Increasing Student Success in STEM: A Guide to Systemic Institutional Change

Campus Case Studies

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A Keck/PKAL Project at the Association of American Colleges & Universities (AAC&U)
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California State University Chancellor’s Office Case Study

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Institutional context regarding STEM education
The California State University (CSU), with 23 campuses, almost 437,000 students, and 44,000 faculty and staff, is the largest, the most diverse, and one of the most affordable university systems in the country. Within California’s Master Plan for Higher Education, the mission of the CSU is to provide affordable, high-quality education to the top third of the state’s high school graduates, offering degrees at the masters and bachelors level, with some professional doctorates added in the last few years. Campuses like CSU Long Beach and CSU Northridge each enroll more low-income undergraduates supported by Pell grants than the entire Ivy League. Campuses small and large serve diverse regional communities – rural and urban – from Arcata in the north to San Diego in the south. The CSU is California’s engine of economic prosperity, civic health, and upward mobility.

In 2011-2012 the 23 CSU campuses graduated 76,427 baccalaureates; 10,651 of them were science, technology, engineering and math (STEM) students. The CSU educates more Hispanic, African-American, and American Indian undergraduates than all other institutions in the state combined. Indeed more than a quarter of the CSU’s STEM baccalaureates are Hispanic, African-American, and American Indian. Yet by some measures this degree production represents only half of the CSU’s capacity. Six-year graduation rates are near 50% and lower for students of color. Graduation rates in STEM are even lower: 35% for majority-population students and 17% for under-represented minority students, according to Consortium for Student Retention Data Exchange data for the cohort that began in Fall 2005.

The W. M. Keck Foundation supported PKAL STEM Education Framework Project (the “Framework Project”) assembled a team of administrators responsible for many of the CSU system’s sustained investments in STEM education and learning. However, we recognize that adoption and support for active and collaborative learning in the classroom is not widespread across the CSU. Others have come to the same conclusion; “these practices remain optional rather than essential” (Kuh & Schneider, 2007; Kuh & O’Donnell, 2013). While rich, out-of-classroom STEM learning communities are common on our campuses, the in-classroom experiences remain largely lecture-formatted, especially in introductory STEM courses. We thought the Framework Project might help us identify strategies to improve STEM learning and scale evidence-based practices system-wide, recognizing there was a large organizational change component embedded in the work. This is our discovery narrative presented as a case study.

Initial Vision for Improving STEM Education
We began the W.M. Keck Foundation-supported Effective STEM Education Framework
project in 2012 with an initial vision communicated as part of the team recruitment process. 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” (HIPs; 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 the CSU to graduate all students interested in STEM majors.

**Initial Challenge #1: Leadership Change**

The Keck-funded Framework Project started at the same time the CSU system office (Office of the Chancellor; CO) experienced unforeseen, but never unexpected (Kezar, 2012), personnel changes. To form the “CO Framework Team,” the initial team leader recruited a set of administrators and program directors with system-wide perspective, STEM project portfolios, and STEM faculty communities. Shortly after the team formed, the initial team leader changed jobs. In fact some of the administrators and program directors on the Framework Team took on components of the initial team lead’s administrative project portfolio.

The CO Framework Team agreed to continue work as a “collaborative leadership” team. At the start team members recognized that we did not share an administrative organizational structure, nor did we 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 Framework Team members were driving evidence-based STEM-related initiatives, but their efforts were not strategically coordinated. In hindsight the accidental design of the CO Framework Team turned out to be a happy coincidence, unintentionally mirroring a “collaborative academic leadership” team (Humphreys, 2013). Importantly 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 all-around 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.

**Initial Challenge #2: Lack of Shared Vision**

In 2009 the 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 Framework 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 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 CO Framework 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. However, after six months we were faced with another Framework Project deliverable, and we were forced to admit we had made little progress toward a shared vision, much less actions aimed at advancing that vision.

Landscape and Capacity
The CO Framework Team embarked on a fact-finding mission during Fall 2012 and Winter 2013. Building on faculty feedback collected by the CSU Program for Education and Research in Biotechnology (CSUPERB) and the system-wide Institute for Teaching and Learning (ITL), team members visited with and discussed faculty members’ needs on campuses also involved in the Keck-supported project (CSU East Bay, CSU Fullerton, CSU Fresno, CSU Los Angeles, San Diego State University and San Francisco State University). Campus-based teams 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 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 make that happen. Faculty and administrators interviewed and surveyed agreed that the most important role for the Chancellor’s Office team would be as convener. Relying on the “birds of a feather” effect, faculty said they greatly valued Chancellor’s Office-hosted discussions, deliberations, 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.

The CO Framework Team next analyzed how our ongoing programming might complement and support a system-wide Effective STEM Education initiative. We saw the advantages of aligning with and supporting existing CO initiatives such as the CSU Graduation and Bottleneck Course initiatives. As we began discussing strategies, we discovered that team members approached system-wide change differently in their respective roles. Some team members were more
comfortable than others driving strategic change initiatives. Some had flexible financial resources to co-fund mini-grant programs, for instance; others did not. Some thought a centralized, cohesive project team could share the “risk” associated with advocating for and supporting effective STEM education. Others didn’t see safety in the group and preferred a single spokesperson or program director model. Some didn’t want subsets of the team pursuing different strategies with different implementation plans; instead they preferred the entire team working together on a common strategy and action plan. The Effective STEM Education Framework project forced the team to negotiate these operational strategies, but confusion about the development or usage of a framework persisted and slowed progress towards a shared vision.

As a team we decided to bring in a facilitator to help pull the team together, focus the team, and get ready to move forward. We planned an all-day, facilitated, face-to-face retreat and included other stakeholders and leaders from the Chancellor’s Office. The facilitator selected had worked with Chancellor’s Office staff previously and was known to be adept in working with fragmented or unfocused groups. The retreat was held at the Chancellor’s Office in a windowless room with just enough seating for us all. Team members were asked to clear their calendars that day and resist email and phone communications.

Over the course of the day, we shared campus feedback, STEM faculty surveys and our data analyses. By midday the group decided our starting vision was too narrowly focused on experiential learning and coordinated information sharing. The campuses were looking for centralized leadership and advocacy for effective STEM educational practices. Framework team members agreed that we should advocate for all HIPs – from first-year experiences to service learning. But we also recognized that campuses were having much greater difficulty adopting evidence-based instructional practices and incorporating HIPs into classrooms. As a team, we wanted to employ both HIPs and “scientific teaching” (Handelsman, et al., 2004) to advance cohesive layers of student learning throughout the CSU STEM curriculum.

We agreed upon tactics grounded in work by Kezar (2012) recommending, “…focus on three key components…(1) deliberation and discussion, (2) networks, and (3) external support and incentives.” Paraphrasing comments from one team member: she didn’t want to figure out a generalizable framework for effective STEM education, but she did want to bring in external grants to support student success, curriculum reform efforts, and faculty professional development. In hindsight, our team’s new-found clarity was a result of our own year-long deliberation and discussion and the leadership network we developed. The Framework Project

“We also are working to balance our ‘voice’ as a group. Some of the empowered team members want to start ‘doing;’ others don’t want one part of the team ‘doing’ until all can participate or contribute.” – anonymous team member

“...from my perspective it felt a lot like writing. You spend the first 80% of the time very frustrated and faintly car sick, and then you eventually figure something out...In our case the significant turning point was the day-long (facilitated) meeting...the outcomes of which informed our subsequent grant proposals.” – anonymous team member
forced this discussion, but also provided a mechanism to knit together system-wide STEM initiatives. As a result the facilitated retreat was a complete, unqualified success.

A Shared Vision for Improving STEM Education
After the day-long retreat the Framework Team had a new vision and associated strategies. The Framework Team crafted this vision: “In 2018, when this group has contributed to the advancement of effective STEM education across the CSU, 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 CO Framework Team’s contributions 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 better reflective of California’s demographics.

Choosing Strategies
During the team retreat, the CO Framework Team 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 felt we could make progress on both fronts during the Keck Framework Project grant window.

Implement
We first addressed the need for a centralized Effective STEM Education resource for the CSU. Some Framework Team members advocated passionately for a program director position in the Chancellor’s Office. A proposal was made to CO leadership even though the timing was not optimal. The State of California was in the throes of the budget crisis brought on by the Great Recession. Predictably the request was denied. This outcome forced the team to truly embrace the “collaborative leadership” model and “own” the shared vision to move forward. For the near term we embraced a puzzle analogy, understanding that our aggregate efforts - if aligned with our vision and strategies - could provide system-wide leadership around effective STEM education. The Framework Team re-committed to continued, recurring teleconferences to advance our shared vision even after the end of the Keck-supported work period.

The Framework Team first contemplated pooling existing monies from our puzzle of programs, but concluded mini-grants (<$15,000) would not be impactful. There was some evidence that mini-grants might allow sufficient faculty release time for effective single
course revisions. However, the team thought the work of improving undergraduate STEM education required greater institutional commitment and cross-divisional campus involvement. Recognizing that CSU resources were severely constrained by the budget crisis, the team decided to make all-out efforts to win external support for effective STEM education on CSU campuses. The Framework Team decided to focus on transforming the first year experience to reduce the loss of STEM-interested freshmen on CSU campuses, especially in underrepresented and at-risk student populations. The team identified a number of grant opportunities offered by external funding agencies and went into action writing proposals.

**Measure Results**

During the spring, summer and fall of 2013, CO Framework Team members shared data and crafted three proposals submitted to the Corporation for National and Community Service, the National Science Foundation, and The Leona M. and Harry B. Helmsley Charitable Trust. By winter 2014 we were successful in garnering two new grants totaling more than $5 million in external support for effective STEM education efforts across the CSU. Our shared vision, informed by deliberation and learning, allowed us to put down on paper creative, intentional ideas for improving STEM education based on the gaps we learned about from our campus colleagues. Together the two grants will provide resources, personnel and financial support for campus-wide efforts to improve undergraduate STEM education. Press releases were issued to raise the profile of the Framework Team’s efforts and our objectives.

VISTA (Volunteers in Service to America) is a part of the national service movement through the Corporation for National and Community Service and is often referred to as the domestic Peace Corps. The AmeriCorps-supported CSU STEM VISTA will place fifteen individuals in CSU STEM departments, institutes or colleges to increase student success, particularly among traditionally underrepresented students. This is a significant cost-savings to new initiatives and programs. VISTA placements provide campuses with a full-time position for a year, a real-cost savings of ~$47K the campuses do not pay. CSU STEM VISTA members will collaborate with industry partners, local community organizations, and schools to increase hands-on learning experiences such as community-partnered research, service learning, internships and undergraduate research. The hope is that VISTA members can jump-start departmental and college efforts to better intercalate and integrate effective HIPs as part of the STEM curriculum.

The Helmsley Trust grant will support CSU STEM student success by providing immersive educational STEM experiences beginning the summer before college and continuing through the entire first year on CSU campuses. The CSU STEM Collaboratives initiative will incorporate and integrate high-impact practices on three concurrent fronts: summer bridge experiences, to take place prior to fall of the freshman year; first-year experiences that cross departmental, disciplinary, and divisional lines to engage STEM students through the first full academic year; and redesign of introductory, gateway courses critical for engagement and success in STEM.

“I think I had the enthusiasm of ignorance at that point and that has been tempered by the scope of the task of convincing faculty of the importance of changing to a more “scientific” style of teaching and concurrently obtaining administrative support...” – anonymous team member
The premise of this project is that the CSU already has all the incoming students and pedagogical evidence that it needs to provide California with an ample and diverse supply of STEM graduates. The Framework Team wants to facilitate a new conception of the status quo, with sustained faculty and professional development and other administrative structures that build engaging, evidence-based practices into curriculum, policy, the business model, and day-to-day practice, so that our best work is offered consistently, systematically, and reliably.

We already recognize that the work of the Framework Team has changed some conversations in the Chancellor’s Office and across the system. Chancellor White included references to HIPs in his 2014 State of the CSU address, calling for the expansion of “high-impact practices that support persistence to degree such as undergraduate participation in applied research, service learning, internships and study abroad.”

**Disseminate Results and Next Steps**

The Framework Team plans to work together to execute on the two new grant-funded initiatives. We will organize annual system-wide Effective STEM Education summits. The first one will be hosted and organized July 2014 by the CSU Institute for Teaching and Learning. The Helmsley Trust Grant will support Effective STEM Education summits the following two years. These summits will gather not only Helmsley Trust-supported campus teams, but also other campus teams funded by our “puzzle of programs and initiatives,” as well as other faculty and administrators interested in learning how to improve STEM education and STEM faculty development.

The Helmsley Trust grant has a large assessment component, as does the CSU STEM VISTA grant. Our hope is to gain insights into effective and best STEM education practices as campuses pilot changes in the first-year experience as part of the Helmsley initiative and as they pilot new projects and strategies within the CSU STEM VISTA program. The CSU’s Data Dashboard will integrate work begun as part of the Graduation Initiative and other work on a High-Impact Practice database, along with campus learning around Helmsley Trust supported work going forward. As the Data Dashboard develops, it will be available to campus teams planning to innovate, adopt or scale evidence-based practices across the STEM curriculum.

Interestingly the use of a framework process for strategically important discussions is taking root in the way we operate. CO administrators found the framework helpful in thinking about how we might draft Requests for Proposals issued by our “puzzle of programs.” For example, applicants may be asked to reflect upon and respond to questions that correspond to categories of the framework (context, vision, landscape and capacity, etc.). Our hope is that building a framework around STEM student success will help applicants be more effective, strategic and successful.

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“With the Helmsley Trust grant I believe we will see improvements in STEM education in the future. The challenge will lie in effectively communicating the improvements within and beyond the CSU to secure additional support for larger scale implementation.” – anonymous team member

“The framework itself was a mixed blessing...But having to return to it repeatedly, over the course of a couple of years, added a discipline and consistency to our thinking that we may have lacked otherwise.”

– anonymous team member
Reflection on the process
As a result of early organizational challenges faced, the CO Framework Team used what might be described in hindsight as a “vision development process” (Kezar, personal communication). The team struggled to work within the Framework. Several team members were unfamiliar with strategic framework constructs, the organizational change literature, learning organization concepts, or business strategy formulation. Team members felt pressure to produce a generalizable Effective STEM Education Framework. To change the dynamic, facilitators and experienced team members characterized the framework as a tool for discussion and deliberation. It was necessary to separate our deliberations and long-term vision from the Keck grant-funded activities and deliverables to Project Kaleidoscope. Only then was the team able to focus on vision and strategies for effective STEM education.

In addition our team members were initially reluctant to talk about organizational change theory or formulate vision statements. For some teams involving university administrators and program directors with varying levels of exposure to strategic change initiatives, time spent talking about organizational change theory up front might be time well-spent. Indeed some of us thought that talking about federal policies around STEM education were relevant to and provided a context for our work. However, our Framework Project experience was that individual team members – especially relatively junior administrators - needed first to feel empowered to drive change. Only after senior administrators attended the retreat and explained how new initiatives around STEM education aligned and even meshed with ongoing, CSU system-wide initiatives, did individual team members gain confidence to formulate a shared vision. The collaborative leadership model provided a wonderful leadership development opportunity for individual team members – an important lesson learned.

The CO Framework 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 Framework 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


Cal State East Bay and the Institute for STEM Education

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Campus Context
California State University, East Bay (CSUEB), located in the Bay Area, is one of twenty-three campuses in the California State University System. Its proximity to STEM oriented businesses in San Francisco and Silicon Valley, as well as numerous federal labs (such as Lawrence Berkeley and Lawrence Livermore National Labs), creates significant demand for graduates with STEM degrees. The availability of such graduates is essential to the East Bay’s ability to continue to attract and retain STEM oriented companies. Such businesses, which are growing faster than others in the region, generally require workers with a postsecondary education (roughly 75%) and/or bachelor’s degrees (roughly 50% of workers) (Levy, Haveman, Belzer, Srivastava, Braun & Popuch, Oct., 2011, for East Bay Economic Development Alliance).

In response to this regional context, CSUEB launched a new initiative in 2009 to become a quality STEM-centered institution. To that end, the CSUEB initiative is focused on increasing the capacity of the university for leadership in STEM education in the region, including efforts to enhance teaching and learning of science, mathematics, engineering and technology at all levels of education (K12, community colleges, and on the CSUEB campus itself). When the mission for building a campus that is a recognized leader in STEM and STEM education is fully realized, success will be evidenced by increased student enrollment in STEM majors, with enrollments reflecting the diverse population of the region, wide spread integration of research-based pedagogies and programs that engage students and increase the numbers of students persisting in STEM majors to graduation and career, a significant increase in the recruitment of STEM majors into the Teacher Preparation Program, with enhanced emphases on deep content knowledge and innovative pedagogies, and finally, 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.

Regional data examined as part of the initiative, such as standardized test scores and declining high school graduation rates in K12 schools, suggests 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 increasing the number and diversity of students graduating from high school, entering CSUEB as freshmen, college and career ready with the intent to major in STEM, and then retaining students through graduation, will require enhanced learning opportunities at all stages of the P-20 education continuum.
Institute Formation, Organizational Structure and Staffing

With CSUEB goals and these identified needs in mind, faculty in the College of Science drafted a concept paper for an institute that would draw upon expertise from both the College of Science and the College of Education in order to focus on STEM education – supporting faculty research in this area, 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 (e.g., Bayer USA Foundation, Wareham Development) that was used to hire an interim Director. The interim Director worked with the Dean of the College of Education, 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. Individuals that had worked on the proposal became the founding members of the Board of Advisors, and the interim Director was hired on a permanent basis in June, 2012.

The Institute Board meets twice monthly during the academic year to provide direction for numerous initiatives now underway. The Board’s role includes input into how the Institute supports the work of two centers, the Center for Math Education and Research (CMER) and the Center for Science Education and Research (CSER), and initiatives associated with its leadership role in a regional STEM education effort known as the Gateways East Bay STEM Network.

Gateways, funded largely by grants awarded to the University and managed by the Director, demonstrates the commitment of the Board and the campus President (who serves as Co-Chair) to working collaboratively with colleagues in the preschool community, K-12, area community colleges, and representatives from local businesses and industry to develop, assess and grow highly effective and engaging STEM education programs for students of all ages. The Gateways Steering Committee and its four action groups provide a platform for diverse community stakeholders to come together to align strategies and resources, share expertise, analyze data and to have a larger collective impact. Working together with each other and with community partners to address the barriers students face as they move from cradle to career, CSUEB faculty see a potential for improving high school students’ college and career readiness upon graduation from high school and for recruiting more high school graduates into STEM college and career pathways offered by two and four year colleges and universities.

Staff working on behalf of CMER, CSER and Gateways are co-located with staff who work solely for the Institute and report to the Institute Director. Until recently, all were grant funded and, in most instances, funded by multiple grants awarded to different Principal Investigators (PIs). The Provost’s recent pledge of permanent University funding to sustain the Institute staffing demonstrates institutional support required for what faculty participants intend.

While day-to-day direction is provided to staff by their respective PIs, the PIs have empowered the Institute Director to also provide direction as needed. This allows the Director to tap into the diverse array of knowledge, expertise and perspectives possessed by the staff team as summarized in Table 1. It also helps to ensure the cohesiveness and integration of efforts where appropriate, and
supports the overall needs and success of the Institute. Initially, the Director was recommended by
the Board of Advisors and approved by the Provost and the President. Ongoing annual evaluations
are conducted by the Provost with input from the Board of Advisors.

Table 1
Staff Positions and Expertise within the Institute

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<th>Entity and Position</th>
<th>Expertise</th>
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<tr>
<td>Institute &amp; Gateways: Director</td>
<td>Education policy, school finance, private and non-profit sector management, technology, STEM, intersegmental research and education partnership development, ethnographic research, grant writing and reporting</td>
</tr>
<tr>
<td>Institute: Project Manager</td>
<td>Science, technology, ethnographic research, student services, teaching</td>
</tr>
<tr>
<td>Gateways: Associate Director</td>
<td>Teaching, mathematics, early childhood, professional development programming</td>
</tr>
<tr>
<td>Institute &amp; Gateways: Lead Researcher</td>
<td>Ethnographic research theory and methods, bilingual education, early childhood, grant writing and reporting, teaching</td>
</tr>
<tr>
<td>Institute &amp; Gateways: Administrative Assistant</td>
<td>Project management, event management, human resources, mentorship</td>
</tr>
<tr>
<td>CMER/CSER Affiliated Grants/PIs: Administrative Assistant</td>
<td>University administrative operations, student admissions and support</td>
</tr>
<tr>
<td>CSER: Director</td>
<td>STEM education, legal, K12 schools and districts, grant writing and reporting</td>
</tr>
<tr>
<td>CSER Affiliated Grants: Administrative Assistant</td>
<td>Administrative support services</td>
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<tr>
<td>CSER Affiliated Grants: Post Doc Researcher</td>
<td>Quantitative research methods, science</td>
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Vision for Improving STEM Education
The mission of the Institute for STEM Education, consistent with CSU East Bay’s mission as well as its STEM initiative, is to advance STEM teaching and learning in parallel with the rapidly changing knowledge, practices, and needs in STEM fields and disciplines. The Institute’s long-term goals are to:

1) Provide faculty, students, and staff with support needed for collaborative endeavors aligned with the Institute’s mission and vision.
2) Prepare the STEM workforce and offer opportunities for returning to pursue advanced degrees and certificates.
3) Advance teaching and learning in STEM fields and disciplines in students’ early years, in K12 schools, and in higher education.
4) Establish and continuously engage a community of STEM education supporters, including formal and informal educators, students, representatives from business and industry, and many others in the community-at-large.
5) Provide leadership for STEM policies.
Rather than developing a separate goal addressing issues of diversity, the proposers of the Institute saw the need to represent the diversity of the region and this campus in an integrated way throughout all of its goals. Therefore, all of the Institute’s goals, together and separately, focus on building and supporting the breadth of diversity of our community and students, with a special emphasis on underrepresented groups in STEM disciplines. Institute participants and staff work to ensure that the commitment to diversity is reflected in the strategies and actions taken to realize these goals.

**Landscape and Capacity**
Given our ‘cradle to career’ approach, the Institute has attempted to gather and analyze data across the education continuum.

**K-12 Schools**
Research and data gathered to inform the goals and strategies of the Gateways East Bay STEM Network made visible 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 the need to enhance learning opportunities for students in the region (which we are doing in after school programs and through professional learning communities with teachers and faculty). Our recent collection and review of data at the high school level (Engel, for Gateways East Bay STEM Network, Nov., 2013) suggests that many students are getting STEM learning opportunities in high school, but there is significant room for improvement. Roughly one hundred and twenty thousand (120,000) high school students residing in Alameda and Contra Costa counties attend one of sixty-six (66) schools within one of twenty-five (25) school districts. Approximately forty percent (40%) are served by seventy-one (71) California Partnership Academies. Fifty percent (50%) of the academies are STEM oriented. Nearly twenty-two thousand (i.e., 21,861 or 18%) participate in Regional Occupational Centers/Programs offered by four Joint Powers Authorities, and fifty percent (50%) of these programs are STEM-oriented (Engel, Nov., 2013).

Six area school districts are home to sixty (60) ‘linked learning’ pathways in which A-G coursework required for college entrance is combined with career technical education and work-based learning experiences (Engel, for Gateways, Nov., 2013). These districts include the Oakland, West Contra Costa, Antioch, Pittsburg, Mt. Diablo, and San Lorenzo Unified School Districts.

Many of the roughly 30,000 annual high school graduates in the region enter CSUEB upon graduation, but there is room for improvement. In 2012, 426 freshmen enrolled from the region after attending one of CSUEB’s top twenty-five ‘feeder schools’ (i.e., 20 of 25 top schools are located in Alameda county). All four hundred and twenty-six students were from Alameda County (Campus Institutional Data, 2012/2013 academic year data run). There were no schools from Contra Costa county among the top twenty-five feeder schools. These data suggest that CSUEB is not perceived as a destination university for Contra Costa County and that closer linkage, increased engagement, and more active recruiting efforts with high schools in Contra Costa County have the potential to increase the enrollment of area high school students at CSUEB.
Over half of entering freshmen at CSUEB require at least one quarter of remedial math or English, and at least 40% require both (CSU ERSS and ERSD Statistical Extract, for CSUEB, for 2005-2011). This delays entry into coursework for the major, consequently increasing time to degree. Anecdotal evidence suggests that the students’ struggles to pass developmental mathematics and other mathematics courses contribute to the loss of a large percentage of freshmen indicating a desire to major in a STEM discipline. Joint work with area high schools to address such needs in earlier grades is critical to the Institute’s goal of helping to ensure that high school students graduate, are college and career ready, and are interested in pursuing additional work in STEM.

Community Colleges
A number of the region’s high school graduates will enroll in one of the ten colleges within four community college districts located in Alameda and Contra Costa counties. One hundred and three thousand community college students are served each year across the two-county region. One thousand six-hundred and ninety-five (1,695) students transfer to CSUEB annually (Campus Institutional Data run for 2007-2013).

As part of our landscape examination, we took a detailed look at students interested and engaged in the pursuit of STEM degrees who transferred to CSUEB in 2010-11. The numbers of these students who transferred from the two largest feeder colleges revealed challenges that lie within current STEM college and career pathways as well as existing opportunities to increase transfer rates.

As shown in Table 2, over a four-year period, an average of 28 students transferred from College A to CSUEB and enrolled in a STEM major; of these, an average of 1 (4% of STEM majors) intended to major in engineering, and an average of 5 (18% of STEM majors) intended to major in computer science. An average of 19 students transferred from College B to CSUEB and enrolled in a STEM major; of these, an average of 1 (5% of STEM majors) intended to major in engineering, and an average of 4 (21% of STEM majors) intended to major in computer science.

Table 2

Undergraduate Engineering and Computer Science Community College Transfers*

<table>
<thead>
<tr>
<th></th>
<th>College A</th>
<th></th>
<th>College B</th>
<th></th>
<th>Total STEM Students 2 Colleges</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>0</td>
<td>7</td>
<td>34</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2008-09</td>
<td>2</td>
<td>5</td>
<td>35</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2009-10</td>
<td>0</td>
<td>2</td>
<td>14</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2010-11</td>
<td>1</td>
<td>7</td>
<td>28</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Total Average</td>
<td>1</td>
<td>5</td>
<td>28</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

*Data from Campus Institutional Data (data run for transfers – 2007-2011)
These data show that there is a need to increase the percentage of students transferring to CSUEB to major in STEM, and in particular, computer science and engineering. Establishing relationships with students interested in STEM in high school and continuing to engage with such students as they move through area community colleges will be a key strategy for increasing STEM enrollments at CSUEB.

**CSU East Bay**

Increasing transfer rates of students interested in STEM from high school to community college and from community college to CSUEB is not enough to ensure that business and industry will have access to the highly skilled workforce needed in today’s innovation economy. Data suggest that CSUEB must employ new methods of instruction that will retain STEM majors in greater numbers and accelerate their development in essential areas. At present, roughly 19% of freshmen in the Class of 2005 entering CSUEB as a STEM major graduated as a STEM major within six years. Approximately 3.6% continued work towards a STEM major (a total of 22% from the Class of 2005 persisting in STEM majors and/or career pathways) (CSU ERSS and ERSD Statistical Extract, for CSUEB, for 2005-2011). While they did not major in STEM, 32% of freshmen in the Class of 2005 entering CSUEB as a STEM major graduated or persisted in a non-STEM major in year six. Forty-six percent (46%) of the students left CSUEB without a terminal degree (CSU ERSS and ERSD Statistical Extract, for CSUEB, for 2005-2011).

A closer look at retention issues showed that problems with the retention of STEM majors within the major begins in year 1 and continues each year. The data is as follows: 1) Year 1: 23% loss, 2) Year 2: 44% loss, 3) Year 4: 72% loss, 4) Year 5: 78% loss, 5) Year 6: 78% loss (CSU ERSS and ERSD Statistical Extract, for CSUEB, for 2005-2011).

Many faculty members cited students’ needs for developmental math 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% of CSUEB freshman require developmental English. Fifty-two percent require developmental mathematics, with roughly one-third requiring Math 800 (the first course covering pre-Algebra in a three course sequence) (Olkin & Callahan, self-reported pass-rate data, Feb., 2014). Roughly one-third of students do not pass Math 800 in the fall quarter (Olkin & Callahan, self-reported pass-rate data, Feb., 2014). Thirty-nine percent (39%) of students needing these courses require both developmental English and mathematics. We do not have access to these data solely for STEM majors.

Retention data for the Fall 2005 cohort (CSU ERSS and ERSD Statistical Extracts for CSUEB, for 2005) showed the following loss pattern for those taking developmental math and/or English classes: 1) Year 1: 20% loss, 2) Year 2: 34% loss, 3) Year 4: 41% loss.

The percentage loss in years one and two mirrors the percentage loss of STEM majors. The loss in year four was significantly less than that of STEM majors in year four. These numbers contributed to a working hypothesis that many STEM majors needing developmental math and/or English leave CSUEB or decide somewhere between the end of the second year and their fourth year to transfer to another major if/when they are not doing well in developmental English and/or math.
courses. (Retention data sources: CSU Statistical Data Extracts for 1999-2012, for CSUEB)
(STEM retention data source: California State University Graduation Rates Consortium for Student Retention Data Exchange (CSRDE),
http://www.asd.calstate.edu/csrde/index.shtml#stemi)

Analysis, Emerging Issues & Capacity
Detailed examination of the data surrounding developmental math and English needs of CSUEB students and possible effects on the retention and graduation rates of freshmen entering as STEM majors reinforced earlier convictions and strategies surrounding the Institute’s work with K12 and community college partners. Through its role in the Gateways East Bay STEM Network, and through joint efforts with community stakeholders, the Institute can work to ensure that students graduate from high school college-and-career ready without the need for remedial coursework.

Within the CSU East Bay campus itself, the 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) address needs and retain the connection to STEM for students who may be in freshman learning clusters (i.e., three thematically linked courses) that are not specially designed for STEM majors due to their developmental needs; 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.

During discussions of how to bring about the potential changes needed at the University to impact these three areas and the complexity of supporting multiple change efforts simultaneously (not just one), the following theory of change emerged. As the figure makes visible, through these interacting components of change, the goal is to reach increased student engagement and persistence, since we argue that without either of these elements, particularly with traditionally underrepresented groups, we cannot meet our ultimate goal of retention and graduation of all STEM majors. Therefore, this particular theory of change is focused on bringing together the components necessary to impact transformative changes that can afford students the kinds of opportunities necessary to ensure engagement and persistence in STEM majors, leading to graduation.
The theory is based on a belief that transformational change requires institutional support, faculty development, and changes to the infrastructure available to aid faculty as change makers. With these three things in place, environmental changes, cultural change and changes in instruction and curriculum can occur. These changes then generate increased student engagement and persistence in STEM majors. Our analysis of capacity indicates that, through the Institute and its collaborative efforts, we have the initial capacity to impact each of the three areas of support necessary. We also recognize that increasing the Institute’s capacity is necessary to ensure that we reach our ultimate goal of retention and graduation of all STEM majors (with increased numbers of STEM majors). A more granular example of the theory of change in action shows how we envision that initiatives may develop with initial implementing partners working on a particular project and others ‘shadowing’ and learning from the work. The particular approach can then be refined, go to scale and be sustained over time as support, faculty development and infrastructure needs (precursors to change) are met, both in and through existing capacity and, simultaneously, as a means through which we can affect continuous improvement and enhancement of capacity:
Strategies and Readiness to address challenges

While Institute staff worked with the Board and campus administration to address the three areas described above in order to establish the conditions needed to support and sustain change, specific strategies were identified for improving outcomes for our students. Many of the potential strategies emerged as Institute staff worked with faculty to write grants to resource their work. For example, as faculty in biology, chemistry and physics worked with Institute staff to submit a proposal for a WIDER (Widening Implementation and Demonstration of Evidence-based Reforms – NSF) grant, a substantive literature review made visible the need to develop a theory of change that reflected the three integrated support elements discussed above (e.g., Henderson & Dancy, 2011). Areas for a range of strategies within and across those three components that build on existing capacity included increased support for freshmen as they enter the University (e.g., reformulation of the existing freshman cluster/learning communities model with an increased STEM focus), evidence-based, student-centered introductory courses (e.g., implementation of culturally relevant pedagogies, redesign of courses, etc.), and development of a database for a case management intervention(s) program. The take up or refinement of many of these approaches surfaced through the grant development process (and building on existing work). The take-up is visible in Table 3 below (e.g., redesign of three developmental math courses). In addition, publications by AAC&U and information learned through participation in AAC&U’s annual STEM conference informed the discussion about high impact practices and possibilities on campus. Because financing is an ongoing constraint, strategies that ultimately were initiated were those that had Principal Investigators who succeeded in securing funding. The range of ideas about campus needs and faculty interests that have emerged are shown in Table 2.

Table 3
Summary of Campus Needs and Strategies Identified
<table>
<thead>
<tr>
<th>Campus Need and Strategies Identified</th>
<th>Resourced?</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developmental Math and English Needs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Redesign first of three remedial math courses so students are more successful</td>
<td>Yes</td>
<td>Implementing new math curriculum and strategies for the first course in Spring 2014. Planning changes for remaining two courses in 2015 to support faster completion.</td>
</tr>
<tr>
<td>• Redesign remaining two remedial math courses.</td>
<td>Yes</td>
<td>Two designs tested in Fall 2013. Third design created in response to Fall and tested in Winter 2014.</td>
</tr>
<tr>
<td>• Embed the teaching of English across the curriculum through peer feedback methods</td>
<td>Yes</td>
<td>Two designs tested in Fall 2013. Third design created in response to Fall and tested in Winter 2014.</td>
</tr>
<tr>
<td>Retention of STEM Majors Needing Remedial Coursework</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Develop a new interdisciplinary STEM freshman learning cluster for these students that focuses on problem solving and inquiry</td>
<td>No</td>
<td>Initial scoping sessions held. Working to i.d. resources for faculty time.</td>
</tr>
<tr>
<td>• Develop case management system and hire case manager to continuously engage students in events and mentoring with other STEM students, faculty, and industry professionals, and connect students with support when needed.</td>
<td>No</td>
<td>Proposals in development. Possibility for Fall 2014</td>
</tr>
<tr>
<td>Retention of all STEM Majors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Improve written communications through writing in the context of science</td>
<td>Yes</td>
<td>Initial pilot conducted. Approach redesigned based on student feedback.</td>
</tr>
<tr>
<td>• Open dialogue and engagement with diversity and social justice issues and concerns</td>
<td>Yes</td>
<td>Resources and support system for faculty created and implemented in 2013-14</td>
</tr>
<tr>
<td>• Revisions to first year biology course</td>
<td>Yes</td>
<td>Resources secured for course revisions and action research.</td>
</tr>
<tr>
<td>• Adapting and testing new instructional strategies originally identified as part of faculty members’ work in the community supporting professional development for middle school teachers</td>
<td>Yes</td>
<td>Ethnographic study in progress.</td>
</tr>
<tr>
<td>• Increase opportunities for students to engage with faculty on research</td>
<td>Yes</td>
<td>Center for Student Research established. Students participated in research competitions. Expanded offerings planned in 2014</td>
</tr>
<tr>
<td>• Increase opportunities for students to engage with faculty around the scholarship of community service</td>
<td>Yes</td>
<td>Efforts to commence in 2014</td>
</tr>
</tbody>
</table>
The diverse array of initiatives put forth by faculty members in the three high need areas demonstrates the high level of interest and desire to improve learning outcomes for our diverse student body. The variety (multiple approaches) is also consistent with beliefs that low retention and graduation rates are a result of a variety of factors and that attaining better outcomes is a complex endeavor. There is not a one size fits all solution. Faculty initiative to develop the Institute as a ‘home’ for ongoing data collection, analysis, strategic planning and support for the execution of initiatives demonstrates commitment to bringing about larger scale change.

The initiatives outlined above are all in their early stages of development, and it is too soon to know the exact effect on student development, retention and graduation. Each initiative has a research element so what is being learned and accomplished will be discoverable. With assistance from Institute staff, findings will be shared with the departments and colleges represented on the Board and across the campus more generally. Pending grant proposals will establish a case manager and case management system that will allow for more granular information about STEM majors entering in the fall of 2014. More detailed data, for example, about STEM majors and the reasons why they do/don’t persist under different conditions will be discoverable. At present, faculty and staff have access to data for cohorts of students. We cannot examine the students’ individual paths and trajectories.

The Institute has impacted the work outlined in Table 3 in numerous ways. The ideas embedded within the majority of the initiatives listed were generated by members of the Board of Advisors who used the meetings to further refine their understanding, ideas and proposals. In many instances, staff helped to gather data, identify potential funding sources, write grant proposals, consult on research designs, locate partners, and process paperwork needed to implement the initiatives. In doing these things, the Institute is fulfilling its role is of providing the infrastructure and support needed for faculty leaders as depicted earlier in this paper as part of the theory of change diagram.

**Implementation of Chosen Strategy**

While the exact approach to implementing the numerous strategies varies, in this section we will illustrate how the Institute and faculty Principal Investigators worked together on two particular strategies. Specifically, one of the earliest funded projects included a multidisciplinary group of seven faculty members from STEM, English, and the library who worked together to integrate and embed reading, writing, and information literacy strategies into courses in biology, chemistry, physics, and earth sciences. This project was funded by Programmatic Excellence and Innovation in Learning (PEIL), a campus faculty grant program currently in its second year, sponsored by the
Provost’s office. PEIL is designed to support faculty-driven change in teaching and learning. The primary objectives of the 2012-2013 project were to promote and assess critical thinking, reinforce core concepts in science, integrate high-impact teaching and learning strategies, and align assignments/activities with course, program, and institutional learning outcomes. Results from the project revealed moderate learning gains (30%) in course content and skills. Students’ perceptions of the most valuable learning strategies were the peer tutoring opportunities, in-class engagement strategies (e.g., clicker questions, white boarding, storyboarding, dissections), and on-line formative assessments (e.g., Pearson’s Mastering series).

In 2013-14 a second PEIL project was launched which aimed to improve writing in business marketing and management classes through group work and a formal peer feedback process. Three instructional models have been developed, documented, and are now being assessed. A cross case analysis will make visible the details about the models, including what they were, the demand placed on faculty who implemented them, issues encountered during implementation and lessons learned. Students’ perceptions of the benefits of each model and an analysis of student work and improvements in writing are also in progress. Once completed, the faculty members affiliated with the Institute who completed the first PEIL project can compare and contrast the approach tested previously and the approach developed in the College of Business to determine what, if anything can be applied to new models in STEM coursework.

In parallel to this work, Institute staff members have been consulting with K12 and community college partners in the East Bay STEM Network to identify innovative approaches partners are developing and testing. Staff have also been gathering data to assess the degree to which lack of preparation in English and/or mathematics may be impeding students’ success in STEM college and career pathways. In late summer or early fall of 2014, Institute staff will organize an event to enable faculty and other educators and staff to discuss what is being learned and how partners can work together to better address developmental English needs common across each segment.

Another PEIL project launched in 2013-14 by two faculty from CSUEB’s mathematics department, including the co-chair of the Institute’s Board of Directors, has focused on the redesign of the first of three courses in CSUEB’s remedial math sequence. In addition to new curriculum and teaching methods, the faculty designed a preparation program for the graduate students and/or adjunct faculty who frequently teach the course. Institute staff, partially funded by the PEIL program, have been working with the Principal Investigators to document what and how new learning opportunities are being created for students, the ways in which students engage with the new opportunities, and evidence of learning that is taking place. Principal Investigators have just been notified of funding for a second PEIL proposal for 2014-15 that would, building on efforts in the current year, complete the new design for the entire three course sequence and assess the impact on student learning. Developmental math initiatives like this one at CSUEB will also be a focus of the event that the Institute and the East Bay STEM Network will host in late summer or early fall of 2014.
**Measurement of Results**

The Institute’s staff team includes education researchers who are assisting the Board with the documentation of the Institute’s development and the development and impact of initiatives it supports across time. Methods employed include quantitative data collection and analysis as well as empirically based ethnographic research methods that allow us to discover how innovations are enacted in instructional settings, what happened with which students and under what conditions, etc. As part of some projects, such as the redesign of a remedial math course, staff has assisted the Principal Investigators in developing research questions that address not only that something was accomplished but also how it was accomplished. In other words, faculty researchers and implementers are collecting student data in order to measure success, such as pass rates. At the same time, they are surveying and interviewing sample students in order to measure shifts in attitudes toward mathematics. 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 given new conceptual and inquiry-based pedagogies. Finally, the faculty is being assisted in measuring what is made available to students and how it is made available through the collection of ethnographic field notes, interviews of Graduate Student instructors, and collection of self-reported head notes (i.e., pertinent reflections or recollections documented after the fact) compiled by these same instructors. 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.

**Dissemination and Next Steps**

Key findings surrounding the Institute’s development, the development of specific initiatives, and related research are shared through events held for the campus community. For example, last year the campus launched a Week of Research in which both faculty and students give presentations and poster sessions featuring their work and research findings. The second annual event is being held in the spring of 2014. The Institute also shares its work with the campus community through poster sessions at the annual Diversity Day. Dissemination across the East Bay is supported by events such as a quarterly leadership conference for school district partners sponsored by the Institute’s Integrated Middle School Science project. The sharing of strategies and results surrounding improvements in teaching STEM at the higher education level and in preparing STEM educators has been accomplished through the hosting of northern and southern California conferences for all CSUs and by faculty participation in webinar presentations organized in concert with the CSU Chancellor’s Office.

**Reflection**

Participation in the Keck/PKAL initiative has allowed CSU East Bay to learn about the many different ways faculty on other college and university campuses are approaching the STEM education change process. Some entities are growing new teaching methods and programmatic initiatives by starting with early adopters in a single department or college. Others are working across two or more colleges. In some instances, but not all, faculty from STEM fields and disciplines are working closely with colleagues in education working to reform STEM teacher preparation programs. One institution’s challenge to the approach to change developing at CSU
East Bay was especially helpful in clarifying our theory of change. Another Institution’s detailed data system inspired us to pursue a new system for our campus so that we can know more about decisions students are making as they pursue STEM college/career pathways. New insights gained from the ongoing interactions have contributed to an iterative design process and to the non-linear nature of our work. The constant need and desire to adjust plans and actions based on new knowledge and insights acquired makes it challenging to develop a Framework for informing the work of others. The elements depicted in version 2.4 of the Keck/PKAL STEM Education Framework are representative of the key steps we have engaged in during the past two years. However, our experiences would suggest more of a connected web between the elements as opposed to two-way arrows between selected elements. New information, experiences, funding opportunities, and shifting campus priorities have necessitated a much more dynamic process.

References


California State University Graduation Rates Consortium for Student Retention Data Exchange (CSRDE), http://www.asd.calstate.edu/csrde/index.shtml#stemi.


CSUEB Campus Institutional Data (2007-2013). Data reports run for academic years (transfer and STEM major trends - from community colleges in Alameda and Contra Costa counties).

CSUEB Campus Institutional Data (2012/2013). Data reports run for academic years (Alameda and Contra Costa County high school students enrolling in CSUEB as freshmen).


Cal State Fullerton College of Natural Sciences and Mathematics Case Study
Authors: Michael Loverude (mloverude@Exchange.FULLERTON.EDU) and Robert A. Koch (rkoch@Exchange.FULLERTON.EDU)

Campus context regarding STEM education

Cal State Fullerton and the College of Natural Sciences and Mathematics (CNSM) have a history of supporting STEM education and innovation in instruction. The most recent efforts can be traced to the Cal State Fullerton Undergraduate Reform Initiative (CSF URI) that proposed to retain greater numbers of beginning science and engineering majors, provide these students with knowledge and experience essential in the modern workplace, ensure that future teachers have the understanding, skills and attitudes necessary to promote student success, and educate a citizenry more literate in science and engineering. Two important outcomes of this project were: a) the planting of the seed of active learning in the classroom in STEM instruction and b) the hiring of discipline-based education researchers into the departments of biological science (Dr. Nancy Paleaz), chemistry & biochemistry (Dr. Barbara Gonzalez), and physics (Dr. Michael Loverude) to complement the math educators who were already members of the department of mathematics. These three individuals brought department-based science education research to the recently created Center for Excellence in Science and Mathematics Education (CESME). Over time, CESME evolved into the current Catalyst Center for Research on Teaching and Learning in Mathematics and Science (Catalyst Center), a collaboration between the colleges of natural sciences & mathematics and education. Dr. Michael Loverude is the Catalyst Center director.

The CSF URI also led biology curricular change project that addressed the major steps in adapting successful strategies to design, implement and evaluate four new core course experiences that spanned the first two years of the biology major and set the foundation for the four concentrations that followed in the upper division. Again, the two most important outcomes of this project related to active learning and hiring: a) the development and implementation of a set of four integrated active learning, inquiry-based core courses and b) the hiring of three additional biology educators to help in course creation and the professional development needed for the implementation effort. These three biologists added critical university-level educational expertise to the Catalyst Center. Three projects followed on the coattails of the CSF URI and biology curricular change efforts and shifted the focus to smoothing the transition of transfer students into STEM majors. Together these projects coordinate activities of Cal State Fullerton with five regional community colleges to smooth the transfer process by providing STEM learning communities using Supplemental Instruction, offering summer undergraduate research experiences as bridges to the transition, peer mentoring that spans the two-year-to-four-year campus transition, STEM advising and counseling, and tailored orientation programs particularly designed to address the needs of underrepresented groups.

1 NSF DUE grant (1996-99)
The creation of the Catalyst Center and the introduction of Supplemental Instruction (SI) as implemented and studied by math and science educators in the Catalyst Center led to a robust and highly successful program. SI sessions were added to several bottleneck courses in math, biology, chemistry and physics and impact all STEM majors. Data collected since the inception of the program in 2005 indicate that attending five or more SI sessions increased persistence and improved graduation rates for all participants and narrowed or, in some classes, closed the achievement gap for underrepresented minorities and women.

Despite these many efforts, there appeared to be a waning of the campus push of the late 1990’s and early 2000’s 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. 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.\(^5\)

The collection of these efforts and problems superimposed on the background of the national effort to replace the standard lecture mode of instruction in science and math classes as promoted by several influential efforts\(^6\), set the stage for the participation of Cal State Fullerton in the Keck/PKAL STEM Education Framework Project.

In summary, though there was a history of reformed instruction in CNSM, there were signs of a need for renewed attention in entry-level STEM courses. Data suggested that student success across different sections of the same course was dissimilar and that certain key courses continued to be barriers to student success. While the existing programs provided extensive support systems for student success, they were not having an impact on classroom teaching by the faculty—which research suggests is a key element in student success. The CNSM dean identified a potential solution: to train more instructors (both tenured-tenure-track faculty [TTF] and non-TTF as well as teaching associates) in the special skill sets required for the implementation of active-learning, inquiry-based instructional techniques, and assembled a team to participate in the Keck/PKAL STEM Education Framework Project. Following the initial meeting of the Framework Project, the team members discussed this conjecture and challenged its validity, proposing a rigorous study of existing practices and attitudes of CNSM faculty. This outcome led to the process and actions that compose this case study.

**Vision for improving STEM Education**

Ultimately, following several meetings with vigorous discussion of the state of active learning in the CNSM classroom, the team agreed upon an approach to addressing the issues.

The vision for the science and math education framework change project is to develop a culture in CNSM in which instructors (TTF, non-TTF and TA) use evidence-based, scientific approaches to teaching and student learning in classroom, online, and laboratory instruction in courses across

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the curriculum.

The goal is to establish a program that can be institutionalized to provide professional development for the CNSM faculty to engage in scientific teaching. The project, which seeks in the long-term to induce active change in curriculum, advisement, mentoring, special programs, and professional development, will be orchestrated by the Catalyst Center and, ultimately, sustained by support from CNSM and the University.

In the short-term, the project will begin by offering new incoming instructors professional development that is tailored to the specific needs of the science and math instructors of lower-division, upper-division and general education students. However, the research on faculty change suggests that the most successful interventions are long-term efforts that seek cultural change in an institution. A major challenge to establishing and ultimately sustaining any program of this sort is the availability of fiscal resources for creating the initial interventions and proving them to be successful. Thus, a key element of a successful implementation would involve securing internal or external funding.

Landscape and Capacity

As described in part 1, the first finding of the newly convened project team was that there was a lack of consensus on the existing state of affairs regarding scientific teaching in CNSM. While we 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. That is not unusual; for a variety of reasons the extent to which faculty practices reflect scientific teaching is not data collected by most institutions. Another potential institutional partner, the Cal State Fullerton Faculty Development Center (FDC), does offer selected professional development short courses designed to offer glimpses into the active learning classrooms. However, comprehensive data are not collected on overall faculty performance even for those who attend the workshops. Furthermore, discussions with CNSM faculty suggest that they do not view the experiences offered by the FDC as universally applicable and that most would prefer workshops that incorporate science- and math-specific exercises and approaches, including examples that apply to classroom and laboratory in lower- or upper-division as well as general education courses.

With respect to faculty and courses, institutional research could supply data that indirectly pertain to the goals we have set for this project. This work dovetails neatly with current efforts by the CSU Chancellor’s Office to improve graduation rates and progress toward degrees. Accordingly, several general education and lower-division service courses were identified as primary bottlenecks based on the percentage of students who earn less than a 2.0 grade-point-average. In addition, we have identified courses in which selected instructors have a history of significantly lower-than-average student success rates in all sections of a particular course that instructor teaches; e.g., we identified a biology instructor whose students consistently score 30% lower than the students of her peers in parallel sections of the same course. In the former case, underrepresented groups perform at lower levels than represented groups. The two data sets provide indirect evidence that actions need to be taken—these potential actions include revamping the curriculum to make course content more effectively available to students and improving
instructors’ ability to communicate effectively with students. The latter is being addressed by this project, the former by other projects.

With respect to students, institutional research has supplied data on student demographics based on their credentials upon admission—these data include both first-year and upper-division transfer students. From the bottleneck data, which the team attributes partially to the potential absence of scientific teaching, we know that underrepresented minorities tend statistically to complete the courses with lower grades than their represented peers.

The conclusion of the institutional research data analysis was that we did not have the information we needed to determine where the CNSM stood with respect to the prevalence of the use of scientifically proven teaching methods by its faculty. 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. Were faculty members already achieving our vision? So, we developed a survey that would address the questions: How do you know if your students are learning what you expect them to learn? How do you know that what you are doing in the classroom is being effective? While there are limits to what can be learned from self-reported data, we felt that these surveys would help establish an initial baseline for preliminary phases of our project. We also did not want to be perceived as evaluating faculty. As the project continues, we will consider using classroom observation protocols as formative assessment of faculty practices in order to develop a more complete description of what is happening in the classroom.

Two surveys were performed. One instrument was the “Approaches to Teaching Inventory” (ATI), a published and validated instrument that allowed us to compare CNSM faculty to the literature data. The ATI included sixteen multiple choice items constructed to define approaches that faculty use in their teaching, asking them to reflect on the purposes of their teaching and the goals they set for their classes. This survey characterizes faculty/student roles (ranging from highly faculty-centered to highly student-centered) and the nature of the content, from a strictly transmission model focusing on facts and skills to a constructivist model focusing on concepts and changing student thinking.

The second instrument was a survey adapted from the works of Henderson, developed to determine the effectiveness of the “New Physics and Astronomy Faculty Workshop” and Tanner, develop in support of her Howard Hughes Medical Institute-supported project to promote scientific teaching among biology faculty.

An initial use of the above instruments, which assessed faculty use, skills, and attitudes about

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scientific teaching, was completed with 45 responses out of 110 full-time faculty and lecturers. Of respondents, 30 stated that their department was 'supportive' or 'very supportive' of efforts to improve instruction, and only one responded that the department was 'not at all supportive.'

Faculty identified a number of barriers to adoption, but most of those barriers reflect institutional constraints: not enough time (30 responses), too much material to cover (22 responses), challenges due to class size (16 responses) or room configuration (16 responses). Only two respondents indicated skepticism of the value of these strategies, and only three cited resistance from colleagues.

Faculty expressed interest in most of the professional development strategies suggested, and on average faculty expressed interest in participating in two of the seven models. Two strategies were most popular – 19 faculty expressed interest in mini-grants, and 19 faculty expressed interest in “Opportunities to observe multiple other instructors' approaches to teaching.”

We interpreted these responses to show that faculty wanted the opportunity to be creative, have agency in adopting research-based instructional strategies, and have support from a mini-grant that allow them to pilot various approaches and gives them flexibility to adopt strategies that make sense for their particular circumstances. The desire to observe other faculty was unexpected, but makes sense in light of the research that shows university faculty to have less peer-peer interaction vis-à-vis analytical classroom observations. Also, there was interest in small group discussions, semester-long partnerships with researchers, and a multi-day summer workshop, with each garnering about ten responses.

**Issues emerging from Landscape & Capacity Analysis**

The survey responses suggested that a single professional development strategy might not be appropriate for our faculty. In retrospect, that is not surprising; the faculty we surveyed are a diverse group in terms of their disciplines, their teaching assignments, and their experience levels. A new faculty member teaching a large lecture course in introductory physics for the first time has different professional development needs from a veteran instructor who is seeking to implement problem-based learning in an upper-division biology course that she has taught many times.

Similarly, the faculty responses with respect to barriers have implications for professional development strategies. The greatest barrier identified was not at all surprising: time. We 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.

One portion of the survey data particularly relevant to the success of this project concerned the responses to questions exploring faculty stipends. Faculty members were asked to indicate which of a list of incentives would make it attractive for them to participate in the project. There was no
clear signal as to which incentive would be most effective in recruiting faculty: academic year release time (17), summer salary (16), additional pay for professional development activities (9), support in the form of a graduate assistant or grader (17), and funds to purchase teaching materials (10). Finally, a few faculty members chose funds that would be support research activities: student support (8 responses), research equipment (8), and travel funds (9). Ten faculty members indicated that no incentive would be necessary. With respect to incentives in general, it was clear that some form of incentive was desirable, but there was no clear consensus on what that incentive should be.

Overall, we predicted that we would need to provide the tools/environment for faculty to achieve this goal (and to change their behavior if necessary): 1) professional development opportunities; 2) support for trying new methods; 3) tools to assess faculty success; 4) incentive to try new approaches; 5) freedom to take the risk (which may require changes to retention, tenure and promotion criteria).

From our survey data we found that, for faculty, the primary issues were resources challenges (the first four areas) and the unpredicted area of logistical challenges (e.g., classroom configuration). We were somewhat surprised that policy challenges that might foster a greater sense of freedom to take risks were not identified as a concern of the faculty. That might reflect a consensus on the part of the faculty that the department and college are supportive of classroom innovation, which is consistent with other survey responses, but it is at least as likely that the instruments did not adequately query that issue.

The prominence of resource challenges among faculty responses further reinforced our goal to seek external funding for a pilot program that can be institutionalized if proven successful. The funded activities would include professional development, which would be led by members of the Catalyst Center with help from a qualified post-doctoral fellow, would involve training workshops, peer observation and critiquing by the members, and piloting of various evidence-driven teaching modalities. Support for trying new methods and incentives for trying new approaches would include: the awarding of mini-grants to pay for assigned time and necessary resources to test strategies in different settings, the hiring of teaching assistants, and the purchase of teaching materials; the funding for research opportunities to cover the hiring of research assistants, purchase of research equipment, and covering travel for dissemination of findings; and personal salary incentives in the form of stipends for training or piloting and summer salaries. The logistical challenges would not require additional funding, but would require controlling class sizes, expected course coverage, time per class meeting, and classroom configuration.

Strategies and readiness to implement them

Based on our analysis of faculty responses, and our survey of the research literature and the work of others, we developed a multiphase strategy to address our goals. As we developed the strategy, we sought to think broadly and identify program elements that would allow us to reach our goals without being constrained by cost.
Once we had identified program elements, it became clear that we could not accomplish most of the objectives with existing resources. There is a cadre of faculty in the various CNSM departments who are discipline-based education researchers, but our faculty tend to be very busy and many are already overcommitted. We did not want to institute programs that would increase the burden on the faculty, either those who might lead workshops or those who would participate in them. Therefore we identified a crucial additional goal: to secure external funding to support the implementation of a program to addresses the challenges outlined in previous section and provide time and resources to support faculty pursuing new strategies.

The elements of our plan were developed with an eye to the survey results. Responses indicated that a significant proportion of the present faculty are interested in participating in a program; we also anticipated that newly hired faculty would have a built-in incentive to value support in their teaching. In addition, we were cognizant of recent scholarship on the adoption of research-based instructional strategies and the reasons that faculty either do not adopt these strategies or cease to use them after an initial trial. The proposal would have two phases with the objectives as follows.

Phase 1:

- Bring to campus a series of prominent speakers to promote wider understanding of scientific teaching and the research on teaching and learning in the STEM disciplines.
- Recruit faculty to participate in on and off-campus workshops by disciplinary specialists to promote scientific teaching.
- Convene small groups of disciplinary faculty who will meet for discussions of mutual support and problem-solving regarding scientific teaching practices.
- Create and support partnerships between faculty and DBER scholars, student researchers and assistants to identify and implement appropriate instructional strategies, performing experiments in scientific teaching.

Phase 2:

- Support partnerships to identify appropriate means of assessment and document student learning.
- Create and support additional small groups and partnerships to expand the impact of Phase II activities.
- Perform a broader study of the short- and long-term impacts as we explore means of further growth and institutionalization.

Implementation of strategies

There is ample evidence that the adoption of innovations is a sociocultural phenomenon. In his influential book *Diffusion of Innovations* (5th ed. New York: Free Press. 2003), 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.

The studies on instructional innovation suggest that the following approaches are generally not successful:

- top-down approaches to change (e.g., directives from deans or department chairs);
- 'dissemination' of an innovation by its inventor to be used without modification; and
- criticisms of traditional pedagogy that can be perceived as attacks on faculty using traditional models.

On the other hand, effective change strategies are those that:

- either align with faculty beliefs or seek to change them;
- involve a long-term intervention (greater than 1 semester); and
- reflect the complexity of the university culture and context.

Several national models exist of instructional change strategies that focus on the early phases of the adoption process, helping faculty learn about new instructional strategies and view the evidence for their success. Some are broad initiatives across STEM, like Project Kaleidoscope.11

For biology faculty there is a five-day workshop organized by the Howard Hughes Medical Institute and the National Academies, the National Academies Summer Institutes on Undergraduate Education12. These workshops grew out of recommendations from the National Academies report Bio201013 and have been shown to achieve improved awareness of research-based strategies.14 Three members of the CSUF Biology department have participated in this workshop and will serve as guides in bringing the strategies they learned to the professional development program.

In physics and astronomy, professional societies (APS, AAS, and AAPT) have instituted new faculty workshops.15 New faculty are introduced to active learning strategies by experts in physics and astronomy education research and given opportunities to network with these experts as well as peers.

A key element of adoption of innovations is increasing awareness. In order to raise the visibility of scientific teaching, the Catalyst Center will host a seminar series featuring off-campus experts who can make the case for discipline-based education research and instruction. Our plan is to host four prominent national speakers each academic year, reflecting a variety of disciplines and

12 http://www.academiessummerinstitute.org
15 e.g., http://www.aapt.org/Conferences/NewFaculty/.
instructional modes.

The types of professional development activities we have identified include:

A. Faculty travel to participate in off-site professional development activities, including, but not limited to: Physics and Astronomy New Faculty Workshop, National Academies Summer Institute on Undergraduate Education, Scientific Teaching Assessment and Resources (STAR). When appropriate we would seek to send pairs or teams, e.g., a new faculty member with an experienced one.

B. Informal teaching brown bags, offered on a drop-in basis, in which faculty can discuss teaching in general, specific concerns, or research articles.

C. One-time workshops on a specific instructional approach or strategy, led by on- or off-campus experts.

D. Semester-long small groups of faculty who share a focus (e.g., introductory biology, general education astronomy, courses for pre-service teachers) and can meet in person, share a journaling experience, and potentially observe one another’s teaching in person or through video.

E. Semester-long partnerships between individual faculty and a postdoc, graduate student, and/or undergraduate student working on a specific scientific teaching project. There are now several venues for publication of peer-reviewed new curriculum—e.g., the National Center for Case Study Teaching. Producing one or more of these could be measurable outcomes—collaboratively and also involving students.

**Measurement of results**

Meaningful change requires not only dissemination of information but also accountable engagement with an innovation. Change occurs not when the information is received, but after personal experience—ongoing accountability and follow-up are essential.\(^\text{16}\) \(^\text{17}\)

Assessment activities will include a repeat administration of the original survey instruments. But, we further anticipate that professional development activities and the experimental approaches taken by individual faculty will drive the need for better means of assessing student learning. Therefore, we will seek 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 is working to

prepare a manuscript for a scholarly journal to document their results and the process of professional development. While we cannot anticipate that all interventions will be this successful, the model of a small team of faculty driving scientific improvement of a specific course or unit is one that we will seek to replicate.

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 we perform 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.

 Plans for dissemination and next steps

Our next steps are as follows:

- 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, and
- continue to seek external funding.

It would be premature to disseminate results at this point, but we are hopeful that our project will offer some insights that are unique in the published literature; we are seeking to institute scientific teaching across an entire college and have collected data from five different academic departments. When appropriate, we hope to publish research results in scholarly journals.

 Reflection on the process

A team of four attended the first Keck/PKAL meeting: project lead and acting dean Robert Koch, assistant vice president for institutional research Ed Sullivan, and faculty Bill Hoese (Biological Science) and Michael Loverude (Physics). After this initial meeting, the team was expanded to include four more instructional faculty: Sean Walker (Biological Science), Jeff Knott (Geological Sciences), Phil Janowicz (Chemistry and Biochemistry), and Scott Annin (Mathematics).

The greatest challenge was developing a shared vision. The first Keck/ PKAL meeting focused a great deal on process, and the primary task that was set before us was to craft a vision statement. The project leaders seemed to assume that the campus teams arrived with a goal in mind and were simply in need of a structure that would help them to accomplish that goal. However, it seemed that some teams were struggling to articulate what it was that they hoped to do. For our campus team, the vision statement that was articulated was quite broad—broad enough that it required the participation of additional faculty who had not been part of the Keck/PKAL workshop (one from
each department in the College of NSM). When this larger group convened, we struggled for quite some time over what it was that the project intended to accomplish. The group had vigorous discussions and the initial assumptions that drove our very participation in the project were challenged. We did not agree, for example, on how prevalent scientific teaching was among the current faculty, and on the extent to which different groups would be willing to participate in professional development. Within the team, there was concern about the time demands of this project, and the sense that it might turn out to be yet another unfunded service project. One member of the team is untenured, and the team (quite rightly) expressed concern on his behalf about whether there would be any deliverables that could be included in a potential tenure packet.

While we were struggling with this level of question, it was not useful to us to follow the guidelines and process that the project put forth; we were not ready to develop a graphical representation of our project until we knew exactly what it was we intended to do. We felt that it was not useful to be provided with rubrics before we had anything that we could use them to evaluate. It would be useful to have this information later, but we had first to come to some consensus on our goals and the existing state of affairs on our campus.

The challenging of assumptions that characterized our earlier meetings seemed at times to be contentious and not productive. In part it reminded us that judgments of teaching quality have high emotional stakes for faculty, particularly those at a comprehensive university where teaching is a significant portion of faculty workloads. Claims about the prevalence of reformed instruction among senior faculty, for example, were perceived as criticism or even attacks. While the initial contention led to some uncomfortable meetings, these discussions turned out to be a very useful part of our process, and the challenging of initial assumptions led us to what might well be the most fruitful part of the work thus far. As noted above, the questions posed by faculty and the lack of consensus on their answers clearly demonstrated the need for the team to do some homework.

The homework that was required of us involved looking outward as well as inward. As we argued over core assumptions, faculty brought in examples from published work. It was at this time, for example, that we adopted the terms ‘scientific teaching’\textsuperscript{18} and ‘research-based instructional strategies’\textsuperscript{19}. Thus our process sent us toward the published literature on faculty adoption of scientific teaching processes, and faculty attitudes toward teaching. From that reading and the prior experiences of several team members, we were able to articulate our goal more concretely and move on to the next phase. We also recognized at this point the magnitude of the task that we had adopted, and decided that we would need additional resources, so should prepare a grant proposal. The idea that we would be preparing a grant dovetailed with our planned study; a proposal would be strengthened by data and the data would better inform the project planning team in developing appropriate strategies. Thus, we developed a study to collect data on the current practices of faculty in the College of NSM, their attitudes toward teaching, and their interest in participating in professional development. For each aspect of the study, we adapted and adopted

survey instruments published by others.

A final challenge that is worth noting is the fact that our process led us to articulate goals that were not reachable using purely internal resources. Some initial pilot projects have been successful, but we are at a point where we would need additional funding to expand our efforts. However, the competition is fierce and our pursuit of external funding for this project has thus far been unsuccessful. As a result, our project has lost some momentum just at the point when we feel that we have learned something. The core team members remain committed, and we are exploring every option at this point, but there is a serious danger that without funding the project will eventually dissolve until a new champion is ready to take up the cause.
1. Campus Context

The W.M. Keck Science Department was founded as a “bold experiment and an innovative and multidisciplinary program in the natural sciences” by Claremont McKenna (CMC), Pitzer, and Scripps Colleges (collectively “the 3C’s”) in 1964. The Department, administered cooperatively by the three colleges, was established as a shared resource for science students to provide comprehensive, interdisciplinary instruction in small class settings and numerous opportunities to conduct research.

The three Keck Science colleges are all members of The Claremont Colleges, a consortium of five undergraduate liberal arts colleges (Harvey Mudd and Pomona Colleges, in addition to the 3C’s) and two graduate institutions (Claremont Graduate University and Keck Graduate Institute)—see Figure 1 for a schematic representation. Our faculty is tenured at each of the 3C’s. Although the mission of each of our host colleges is distinct, all promote the teacher-scholar model, in which faculty maintain active research programs and develop and teach creative courses.

The Claremont Colleges

5 independent, undergraduate institutions
2 graduate institutions
7 Presidents
7 Boards of Trustees

- Claremont McKenna
- Pitzer
- Scripps
- Pomona
- Harvey Mudd
- Claremont Graduate University
- Keck Graduate Institute

Figure 1. The W.M. Keck Science Department is hosted by three of the five undergraduate Claremont Colleges that are part of the Claremont Colleges Consortium.

The department offers more than a dozen discrete degree options, including dual-degree
programs in partnership with outside schools of engineering and majors in conjunction with disciplines beyond the sciences. Along with courses in biology, chemistry, environmental science, neuroscience, and physics, Keck Science faculty also offers innovative, interdisciplinary classes designed for incoming first-year students that integrate biology, chemistry, and physics (the “Accelerated Integrated Science Sequence”) as well as just biology and chemistry (“Introduction to Biological Chemistry”).

Departmental enrollment has increased appreciably since its early days, due to expanded facilities in the mid 1990’s and, more recently, because of increased interest in science as a major at CMC, Pitzer, and Scripps. As shown in Figure 2, in the early 1990’s about 40 majors per year graduated from the three Keck Science colleges. By the early-2000’s that number had increased to approximately 100 science graduates annually, and in two of the past three years, over 150 science majors graduated from the 3C’s. In addition to science courses for our majors, the department currently offers general education and other non-major science courses to over 5000 students throughout the consortium.

![Keck Science Department Graduating Majors 1992–2014](image)

Figure 2. The W.M. Keck Science Department has graduated increasing numbers of science majors over the past 20 years.

Increasing student engagement within Keck Science has led the 3C presidents to examine the long-term needs of the department. In addition to supporting the hire of additional faculty to address enrollment pressures, the presidents have focused upon strengthening the underlying academic environment for student success through coordinated leadership. As a result, CMC, Pitzer, and Scripps have jointly created the position of Dean of Keck Science, and since 2009 David E. Hansen has served as the inaugural dean. Dean Hansen reports to all three presidents and functions as an administrator at each of the three colleges. Through monthly meetings with the 3C presidents and academic deans, he is able to foster communication and advocate for the Department at a senior, administrative level. Dean Hansen’s role is unusual, as department heads at liberal arts colleges typically do not have regular access to senior administrators. His leadership within the 3C organizational structure has provided numerous opportunities for productive agreement on major issues, and the shared decision-making process has served to strengthen the science education mission of the host colleges.

In 2011 the five undergraduate Claremont Colleges had the opportunity to develop a shared retention program when Keck Science, Harvey Mudd College, and Pomona College jointly
submitted a proposal to the Howard Hughes Medical Institute (HHMI) 2012 Undergraduate Science Education Program; this joint proposal was subsequently funded. In considering the exceptional resources the consortium can offer as a whole, community building has been identified as a key component to retaining STEM students. Enhancing the 5C community for underrepresented groups is thus a key component of the proposal. Also central to supporting a diverse range of students are summer bridge programs, and the funding from HHMI allowed Keck Science to launch a one-week Summer Science Immersion Program (SScIP) in August 2013 for incoming first-year students from all three Keck Science colleges (the program was successfully again implemented in August 2014).

Our Framework team works under the leadership of Dean Hansen and includes Director of Sponsored Research Bidushi Bhattacharya and Professor of Chemistry Mary Hatcher-Skeers. Because Dean Hansen is also a professor of chemistry, he has represented faculty as well as administrative interests in the Framework project. Professor Hatcher-Skeers serves as academic coordinator for the Scripps College Academy (http://academy.scrippscollege.edu/), and she has brought her expertise working with young women in science to the project. At Keck Science, a number of our instructors have historically engaged underrepresented students at both the pre-college and college levels, and we have also been able to tap them as a resource for the Framework effort.

The Keck/PKAL Framework has played a critical role in creating the inaugural SScIP. In this case study, we present the planning, development, and implementation—as well as the initial outcome and dissemination effort—of the August 2013 SScIP in the context of the Framework.

2. Vision

The principal goal of the Keck/PKAL-HHMI project is to prepare undergraduates to become leaders in science research and medicine. Using the HHMI award, we are developing academic support programs for incoming students, creating new courses and laboratory modules, offering summer student research fellowships, engaging in K–12 outreach, and building a peer community across the 5Cs for students that are traditionally underrepresented in science.

The Keck Science Department is committed to fostering success in STEM students from all socioeconomic environments. The department assumes students will rise to clearly articulated, high expectations when given proper support, and we aim to provide the best outcome for every individual admitted to our host colleges. We envision a thriving peer community that will ensure success through academic and social support for students of every background.

3. Landscape and Capacity

To establish a context within which we can assess and propagate the success of our SScIP, we have studied institutional structure and looked at areas for long-term focus. We have identified in-house expertise to support our goals, have considered our approach to gathering student data, and have examined stakeholders’ awareness of Keck Science curricular and research activity.

To better understand the needs of our students, we have carried out a retention study of student success and persistence in Keck Science. This study, which provides a context for the Framework, has involved requests to CMC, Pitzer, and Scripps for demographic, financial aid, test score, and academic data for all 5,363 matriculating students from 2005–2010 at each college. This comprehensive study database of 200,000 cells provides statistically significant information on
students’ preparation for, and performance in, the science curriculum—moreover, the database provides a baseline to assess the effectiveness of new programs introduced to support students at risk in the sciences.

Data from the department’s retention study immediately pertinent to this issue are as follows: one, a higher percentage of students on need-based financial aid (19%) actually major in science as compared with students not on aid (15%); two, 13% of incoming Caucasian students major in a science as do 13% of incoming African-American and Hispanic/Latino students; and three, the math SAT is a good predictor of success in introductory chemistry (16.8% of the variance in grade in the first semester, 19.6% in the second) but far less so in introductory biology.

Introductory chemistry serves as a gateway course for many of our biological and chemical sciences majors, and we have been concerned that poor performance in this class may lead students to leave STEM majors. Although our students have had highly successful academic careers before attending Claremont, with many valedictorians in the group, some may not be accustomed to the rigors of college. As we have found a correlation between SAT score and performance in introductory chemistry, we opted to develop the Summer Science Immersion Program to prepare students for the expectations and rigors of college-level science courses while building community to encourage their interaction with peer science students at the Claremont Colleges.

4. Challenges and Opportunities

Our institutional research data were obtained from registrar’s and admissions offices at each of our colleges and synthesized by CMC’s Office of Institutional Research. Dr. Bhattacharya is the internal Keck IR data coordinator and interacts with the 3C alumni and IR offices to ensure student data is up to date. Because our students are drawn from three separate colleges, gathering data is a complex process that involves coordination among our three campus offices, each of which provides data in a slightly different format. Keck Science then plays a central role in analyzing the compiled data, and Dr. Bhattacharya regularly manages and updates data on current students and alumni. Our faculty is also working to track students who drop a course during the period when the 3C registrars have not begun to record such information (i.e., the period during which students may drop a course “without penalty”), as we believe it is important to identify student motivation for dropping a course and to support those who de-enroll due to self-perceived performance issues. It could also be instructive to track subsequent science course enrollments for these individuals.

5. Strategies

Gathering 3C data on incoming students has enabled Keck Science to identify areas of focus for the Summer Science Immersion Program. The success of our interdisciplinary courses and active research engagement has also contributed to our decision to offer the program as a study of “The Chemistry of Life,” which has the added advantage of drawing in faculty participants from across the disciplines within the department.

Keck Science resolved to ensure success of the SScIP using a multi-fold approach. In addition looking at models on other campuses and drawing on departmental experience with STEM recruitment and retention programs, we identified a team of experienced instructors to teach in the 2013 SScIP. A number of successful science immersion programs have been implemented throughout the country, such as the LSU Biology Intensive Orientation for Students (BIOS) program. BIOS provides incoming students with an immersion experience to introduce the expectations of college-level academics. The philosophy is acculturation, not remediation. The
LSU program has been thoroughly evaluated and found to be effective in increasing the success of students in its biology curriculum and their retention in the major (Wischusen and Wischusen, *CBE Life Sci. Educ.* 2007, 6, 172–178; Wischusen et al., *J. Coll. Stud. Ret.* 2010–2011, 12, 429–441).

Keck Science has highly qualified and committed faculty and staff to support the SScIP. Our host institutions have been enormously supportive of STEM retention in principle and in action. In the initial stages, the 3C’s provided institutional research data. When the HHMI grant was awarded, the 5C’s coordinated a media release to publicize the award. The Presidents are engaged and informed of progress in Keck Science’s STEM retention program. Furthermore, the August 2013 program was run by full-time faculty and staff, not by individuals hired solely for the project.

The SScIP has been constructed to introduce participants to cutting-edge science and to the expectations and demands of college-level science coursework. Students attended interactive seminars, went on educationally-themed field trips, and performed hands-on laboratory experiments on topics including the structure and function of biomolecules, such as nucleic acids and proteins, and exoplanets, planets in solar systems outside our own. As a final project, the students analyzed the genome and proteome of the bacterium *Tetrahymena thermophila* and had the opportunity to contribute their research results to an international database.

A key question in planning any pre-college summer program is deciding which students to invite. The retention study described in Section 3 had indicated that there is no one group of students uniquely at risk in Keck Science, and thus the program was broadly targeted to students who are in the first generation in their family to attend college; who are from underrepresented groups in science, including women; and/or who attended under-resourced high schools. (To ensure that every eligible student was aware of the SScIP, all incoming first-years were informed of the program.)

During the planning process, we used the Framework to map out the stakeholders who are critical to the success of the SScIP. We noted that the immersion program would provide many students with their first experience living away from home, and we realized that asking these students to arrive one week early for the SScIP could mean sacrificing time with family or time away from paid employment, or both. Consequently, we determined that parental involvement and buy in were important factors, not only for student support and success, but also for perceived success of the overall program, and on the first evening of the program, we held a welcoming dinner to which all family members of the incoming SScIP students were invited.

Keck Science faculty and staff with expertise in biology, chemistry, and astronomy led the program. The instructors included Bidushi Bhattacharya; David Hansen; Mary Hatcher-Skeers; Tom Davis, Lab Lecturer in General Chemistry; Elise Ferree, Professorial Lecturer; Gretchen Stanton, Visiting Assistant Professor of Chemistry; and Emily Wiley, Associate Professor of Biology. The SScIP students participated in field trips, including an evening at the Pomona observatory, led by Bryan Penprase, Frank E. Brackett Professor of Astronomy, and a visit to California State University Los Angeles to learn about race in science culture led by Patrick Sharp, Professor and Chair of Liberal Studies. Jennifer Arias, Scripps ’16; Devyn Parks, Scripps ’15; Freddy Valencia, Pitzer ’14; and Austin Wu, CMC ’16 served as the peer mentors.

In Fall 2011, the department examined the media coverage it receives from the 3C’s and realized that while each college has its own Office of Communication and Public Affairs, none of the offices had a focus on Keck Science, in all likelihood because they each assumed the other colleges were connecting with us to report on curricular and research activity of our faculty, student, and staff. Engaging our stakeholders is critical to continued success of our STEM students from all backgrounds. Publicizing course and research activity to prospective and current students and parents, alumni, the 3C deans, presidents, and boards of trustees, and the general public has
helped bring positive attention to the commitment of our faculty and success of our STEM students. Our joint HHMI award, for example, is a high-priority project for the presidents and academic deans at all three Keck Science colleges. To augment the regular updates Dean Hansen provides them, we decided to reach out to our additional stakeholders through a news release on the SScIP that was posted to our website and shared with the media and communication offices for our host institutions.

Dr. Bhattacharya serves as the inaugural science liaison for Keck Science, and in that capacity she updates the department’s website to include current activity, including a landing page notification, with a detailed, linked feature, about the SScIP. Additional projects have included student interviews, videos of our senior thesis poster sessions, and a departmental video that features the full range of curricular offerings and highlights students from all three Keck Science colleges, including participants in the August 2013 SScIP.

6. Readiness

Keck Science has a history of seeking grant support for innovative STEM programs. Our Accelerated Integrated Science Sequence (noted earlier), piloted through an NSF award and currently funded by the S.D. Bechtel, Jr. Foundation, offers first-year students multidisciplinary module-based instruction that integrates biology, chemistry, and physics and that is taught by faculty in all three fields. Rather than teaching each discipline in parallel, the faculty works together to look at the biological, chemical, and physics aspects of a scientific phenomenon, such as the movement of muscle tissue. This two-semester course covers a comparable amount of material as our separate year-long introductory biology, chemistry, and physics courses. Other classes include a biology course taught by Professor Emily Wiley, who has also served as an SScIP instructor. Her students sequence genes as part of their coursework and actively contribute their results to a database (suprdb.org and Wiley and Stover, CBE Life Sci. Educ. 2014, 13, 131–138). Though the Tetrahymena thermophila database project, Professor Wiley has introduced this project to SScIP students, who have responded with overwhelming enthusiasm.

Beyond the department, Keck Science also has had experience with 5C collaborative STEM initiatives through an NSF-funded program entitled “Research Experience at the Biological-Mathematical Interface,” led by John Milton, the William R. Kenan Jr. Professor of Computational Neuroscience. The focus of this program has been the preparation of undergraduate students for work in teams at the intersection of biology and mathematics, an interdisciplinary approach that has been applied to projects for students in the SScIP.

7. Implementation

In August 2013 the W.M. Keck Science Department admitted the inaugural class of the SScIP. All incoming CMC, Pitzer, and Scripps students were invited to apply, and 38 incoming first-year students participated. In the coming years, we plan to have a comparable number of participants.

The group of students participated in week-long program while living in a residence hall on the Pitzer campus and having their meals in the CMC dining hall. This multi-campus use of facilities was intended to give the students a sense of the truly consortial nature of the department and The Claremont Colleges.

Students learned about “The Chemistry of Life” through a module-based approach through hands-on laboratory work, computer exercises, and field trips. The first day of programming introduced students to the introductory chemistry lab. In addition to training in laboratory safety,
students performed two experiments and focused on good laboratory technique and accurate data recording. Students were able to build upon this knowledge later in the week when they assembled models of biomolecules, ultimately creating a polypeptide chain. The concept of water and life on Planet Earth was extended to the search for life in the solar system and on exoplanets, with telescope viewings of Saturn and other celestial objects at the Pomona College Brackett Observatory as well as a visit to the Griffith Observatory in Los Angeles.

Throughout the week, students learned about science as a discipline, as well as science as a culture. The SScIP students established peer networks and learned about the importance of collaborative work. They travelled to California State University Los Angeles to engage in a dynamic discussion on common portrayals and expectations of scientists in the context of gender and race.

8. Results

During each year, as well as upon completion, of the four-year HHMI award period, the effect of the 5C community for underrepresented groups in science will be assessed formally by Professor David Drew, Joseph B. Platt Chair at the School of Educational Studies, Claremont Graduate University. Professor Drew, whose research group focuses on the use of quantitative research methods, statistical analysis, and model building, is a nationally recognized expert on the improvement of STEM education and closing the STEM achievement gap. Dr. Drew will also work directly with the 5C Office of Black Student Affairs and Chicano/Latino Student Affairs to assess the effectiveness of our efforts to enhance the 5C peer community for underrepresented STEM students. Dianna Graves, Director of Academic Planning at CMC, is assessing the SScIP, and will track the participating students through their four years of college. To supplement the formal assessment of the SScIP, we plan to offer an informal questionnaire to students each year. A survey of the class after the August 2013 program yielded comments such as the following:

- Ahsha Earwood, Pitzer ’17, student participant: “I haven't been stressed out with the amount of work I have received... because I made such great connections, not only with my peers, but with my student mentors and professors.”
- Marzia Zendali, Scripps ’17, student participant: “After my first day in lab, I felt well prepared since I already knew how to use the equipment.... I even helped other students at my table who did not know the techniques! And, I used my lab notebook like a pro!”
- Austin Wu, CMC ’16, student mentor: “The SScIP was not only a fantastic learning experience for the students of the program, (but) as a student-mentor, I was able to experience the science learning process from the perspective of the instructor. Through the program I developed a greater appreciation for the professor’s ability to ‘translate’ such complex scientific phenomena into simple yet accurate terms for students to comprehend and understand.”

9. Plans for dissemination and next steps

The 2013 SScIP has been publicized on the department’s website (www.kecksci.claremont.edu). In addition, the SScIP has been featured in a Keck Science Department video (http://www.kecksci.claremont.edu/News/Keck%20Edit%20Final.mov) on student-faculty engagement and research. As we continue the SScIP in 2014, we will continue to track students and to monitor their success and persistence in STEM courses. We anticipate publishing results in an educational journal at the close of the HHMI SScIP project.

10. Reflections
Based on feedback from SScIP students, we believe Keck Science is fully on track to enhance STEM persistence, particularly for students who are underrepresented in science. Our communication efforts through website and videos have been well-received by students and outside stakeholders, and we note that administrators, as well as non-science faculty, are thinking about STEM student success, with the realization that Keck Science is here to support science students, not “grind them down.” As we continue to build science communities, five of last year’s SScIP participants will serve as student mentors for the 2014 SScIP.

We have found the Framework to be an effective tool for clarifying our methods and goals. It has been useful for revisiting the SScIP in preparation for future years.

Figure 3. SScIP student mentor Jen Arias, Scripps ’16, points at the sky alongside a statue of Albert Einstein at the Griffith Observatory in Los Angeles.
Figure 4. SScIP students and Professor Gretchen Stanton pose with a model of a polypeptide chain constructed as a group project.
University of La Verne Case Study

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1. Campus context

University of La Verne (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, one of the primary and shared pedagogical methods to promote life-long learning has been to emphasize experiential techniques and problem solving through a required capstone research project. The capstone provides every student with the opportunity to work one on one with a faculty mentor/advisor to address a contemporary research question. Students found these projects were extremely beneficial in helping them prepare for graduate studies and industry. However, in the early-mid 2000’s the Biology faculty recognized that only 25% of its students were graduating on-time (within four years) and many students left the university without ever completing their thesis; the capstone project had become a barrier to graduation. Prior to 2006, institutional research had significant problems with tracking students. There was no data available for time to graduation for first generation students and many students chose to decline to answer demography data such as ethnicity. Therefore, the extent to which the problem affected populations of our students was difficult to track.

Data management improved between 2006 and 2010 (Figure 1). Although the average time to completion was 5 years, data show variability by group. The first generation data was the most concerning with the average of 6.1 years versus 4.6 years for non-first generation students. As a HSI with greater than 50% first generation students, our pedagogies need to reflect our student body needs.

![La Verne Time to Graduation by Group](image-url)
In 2007, in an effort to help students overcome the capstone barrier, the department began implementing a series of high impact practices (HIPs) through courses in the junior and senior year that would teach the inquiry and writing skills needed to complete the capstone. Cell Biology, Developmental Biology, Human Physiology and Molecular Biology were adapted to emphasize modern techniques of research. In addition, inquiry-based laboratory learning modules were developed that provided undergraduates at La Verne with opportunities to design, conduct, analyze, and present outcomes of experiments. A four course learning community for juniors and seniors (Research Methods, Biostatistics, and two semesters of Senior Seminar) were also redesigned to introduce the methodology of science, which focused on the development of skills in planning and conducting experiments, analyzing data, and writing up results, all with the aid of faculty as well as a peer cohort.

From 2008 through 2011, the Biology department saw a dramatic increase in on-time completion (Figure 2), showing that the strategies were succeeding. At the time, the department was graduating 10 to 20 students per year. Though this was a significant improvement, efforts to improve the program by like-minded faculty were not yet coordinated effectively. These parallel tracks intersected in 2011 after four faculty, one in 2010 and three in 2011, attended the PKAL summer leadership institute. The institute provided the Biology faculty with the common terminology and guidance needed to communicate and join our efforts together.

Biology also saw new challenges with a rapid rise in incoming freshman; Fall 2009 to Fall 2010 the number of entering freshman went from 20 to 38 and in Fall 2011, nearly doubled again to 67. After successes in our initial efforts, we expanded our focus to the needs of the ballooning freshman class. We realized that although our on time completion rates were up, our retention was low, especially in the first two years. In addition, faculty teaching upper division courses felt that the freshmen were underprepared, both in content and skills; student feedback on course
evaluations supported faculty impressions. Our main challenge was that the Biology department didn’t have a unified set of learning outcomes for students or a framework to assess their learning. The department was a collective of passionate faculty without a shared vision and several 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 framework and goals that were supported by our new campus leaders, President and CAS Dean, as well as the structure needed to help faculty leaders institutionalize departmental change. The team for the KECK/PKAL project began with Dr. Jonathan Reed, the CAS Dean, Dr. Felicia Beardsley, CAS Associate Dean, and Dr. Kat Weaver, a faculty member who had participated in the redesign of the junior and senior series. Dr. Christine Broussard was added to the team when Dr. Weaver went on sabbatical, and the Biology department was consulted through a series of meetings and retreats. After a change in leadership at the university level, the team became Kat Weaver, Assistant Dean of CAS, and Christine Broussard, chair of the Natural Science Division and Professor of Biology.

2. Vision for improving STEM education

The desire to improve STEM education at the University of La Verne came from the mission of the institution to serve the community, in this case the local, regional, and global communities. And given the national dialogue regarding the increased need for diverse STEM graduates, we were well-positioned to contribute to fulfilling the need and to share our strategies to help other institutions improve as well. La Verne has been recognized as an exemplar in Latina/o STEM education. Even with our accomplishments, we felt more could be done to further the success of our students.

To increase success in the capstone, faculty gravitated toward science process skills (research methods) and writing as two primary areas of development the department should enrich in 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 earlier in the curriculum, beginning in the freshman year. Our goal for the project was to properly scaffold these skills to improve retention (to 70% after one year and at least 60% after two years) 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 curriculum in the freshman biology series.

3. Landscape and capacity

In 2011, at the beginning of the framework project, the biology department identified growth and retention as our major challenges. From 2006 to 2011, our department grew from 28 to 81
incoming biology majors (Figure 3). This growth was connected to a number of factors including an increase in recruitment efforts as well as state funding issues within the UC and California State Universities. We hired a 7th faculty member in 2011, but the department continued to rely on adjuncts to teach majors and non-majors courses, including some freshman courses. From 2006 to 2008, retention rates in the department for freshman to sophomore and sophomore to junior years were low (Figure 3); we retained just over 40% of our students after one year and 25-40% of our students after two years. At the time, the freshman series consisted of three courses – Principles of Biology, Plant Biology, and Animal Biology. Based on information from senior exit surveys, one on one interviews with the department chair, and other conversations with students, faculty learned that students thought that the three semester-long courses were too time-consuming. If students decided to come to Biology in their second semester or if they transferred in from a community college without a biology course, they were unable to complete the degree in less than four years from the transfer point.

At La Verne, community buy-in and agreement is extremely important. We debated solutions for these student complaints. Many faculty felt that the Principles of Biology course was too important to our students’ foundation to remove it, others wanted to beef up the Plant and Animal Biology courses (increase them from 4 to 5 units) and include more concepts from the Principles course. Although we were not united in the decision, because of workload issues, increasing freshman class size, and student complaints, the faculty decided to remove the Principles of Biology course. However, it did not improve our retention rates and complaints actually increased. Students that completed only Plant and Animal Biology felt that the courses did not prepare them for their upper division courses; essentially the overview of all of biology that the Principles of Biology course offered was necessary for the next level.

“For a sophomore, previous courses are Animal and Plant Biology only.” “…nor did plant or animal biology prepare me”

The following year, the faculty decided to require underprepared students (those that did not test into College Algebra or higher on entrance exams) to take Principles of Biology and allowed prepared students the option to take the course to review foundational concepts. Prepared students
could take either Plant Biology or Animal Biology in their first semester, as these courses were offered both fall and spring semesters.

In 2009 and 2010, we saw an increase in retention numbers as the number of entering freshman was increasing. This increase in retention seemed to be due to the requirement of Principles of Biology for students that required math remediation, which provided them with the foundation to proceed in the major. However, we also felt that we hadn’t addressed the original issue, which was preparedness for the upper division biology courses for all students. Principles of Biology was a successful course because it offered students a background to all concentration areas within the major. Students that only took plant and animal biology, because they tested into College Algebra or higher, missed that foundation course.

In 2010, several faculty read the AAAS publication Vision and Change in Undergraduate Biology Education: A Call to Action. This publication confirmed the need to have department level discussions around learning outcomes in biology. Several faculty, including our department chair, attended leadership conferences, learned about new pedagogies, and realized the importance of tying assessments to learning outcomes within courses and the department, and using this data to follow through on evidence based decision-making.

At the same time, the College of Arts and Sciences hired a new Dean with ties to AAC&U, who was willing to bring people to campus, help faculty apply for grants, and send faculty to conferences to learn more about science pedagogy. In addition, a new president in 2011 was able to work with the CAS Dean to scaffold high impact practices into a shared La Verne Experience – including the start of a freshman learning community (FLEX) and a shared learning experience (one book, one university) (Appendix 1). All departments in the university were requested to offer a FLEX course, tied with another department and taught by full time faculty. FLEX pairs were also connected with a writing class, which provided students an opportunity to reflect on their learning within the community. For the biology department, we identified Plant Biology and General Chemistry 1 as the FLEX pair for all incoming biology majors (Appendix 1). Students would then move to Animal Biology and General Chemistry 2 in the spring semester, preserving the cohort. In the fall 2012, we were up to 103 incoming freshman. With the FLEX course, we were able to maintain 60% retention after one year.

4. Identify and analyze issues emerging from Landscape and Capacity Analysis

The leadership change, knowledge gained from conferences and publications, and common language from the La Verne Experience and KECK/PKAL framework gave the biology department an opportunity to focus on improving retention and continue with our practices that improved our graduation rates, all while seeing continually increasing freshman class sizes.

Initial attempts to improve retention in the freshman year (in 2008) did more harm than good. It was important to the process to gain community buy-in. A major change to the freshman curriculum and departmental learning outcomes cannot 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 framework 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, and this process required us to look at the data as well as national trends in pedagogy before making decisions to move forward. 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 because they are under-prepared. In addition, because many of the faculty pushing for change were junior faculty, an outside expert provided context to our campus issues and potential pathways to change.

5. and 7. Choose/Implement Strategies

Figure 4. Strategies adopted by the Biology Department within the framework process

![Diagram of strategies](image)

This part of the framework process was iterative for our group because our strategies had to be done consecutively. Our goals were to capitalize on institution level changes and the La Verne Experience platform to increase retention to 70% after one year and at least 60% after two years. Because we wanted to have community buy in within 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. We chose a strategy, implemented, evaluated more data and then moved forward. In this way, our own process was cyclical.

Our first strategy was to utilize administrative support and changes happening at the university level to facilitate change at the department level. The biology department, with the support of the CAS dean, had sent four faculty to the PKAL leadership institute. Those faculty began to mentor
newer faculty, going together to the AAC&U/PKAL STEM meeting and participating in a post conference session on institutional change. In addition, we decided as a department to participate in the FLEX initiative (Appendix 1). As a university, the FLEX courses were required to be covered by full time faculty and planning sessions were held to support the connection of content between FLEX courses.

Our second strategy was to gain faculty buy-in for change at the freshman level. We held a two-day departmental retreat led by Dr. Susan Elrod, an external facilitator, 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 freshman level learning outcomes, which would later be the foundation of further change, strategy 3 – a new general biology series.

In preparation for the department retreat, faculty read the AAAS Vision and Change Report and the AAMC-HHMI Scientific Foundations for Future Physicians. These two reports provided a set of program-level learning outcomes to draw from and a national perspective on curriculum change. For the retreat, our focus was to: 1. Examine data, 2. Refine the department's mission and vision, 3. Discuss program learning outcomes, in particular for the introductory course series, 4. Define introductory course series elements and assessments, and 5. Decide on next steps and create a plan for action through the academic year. The CAS Dean also encouraged us to clarify and simplify the learning outcomes before revising the curricular map, coordinate the learning goals with the campus-wide discussion on Baccalaureate Goals, and align our freshman series with the FLEX program and address the high DFW rates as well as high attrition from Freshman to Senior year.

At the outset, we did not have departmental learning outcomes for our students, at any level. The retreat provided us with the opportunity to work together to review Vision and Change and develop our own learning outcomes. We developed learning outcomes for each of the following seven freshman level learning areas:

1. Scientific inquiry, its power and limitations.
2. The diversity of life as a product of continuing evolution.
3. Structure and function from the molecular to the organismal level.
4. The pathways and transformations of energy in biological systems.
5. Living systems are interconnected and interacting.
6. The relationship between science and society.
7. Information flow, exchange, expression and storage in biological systems.

We 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 La Verne. Faculty teaching Plant and Animal Biology assessed whether those 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 other four-year private and public institutions. Faculty also examined the graduate prerequisites from MD, DO, PA, and graduate institutions as well as new MCAT guidelines to compare student needs.
Because we needed time to develop a new curriculum for the freshman series, we utilized our existing courses within the FLEX framework (Appendix 1). We then examined the retention data from fall to spring (74%) and fall to fall (60%) in order to evaluate its effectiveness.

Our third strategy was to implement curricular changes in the freshman series, FLEX 2nd edition (Appendix 1). In fall 2013, the department, with encouragement from the Dean, decided to change the freshman series from Plant Biology and Animal Biology to General Biology 1 and 2. The goal for the course sequence was to start broad with larger scale content areas that students were more able to relate with, and then to narrow in on more specific topics (macro → micro). In the second semester, we would then require students to apply the micro concepts into the context of other macro (micro → macro).

To achieve this content structure, we divided the general biology series into six sections: 1. Ecology/Evolution, 2. Animal Diversity, 3. Systems/Anatomy/Cell, 4. Cell Communication/Microbiology, 5. Plant Diversity, and 6. Evolution/Population Genetics/Ecology. Each section would be taught by a different faculty member whose expertise was in the field. This would allow students the opportunity to interact with several faculty from their major and to learn from a subject expert. For faculty, it spread the load of teaching in the freshman year across multiple people. Each faculty taught two lectures and four labs for five weeks, providing ten weeks to focus on research with upper division students.

The department chair held several summer planning sessions for faculty involved within the first course, General Biology 1. As a group, they planned the structure and decided on signature assignments for the course. The challenge was that when someone missed a planning session, it left the group feeling like they had a void to fill.

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 high impact practices at this early and formative stage. As part of a FLEX sequence, General Biology 1 partook in the one book, one university program. This provided a theme of global climate change to unify the three units of the first semester class. Within each of the three units, this theme was carried out through the reading of a primary research article, writing and peer critiquing, and presenting an original research grant through power point. For example, in the first unit, students read a paper about the ecology of spatial and temporal mismatch between butterfly species and their host plant due to climate change. Students wrote a paper discussing the article,
were given in class time for peer critiques of their papers, and finally participated in a class
discussion of the topic. For their research grant, students were introduced to grant writing and then
proposed an original research project related to the unit, which they presented with power point.

The addition of these assignments fulfilled several of our goals. Exposing students to critical
thinking, science literacy, and communicating their science in written and verbal form at the
freshmen level develops these skills early on and prepares them as the rigor increases in subsequent
levels.

For the laboratory component, we redesigned the curriculum with the goal of developing scientific
inquiry. Each lab allowed students to ask questions, develop hypotheses, and carry out data
collection. For example, on the topic of animal physiology, students were given a habitat and
various animal parts. Working in small groups, students designed, constructed, and tested their
animals in various environments in lab. At this early stage, lab activities were designed to promote
science play and creativity, while emphasizing science process.

6. Readiness

Overall, the biology department is filled with passionate faculty that want the best for students. All
faculty wanted to be actively involved in the development of departmental learning outcomes and
participated in the mapping of the outcomes across the freshman year and upper division
coursework. The department has a long history of incorporating high impact practices, including a
mandatory senior research capstone for each graduate. Faculty teach their own labs, focus on
science process and inquiry, and incorporate research into teaching.

In addition to the motivation of faculty to support student learning, the department has been
proactive in obtaining several grants to fund pedagogical improvements. Dr. Broussard received an
NSF CCLI grant in 2007 to help fund inquiry laboratories within Cell and Developmental Biology.
In 2008, the Natural Science Division received a Title V STEM grant to support student research, a
new research laboratory, as well as improve access to technology and outreach to local high
schools. In 2010 and 2011, the Division received another Title V and a USDA grant, again with
support for pedagogy.

In order to implement change into the freshman year Biology series, we needed to examine faculty
workload and scheduling, schedule times to meet within course groups to outline the course, refine
themes, and develop new laboratories and assignments for students. Staffing changes, moving
from one faculty member per course to three faculty per course, required the department chair to
shuffle course loads and get approval from the CAS dean. The benefit was that faculty who had
been teaching the freshman courses were able to teach more upper division courses within their
area of expertise as their unit loads were lessened; two lectures and four laboratory sections took up
three quarters of the yearly teaching load in the old system. As our student numbers were
increasing at all levels, the shifting of loads meant that some courses needed to be covered by
adjuncts, and two faculty volunteered to take an overload the first year, so they could teach in the
freshman course and not have to give up their other courses. Overloads are not a sustainable
solution; however, the department chair was able to negotiate for another new faculty line. Overall, funding for the process was the easiest piece; the CAS Dean provided funding for the facilitator, retreat, and all overloads needed. Time and departmental support were the critical pieces.

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. Our IR staff has limited resources, and we had to wait two to three months for data. As an institution, we are moving towards evaluating baccalaureate goals within the e-Portfolio. The long term impacts on IR could be positive (more data assessed within departments) or negative (more requests to collate data on student success). To compensate for our trouble getting data, we started collecting 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 have decided on signature assignments that we will evaluate from year to year to look at student progress on our departmental learning outcomes.

8. Measurement of 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 (Appendix 1).

For the 2012 FLEX 1st edition, we retained a total of 60% of the incoming Biology majors after one year. For the Fall 2013 Natural Science A FLEX, we retained 77% of Biology majors after one semester.

In addition to looking at retention, in the spring General Biology 2 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 HHMI. The CURE allowed us to examine student attitudes towards science and their learning gains in the second semester course. We will administer it across the General Biology series next year.

9. Plans for dissemination and next steps

Our group has plans to present our change framework as well as our work in Scaffolding Scientific Inquiry from Freshman to Senior Year at the AAC&U/PKAL Transforming STEM conference. In addition, we plan to write up two publications that focus on our work, one on scientific inquiry and another on writing across the curriculum.

10. Reflection on the process

The framework itself was a critical piece for us. As stated, past decisions were sometimes made with little to no cumulative data. Our faculty emphasize high impact practices and work hard to help our students succeed. However, much of our work has 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 our weaknesses was important for us. Our attrition was higher than we expected and above normal.

In many ways, we had a bit of the ‘perfect storm’, many events converging to propel us toward major curriculum reform. Without the external events (new administrators, new professional development opportunities, new campus FLEX academic initiatives, external intervention – KECK/PKAL change framework and facilitator Susan Elrod), 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 freshman series.

A departmental retreat with an outside facilitator to lead us through a discussion and implementation plan was also a critical piece. The facilitator allowed all faculty to have an equal voice in the conversation. In addition, she kept the discussion moving forward and brought in information from outside our university, providing a national context that was needed in the process of developing a new vision and goals. Opening up the lines of communication between faculty and realizing that we agreed on many of the most critical issues within the vision allowed us to move forward as a community. Overall, we feel like the change process is continuous, but we feel that going through this process gave us the tools and language needed to understand each other and what it would take to move forward.