, there was interest in small group discussions, semester-long partnerships with researchers, and a multiday summer workshop, each garnering about ten responses. The survey responses suggested that a single professional development strategy might not be appropriate for our faculty. Similarly, the faculty responses with respect to barriers have implications for professional development strategies. The greatest barrier identified was not at all surprising: time. The project team concluded that faculty stipends and course releases would be absolutely essential to the success of the project. Other challenges, such as class size and room configuration, can be addressed through professional development. Some strategies, such as peer instruction, are explicitly designed for use in large lecture classes that are not configured for group work. In order to establish a program that would institutionalize scientific teaching, the team predicted that they would need to provide a set of tools and create an environment in which faculty would receive (1) professional development, (2) support for trying new methods, (3) tools to assess faculty success, (4) incentives to try new approaches, (5) and the freedom to take risks (which may require changes to retention, tenure, and promotion criteria).

DETERMINE READINESS FOR ACTION
There is ample evidence that the adoption of innovations is a sociocultural phenomenon. In his influential 2003 book Diffusion of Innovations, Everett Rogers describes five phases of adoption: knowledge, persuasion, decision, implementation, and confirmation. He further describes five conditions that influence the rate and prevalence of adoption, including the advantage an innovation provides, the compatibility of an innovation with existing circumstances and values, the complexity of adoption, whether the innovation can be tried in limited doses, and when the use of the innovation is visible. A key element in the adoption of innovations is increasing awareness. In order to raise the visibility of scientific teaching, the CSUF team decided to host a seminar series featuring off-campus experts who could make the case for discipline-based education research and instruction.

CHOOSE STRATEGIES
Based on analysis of faculty survey responses and the CSUF team’s review of the research literature and the work of others, the team developed a multiphase strategy to address its goals. Once the team had identified program elements, it became clear that the team could not accomplish most of its objectives with existing resources. Therefore, the team identified opportunities to secure external funding to support the implementation of a program that would address the challenges outlined in the previous section and provide time and resources to support faculty pursuing new strategies.

MEASURE RESULTS
Assessment activities included a repeat administration of the original survey instruments. But the project team further anticipated that professional development activities and the experimental approaches taken by individual faculty would drive the need for better means of assessing student learning. Therefore, the team’s next step was to develop or adapt more robust assessment strategies. An important focus will be micro-assessment embedded in specific courses. For example, a number of junior faculty in the physics department have implemented research-based instructional strategies over the course of several semesters of introductory general education astronomy courses. They have used published assessment instruments specific to the course and student population as well as field notes and journals prepared by instructors and student peer assistants. Their results suggest statistically significant student learning gains on topics of light
and spectroscopy; the team has recently submitted a manuscript for a scholarly journal to document the physics faculty’s results and the process of professional development (Li et al. 2014). The project will be characterized by ongoing formative assessment; the project team will be attentive to the activities that are taking place and continually strive to improve. A more summative evaluation, in which the team performs a more complete and quantitative study of the overall effectiveness of the project, will occur at three-year intervals. Features of this evaluation will include administration of the original surveys, comparison of survey results to those from the first project year, and short qualitative interviews with project participants, project staff, and department chairs.

**DISSEMINATE RESULTS AND PLAN NEXT STEPS**

Our next steps are to
- continue the analysis of the survey data;
- continue small pilot projects to support individual faculty or small teams;
- perform formative assessment of initial efforts and gather feedback;
- identify appropriate summative assessment for individual innovations;
- continue to seek external funding; and
- publish research results in scholarly journals.

**REFERENCES**


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**Inclusive Excellence**

**Engaging all students in science**

The Howard Hughes Medical Institute announces a new $60 million science education grants initiative that is challenging colleges and universities to increase their capacity to engage all students in science, especially those who come to college via nontraditional pathways.


Contact: 2017ugradcomp@hhmi.org
Improving STEM Retention at CSUEB

- Caron Inouye, associate professor, department of biological sciences, California State University–East Bay
- Chung-Hsing Ouyang, associate professor, department of mathematics and computer science, California State University–East Bay
- Stephanie Couch, director of the Gateways East Bay STEM Network and director of CSU East Bay Institute for STEM Education, California State University–East Bay
- Elizabeth Yeager, lead researcher, Institute for STEM Education, California State University–East Bay

California State University–East Bay (CSUEB) is one of twenty-three campuses in the CSU system. In response to its regional context near a large US city that is a hub for technology and innovation, CSUEB launched a new initiative in 2009 to become a STEM-centered institution.

**ESTABLISH VISION**
The goal of CSUEB’s STEM initiative was to increase the capacity of the university for leadership in STEM education in the region, including thorough efforts to enhance teaching and learning of science, technology, engineering, and mathematics (STEM) at all levels of education. Success of the new initiative would be evidenced by (1) increased student enrollment in STEM majors, with enrollments reflecting the diverse population of the region; (2) widespread integration of research-based pedagogies and programs that engage students and increase the numbers of students persisting in STEM majors to graduation and career; (3) a significant increase in the recruitment of STEM majors into the teacher credential program, with enhanced emphases on deep content knowledge and innovative pedagogies; and (4) a student body in which all members, regardless of major, have an understanding of STEM issues, with the STEM knowledge required for decision making in their daily lives.

**EXAMINE LANDSCAPE AND CONDUCT CAPACITY ANALYSIS**
Regional data examined as part of the initiative, such as standardized test scores and declining high school graduation rates in K–12 schools, suggest that the level of educational attainment of young people in the region is not keeping pace with the emerging knowledge-based economy, putting the region’s economy at risk as well as the welfare of many individuals. Data also show that despite high earnings and large employment growth projections in STEM and STEM-related jobs, relatively few students who graduate from CSUEB leave with a STEM major. Taken together, the data suggest that in order to increase the number and diversity of students who graduate from high school, who enter CSUEB as first-year students, and who are college and career ready with the intent to major in STEM, and then to retain these students through graduation, we must provide enhanced learning opportunities at all stages of the P–20 education continuum.

Faculty members in the College of Science drafted a concept paper on the creation of a STEM education institute that would draw upon expertise from both the College of Science and the College of Education and Allied Studies. The institute would support STEM faculty research as well as collaborative efforts to transform STEM teaching and learning. The initial challenge faced was funding for such an institute. The university advancement office sought and secured the external funding that was used to hire an interim director. The interim director worked with the dean of the College of Education and Allied Studies, the dean of the College of Science, and faculty representatives from major departments across both colleges to further develop a comprehensive proposal for an institute. Approvals were granted by the Academic Senate, the provost, and the campus president in the spring of 2012. The newly established Institute for STEM Education’s mission was to advance STEM teaching and learning in parallel with the rapidly changing knowledge, practices, and needs in STEM fields and disciplines. The institute focused on building and supporting the breadth of diversity of the community and students, with a special emphasis on underrepresented groups in STEM disciplines.
Individuals who had worked on the proposal for the institute became the founding members of the board of advisors. They then developed a governance structure for the institute that has evolved across its early development years. The institute board, which met twice a month during the academic year, then set out to gather and analyze additional data across the education continuum. For example, the research and data this team collected made clear the need to address early numeracy development among young children in preschool and grades K–3, given its profound effect on future success in high school mathematics. The data also demonstrated how little science was being taught in the early grades and pointed to the need to enhance learning opportunities for students in the region. Other data suggested that while many students were getting STEM learning opportunities in high school, there was significant room for improvement. Six area school districts were home to sixty “linked learning” pathways in which college prep coursework is combined with career technical education and work-based learning experiences. The institute board also did a detailed analysis of community college transfer students, finding that there was a need to increase the percentage of students transferring to CSUEB to major in STEM fields, particularly computer science and engineering. Additionally, a closer look at the incoming first-year student cohort of 2007 revealed that the problems with retention of STEM majors begin within the first year with a 23 percent loss of the cohort and continues through year six with a cumulative loss of 74 percent loss (fig. 1).

Many CSUEB faculty members cited students’ needs for placement in developmental mathematics or English language arts as a key factor in the loss of STEM majors. An examination of the data for all students indicated that 54 percent of CSUEB first-year students required developmental English. Fifty-two percent required developmental math, with roughly one-third requiring Math 800 (the first course covering pre-Algebra in a three-course sequence). Roughly one-third of students did not pass Math 800.

![Figure 1](https://example.com/figure1.png)

**Figure 1. The pattern of retention (cumulative percent loss) by year for the 2005 cohort of incoming first-year students declaring a STEM major at CSUEB (no data are published for year three)**

![Figure 2](https://example.com/figure2.png)

**Figure 2. The pattern of retention (cumulative percent loss) for the CSUEB 2005 cohort of all first-time, full-time, first-year students requiring developmental math and/or English classes (no data are published for year three)**

(Source: CSU Student Success Dashboard)
in the fall quarter. Thirty-nine percent of students needing these courses required both developmental English and math. Retention data for the fall 2005 cohort of all first-time, full-time first-year students who took developmental math and/or English classes revealed a pattern of loss that ranged from 20 percent by the end of year one to 41 percent of the total cohort by year four (fig. 2). Data disaggregated for STEM majors are needed and may help explain the low retention rates evident in STEM majors.

IDENTIFY AND ANALYZE CHALLENGES AND OPPORTUNITIES
The above-mentioned data revealed the need to (1) accelerate the development of STEM majors’ English and math capabilities so that students meet minimum qualifications needed to take courses required within the major as soon as possible; (2) strengthen the connection to STEM for students who are placed in developmental math and/or English classes and may be in first-year learning clusters (i.e., three thematically linked courses) that are not specifically designed for STEM majors; and (3) improve the engagement and persistence of students in STEM majors, which can, in turn, ultimately lead to retention and graduation of all students in these majors.

DETERMINE READINESS FOR ACTION
The institute staff worked with faculty members to develop initiatives that would address the three high-need areas indicated above. The diverse array of initiatives put forth by faculty members demonstrated the high level of interest and desire to improve learning outcomes for the university’s diverse student body. Because we believed that low retention and graduation rates are a result of a variety of factors and that attaining better outcomes is a complex endeavor, we decided to use multiple approaches in the initiatives. There is no “one size fits all” solution. Faculty also determined that the institute should become a “home” for ongoing data collection, analysis, strategic planning, and support for the execution of initiatives, which demonstrated commitment to bringing about larger scale change. They wrote and received grants to fund this initiative.

CHOOSE/IMPLEMENT STRATEGIES
All planned initiatives are in early stages of implementation, so it is too soon to know their effects on student development, retention, and graduation. Each initiative has a research element, which will allow us to identify significant accomplishments and challenges and to inform next steps. With assistance from institute staff, findings will be shared with the departments and colleges represented on the institute’s board of directors, across the campus, and with the campus community more generally.

Funding obtained since the institute’s establishment has permitted the hiring of a student case manager who will provide wraparound support for STEM majors, making use of more granular data through a case management system. We anticipate more detailed data, for example, about STEM majors and the reasons why they do or do not persist under different conditions. Data systems are currently being piloted that will allow more fine-grain analyses of students’ individual paths and trajectories.

MEASURE RESULTS
The assessment methods we used include quantitative data collection and analysis as well as empirically based ethnographic research methods. These research methods will allow us to determine how innovations are enacted in instructional settings, what happens to students under various conditions, etc. As part of some projects, such as the redesign of a remedial math course, staff researchers have assisted the principal investigators to develop questions that help determine the most effective instructional changes. At the same time, they are surveying and interviewing sample students in order to measure shifts in attitudes toward STEM. Together, they will be examining student work samples in order to assess shifts in persistence in problem solving as well as shifts in understanding, especially in new conceptual and inquiry-based pedagogies. Finally, faculty members are measuring what learning opportunities are made available to students through the collection of ethnographic field notes, interviews of graduate student instructors, collection of instructor reflections, and student focus groups. In recent months, staff researchers have partnered with the Center for Student Research to develop additional research capacity by engaging students in the work. This affords CSUEB students with opportunities for mentorship and applied learning.

DISSEMINATE RESULTS AND PLAN NEXT STEPS
Key findings surrounding the institute’s development, the development of specific initiatives, and related research are being shared through various campus community events. For example, during the campus’ Week of Scholarship, faculty and students give presentations and poster sessions featuring their work and research findings related to STEM education. The institute also shares its work with the campus community through poster sessions at the annual Diversity Day. Dissemination across the local region is supported by events such as a quarterly leadership conference for school district partners sponsored by the institute’s Integrated Middle School Science project.
Everything must change…Nothing stays the same
Everyone will change…No one stays the same
Yes, everything must change…”
—B. Ighner

In 1974, jazz singer and songwriter Bernard Ighner wrote and performed the popular song *Everything Must Change*. Its message—change is a necessary constant in life—corresponds with what countless contemporary national reports have consistently and urgently indicated in recent years—that change is the undeniable imperative that we must wholeheartedly embrace, even when considering STEM higher education reform. However, sporadic and incoherent attempts at change will not suffice. Rather, what is required is what Frederick Douglas describes for us as “…patient, enduring, honest, unremitting and indefatigable work into which the whole heart is put.”

Without a doubt, the landscape of higher education has shifted dramatically, and it is predicted to shift even more over the next two decades. Already, women—of all racial and ethnic backgrounds—comprise nearly 60 percent of all US college undergraduates. Further, the Western Interstate Commission for Higher Education, in the 2008 report *Knocking at the College Door*, projects that by 2022 the number of high school graduates who are from minority populations will significantly increase, while the number of white non-Hispanic high school graduates will decrease. In fact, in *The College of 2020: Students*, Martin Van Der Werf and Grant Sabatier predict that these trends will result in minority students outnumbering whites on US college campuses by the start of the next decade. These projected shifts in undergraduate student composition make it increasingly likely that all institutions of higher education will experience significant growth in their underrepresented STEM student enrollments, and they emphasize the need for comprehensive change in STEM higher education that is grounded in research theories, relevant to diverse audiences, and informed by the principles of liberal education.

Strengthening our resolve for this kind of change requires the kind of systematic approaches that are often defined within organizational change theory and institutional context. In his 2012 book *Leading Change*, John P. Kotter noted that such approaches can accelerate the implementation of new initiatives, avoid unnecessary resistance, and overcome destructive inertia. This issue of *Peer Review* showcases explicit and highly ordered institutional practices and processes that not only frame the constructs of a model for institutional change, but also support a new language for STEM higher education reform that is shaped by words and deeds of action, reflection, and implementation. Successful integration of these domains sets in motion the kind of deep and pervasive adjustments to institutional policies, procedures, and processes that ensure STEM students, especially those from historically underrepresented groups, can persist in their chosen fields of study.

However, the complexities of change are such that our energies cannot be singularly focused. Ighner, through his lyrics, also reminds us that individual faculty and administrators are no less vulnerable to change than the institutions where they work. Indeed, STEM faculty have been increasingly called upon in recent years to implement new approaches to teaching, conduct research in an ever more competitive climate, and balance the demands of careers that often conflict with personal wellness and wholeness. Hence, as STEM higher education reform simultaneously struggles with the inevitability of change and the intricacies of achieving it, our new language of change must also strategically include particular attention to workplace satisfaction, faculty incentive and reward structures, and career trajectories.

Regardless of the order of magnitude of our approaches, it is accepting the certainty of change—not change itself—that is perhaps the most pressing demand of our reform effort. Absent this, we are destined to fail in mitigating persistent disparities in STEM higher education, achieving collaborative leadership, and, most importantly, aligning what we do with who we serve and how we think.

‘Cause that’s the way of time…Nothing and no one goes unchanged
—B. Ighner
AAC&U is the leading national association concerned with the quality, vitality, and public standing of undergraduate liberal education. Its members are committed to extending the advantages of a liberal education to all students, regardless of academic specialization or intended career. Founded in 1915, AAC&U now comprises more than 1,300 member institutions—including accredited public and private colleges, community colleges, research universities, and comprehensive universities of every type and size.

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