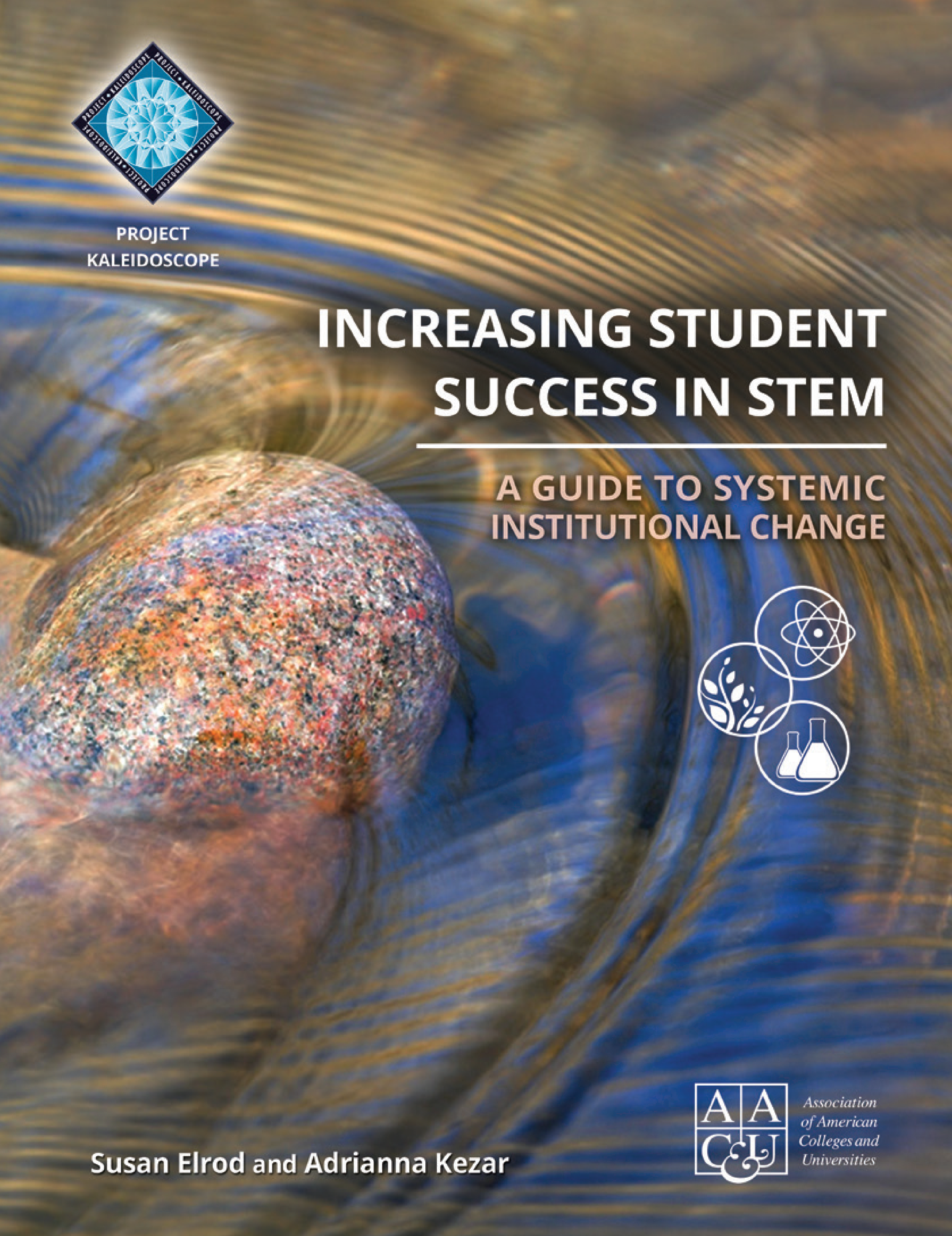

PROJECT
KALEIDOSCOPE

INCREASING STUDENT SUCCESS IN STEM

A GUIDE TO SYSTEMIC INSTITUTIONAL CHANGE

Susan Elrod and Adrianna Kezar

AAC&U
Association of American Colleges and Universities

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EXECUTIVE SUMMARY

This publication describes the Keck/PKAL (Project Kaleidoscope) Model for Systemic Institutional Change in STEM Education. The model was created in response to the need to improve student learning and success, particularly for students from underrepresented minority (URM) populations. Many change efforts in the STEM (science, technology, engineering, and mathematics) disciplines have been developed, but few have reached the transformational level of influencing entire programs, departments, or colleges. This model describes both a process and the content scaffold for campus leaders to plan, implement, assess, and evaluate change efforts in undergraduate STEM education in a way that goes beyond redesign of a single course or isolated program.

The Keck/PKAL model begins by establishing a vision and goals for the change project. It then guides campus teams through an analysis phase of gathering data and collecting information about the current STEM learning and student success landscape. This analysis leads to the identification of specific campus challenges, which are defined by the data and couched in the context, mission, and priorities of the campus. These challenges establish the outcomes of the change project and lead teams to choose, implement, and evaluate specific strategies that will improve STEM student learning and success.

Because any change process is dynamic and nonlinear, this model takes the shape of a flow, much like a river where there are multiple points of entry (and exit) as well as obstacles that create eddies along the way. Included in this publication is a rubric developed to help campus teams gauge their progress through the phases of the change process. This guidebook provides benchmarks, key questions for analysis, timeline information, challenge alerts that help leaders anticipate common roadblocks, and practical tools and information that will assist campus teams in their efforts. One of those tools, a readiness survey, can help teams determine whether they are prepared to implement their chosen strategies and interventions.

This guidebook is for campus leaders and administrators who are poised to mount more comprehensive reforms. It contains advice for leaders on topics such as getting started, addressing implicit theories of change, avoiding mistakes, facilitation and project management, scale of change, team and leader development, and sustaining change, as well as leader reflection questions. All of this guidance is geared toward the practicalities of leading and managing change processes. Example case studies developed by campus teams participating in the project provide real-world illustrations of change processes in undergraduate STEM education.

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- California State University–East Bay
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- California State University–Long Beach
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- San Diego State University
- San Francisco State University
- The W. M. Keck Science Department of
  Claremont McKenna, Pitzer, and Scripps Colleges
- University of San Diego
- University of La Verne
- The California State University Chancellor's Office
- University of California–Davis

These institutions should be applauded for their willingness to dive into this project, explore new territory, and build new models with us. Their success is a result of intense campus passion and expertise as well as tenacity and persistence. We are also grateful for the support of Project Kaleidoscope and the Association of American Colleges and Universities for sponsoring the project and providing staff support and opportunities for presentation at national meetings.

INTRODUCTION

For the past twenty years, countless reports have called for the reform of undergraduate education to improve student learning, persistence, and graduation rates for students in STEM (science, technology, engineering, and mathematics). However, by many measures, the recommendations in these reports have not been widely implemented (Seymour 2002; Handelsman et al. 2004; Fairweather 2008; Borrego, Froyd, and Hall 2010). Aspirational goals for student success in STEM have been set by a report of the President's Council of Advisors on Science and Technology (PCAST), entitled *Engage to Excel: Producing One Million Additional College Graduates in Science, Engineering, Technology and Mathematics* (2011). The report states that STEM graduation rates will have to increase annually by 34 percent to meet the goal of one million more STEM graduates in the United States over the next decade–and the greatest opportunity for progress toward this goal involves increasing the graduation rates of underrepresented minority (URM) students in STEM disciplines, since their graduation rates lag behind those of majority students. More recent reports reiterate the need to focus on creating more student-centered learning environments that are built on foundations of conceptual learning goals and use the most effective research-based teaching, learning, and assessment strategies. A meta-analysis that Scott Freeman and his colleagues conducted of recent science education research papers confirms that when faculty use active learning strategies, as opposed to traditional lecture, student exam scores increase and failure rates drop dramatically (Freeman et al. 2014). Moreover, the increasingly interdisciplinary nature of the global challenges our society faces requires that students engage in learning that will prepare them to address and solve twenty-first-century problems (National Academies 2009, 2010, and 2011). Still other research and program development efforts have shown that changing the learning environment to use more interactive and engaging teaching methods leads to improved student success.

STEM leaders also are recognizing that in addition to improvements in pedagogy and curriculum, multifaceted changes are needed in order to create student success. Student advising, faculty professional development, student research mentoring, academic support programs, clear STEM-focused institutional articulation agreements, and external partnerships with business and industry related to internships and other research experiences are often overlooked within reform efforts and have been identified as central to student success. These multifaceted changes, which include partnerships with student affairs and other support programs as well as entities outside the institution, suggest an institutional rather than a departmental approach to change. Key instructional and curricular reforms also need support from the institution through altered promotion and tenure and other reward structures or funding for professional development.

"There is growing recognition that STEM reform is an institutional imperative rather than only a departmental one."

There is growing recognition that STEM reform is an institutional imperative rather than only a departmental one. For example, the Meyerhoff Scholars Program at the University of Maryland Baltimore County combines specific academic, social, and research support interventions that have resulted in dramatic improvements in graduation of URM STEM students (Lee and Harmon 2013). In addition, research suggests that changes made to improve student engagement, such as implementation of high-impact practices, have benefits for all students but greater impacts on URM students (see, for example, Beichner 2008; Kuh and O'Donnell 2013; Finley and McNair 2013). The Center for Urban Education's Equity Scorecard (http://cue.usc.edu/our_tools/the_equity_scorecard.html) provides a specific approach—both qualitative and quantitative—for addressing URM equity issues across all disciplines at the institutional level.

Thus, change in STEM higher education requires a systemic and comprehensive approach that engages all levels of the institution—from department faculty to student affairs professionals to deans, provosts, and presidents. In response to this change, the Keck/PKAL Model for Systemic Institutional Change in STEM Education, which is presented in these pages, focuses on institutional change in the way that STEM leaders can facilitate this particular type of reform. In fact, one of the major contributions of this report is to help STEM leaders recognize and leverage institutional resources needed for STEM student success. The model was informed by research and developed in collaboration with eleven campus teams from both public and private universities working on STEM education change projects with the support of the W. M. Keck Foundation over a three-year project period.

Fostering Change

In order to make progress toward institutional reform efforts, the authors developed a comprehensive, systemic guide to effective institutional change for increasing student success in STEM. This guide provides a change model that will help campus leaders plan, implement, and assess systemic change strategies that improve recruitment, access, retention, learning, and completion for all students in all STEM disciplines. The model addresses the breadth of ways in which students engage in STEM learning on our campuses, from STEM majors to general education program requirements, quantitative reasoning requirements, or science or mathematics prerequisite courses required for applied majors such as agriculture. It is also applicable to students in the health professions.

As noted above, most prior initiatives and reports about increasing student success in STEM have been aimed at altering individual faculty members' or departmental activities, and there is little research that has helped leaders understand the various interventions that might be implemented that extend beyond departments and create an institutional vision for STEM reform. In addition, earlier efforts have not addressed the policies and practices at the institutional level that often hinder reforms or can be leveraged to enable greater changes. For example, a very common problem is a lack of workload adjustments to provide faculty members with the time to redesign courses or participate in required professional development. This issue is described in detail by Henderson, Beach, and Finkelstein (2011). Their research has identified four categories of change strategies: those that focus on individuals in a prescribed situation or an emergent situation, and those related to the environment and structures of the institution that are either prescribed or emergent. Our project was mostly aimed at helping campuses address what those using the Henderson categorization would describe as the environmental and structural aspects of the system, although individuals are clearly an important aspect of any system.

Since this project began, other multicampus STEM education reform projects have begun with a similar goal of providing a model for more systemic and sustainable improvements in STEM learning and student success. For example, the Association of American Universities (AAU) launched a major initiative with eight member campuses to implement reform in undergraduate STEM education (https://stemedhub.org/groups/aau). Their project centers on the application of an approach by campus leaders that is comprised of three elements: pedagogical reform, appropriate scaffolding and support for faculty members to carry out pedagogical reform, and cultural change. Also, the Association of Public and Land-Grant Universities (APLU) developed an analytic framework to help campus leaders make improvements in science and mathematics teacher education programs (http://www.aplu.org/projects-and-initiatives/stem-education/SMTI_Library/developing-the-analytic-framework-a-tool-for-supporting-innovation-and-quality-design-in-the-preparation-and-development-of-science-and-mathematics-teachers/file).

There are many different approaches to creating change within colleges and universities. A typical model begins with strategic planning. The model outlined in this guide includes some of the practices often included in strategic planning, such as vision setting, identifying benchmarks, and conducting a landscape analysis. However, our approach to change is based on organizational learning practices. Within this approach to change, information gathering and data analysis play a central role in helping individuals identify directions and appropriate interventions for making strategic progress. Participants in any organizational learning planning process must foreground campus data, reflection, and dialogue, and involve nonhierarchical teams in learning and developing innovative approaches. This means having campus teams look at data related to student success to determine the specific challenges and problems and to orient themselves toward a vision for change. An organizational learning model also focuses on learning that occurs throughout the change process.

Reflection is key in the organizational learning process. We asked participating teams to reflect at each stage and to correct errors and identify problems that inherently emerge through the change process. Through reflection, our teams were able to realize when they didn't have adequate buy-in to initiate a change process, when the vision was too top-down or fragmented, when politics were emerging that might sidetrack their efforts, or why they needed measurements of results to ensure future support of the initiative. In the organizational learning process, campus teams use data and information to help guide their choices but also may make use of outside facilitators (both consultants and project leaders) to help them reflect on their processes and adapt along the way. This guide includes many questions that will help facilitate this type of learning and reflection.

The model focuses on facilitating organizational learning, but it also incorporates key ideas from other research on change, such as addressing campus politics, developing buy-in and a shared vision, understanding the power of organizational culture, and helping campus leaders unearth underlying assumptions and values that might create resistance to change. Kotter's work on leading change is another useful resource (2012). It outlines eight steps that are involved in any change process: (1) creating a sense of urgency, (2) building a guiding coalition, (3) forming a strategic vision and associated initiatives, (4) enlisting a volunteer army, (5) enabling action by removing barriers, (6) generating short-term wins, (7) sustaining acceleration, and (8) instituting change. The model described in this guidebook incorporates several steps in Kotter's model.

The Keck/PKAL change model, described below, articulates both the practical steps and logistics of the work of STEM reform and the key phases for leading, supporting, implementing, and sustaining program interventions that result in improved student learning and success, particularly for underrepresented minority (URM) students. Most campuses in the project had URM student success as a primary component of their project goals; however, they took different approaches to achieve improved outcomes for these students based on the different factors identified in the process (e.g., leverage points, existing expertise, capacity, etc.).

"New insights gained from the ongoing interactions have contributed to an iterative design process and to the nonlinear 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 single plan."

—CSU East Bay Case Study

PROJECT REFLECTIONS

Perhaps the most powerful lesson to emerge from observing campuses use the guide is that the change process proceeds in a nonlinear and dynamic fashion.

Using the Model

At the beginning of the project, we started with a draft version of the model, which we modified as campus teams worked through their projects using the model. Throughout the project we identified certain processes that emerged as critical or particular steps that needed to happen simultaneously or interactively. Perhaps the most powerful lesson to emerge as we observed campuses using the model was the idea that the change process proceeds in a nonlinear and dynamic fashion that may be best captured by the metaphor of a river. On many occasions, campus teams found themselves "stalled in the eddies on the side of the river" as they wrestled with creating leadership for change, reworking their visions, or trying to obtain resources and support for the change process. As they worked through the many steps toward change, they "flowed" back and forth between identifying resources and thinking through appropriate strategies, sometimes returning to and altering their visions, based on existing assets or capacity.

We also learned that there is no "one size fits all" approach for promoting change. Campus contexts, goals, expertise, resources, missions, and leadership structures are different at every institution. The project has resulted in a dynamic and interactive set of tools, presented in this guidebook, that will allow campuses to begin their work wherever they find strength and initial leverage points and that will foster a back-and-forth flow as the work progresses. We view the model as a tool or device that allows leaders to create processes that work for their campuses. Ideally, we recommend that campus leaders start by defining a vision and performing the landscape and capacity analysis (examining data and existing assets) before embarking on any planning or strategy implementation activities. We offer this advice because faculties and administrators too often do not have a full understanding of the issues facing students in STEM programs or perhaps even of what is already happening on campus regarding STEM education. We found that most campuses operate in data-poor environments, especially at the faculty and department levels. For example, it is critical for institutions to fully understand the implications of changes in retention and graduation rates for different populations, how well students are doing in key introductory courses, and other factors such as how frequently students change their majors and how they fare on disciplinary or math placement tests.

Because campuses differ in their ability to gather and analyze such data, not every school may be able to start at the beginning of the model. Therefore, we recommend that leaders begin the process by identifying which of the model's elements resonate most with their campus priorities or existing initiatives, faculty expertise, resources, mission, and leadership goals. From there, they can work out a process that will incorporate other elements to help achieve their goals. In this case, consideration of all the elements presented in the model will help leaders anticipate new areas of work, recognize possible barriers, identify opportunities, determine appropriate team composition, begin to build support, and create a reasonable timeline. The remainder of this book will elaborate the elements of the model and how they can best be used to help campuses meet their undergraduate STEM education learning and success goals.

Using This Guidebook

This book will be useful to leaders at a variety of levels. It was written for campus leaders who have convened (or will convene) teams comprised of faculty members, department-level leaders, student affairs professionals, appropriate central administration officers, institutional researchers, and professionals in undergraduate studies offices to achieve improved STEM learning outcomes. We learned from our own work as both researchers and practitioners that institutional change is best executed by a team whose members are working together across functions. In order for institutional changes to occur, it is critical that the team have the support of leadership across campus—including grassroots faculty leadership, midlevel leadership among department chairs and deans, and support from senior leaders in the administration. Campus professionals from student affairs, outreach, and advising are also important members of the team. Each of these groups can play a unique and important role in the change process. Grassroots faculty leaders can identify problems and challenges in the classroom and at the departmental level, can help garner support for change from other faculty members, and often have access to resources on effective pedagogical and curricular strategies within their disciplines. Midlevel leaders, such as department chairs and deans, can provide incentives and rewards, help provide release time for grassroots faculty leaders, and assist in writing grants or identifying resources to support the initiative. Senior-level administrators can help change reward structures that might impede STEM student success, help provide data that identifies challenges to student success, and connect faculty members and department chairs with those in other units across campus who might assist them in supporting students, such as advising professionals, bridge program directors, and educators whose work supports high-impact practices like undergraduate research. Ideally, campuses will create teams that represent these different levels of leadership, all of which are helpful for creating institutional change;

- **Faculty Leaders:** We believe that individual faculty members will be able to use this guide to begin to initiate changes. For example, an individual faculty member in a department can use this publication to understand the type of leadership, capacity, and resource structures needed to support institutional changes. Faculty members can also use the examples in this guide's case studies to begin creating a vision for student success in STEM education at their institutions. The guidebook also can help individual faculty members have conversations with department chairs and other leaders to bring these leaders on board with a broader change process. In addition, faculty can use the guidebook to catalyze discussions in departments to stimulate thinking about starting a change process.
- **Department Chairs and Deans:** Many STEM department chairs and deans have a history of attempting change in isolation from the rest of the institution. As a result, they can face barriers when reward or resource structures block their efforts, institutional priorities channel their efforts elsewhere, and culture clashes affecting their work begin to erode their change efforts. We hope this publication will help department chairs and deans garner the support of senior administrators. We believe that with senior administrative support, department chairs and deans can create more lasting and sustained changes that are aligned with institutional priorities, that leverage other campus resources, and that involve other disciplines and departments. The result of more comprehensive efforts will be altered campus culture and values. Through coordinated efforts, deans and department chairs are much more likely to change the values and cultures on campus that can prevent sustained institutional change.
- **Leaders in the Central Administration:** Strong top-down leadership often creates resistance among faculty and even department chairs and deans. Our campus teams found it invaluable to have STEM faculty deeply involved in the student success vision defining process as well as the data analysis process, as participating in these processes gave faculty a more realistic understanding of campus challenges. Faculty

"We are pleased we were able to find external grants and partners to support and pilot strategic initiatives... However, it will take campus commitment, intentional cross-divisional partnerships, and creativity to institutionalize new evidence-based practices in STEM education within 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."

—CSU Chancellor's Office Case Study

participation in these processes is important for gaining buy-in and support among the people who are instrumental in implementing desired changes. We hope that senior leaders such as presidents or chancellors will give this guidebook to key leaders on campus and encourage them to set up broadly based campus teams in order to rethink STEM education and institutionalize changes.

- **External Audiences:** Finally, external audiences (e.g., industry members, funders, foundation and policy leaders), may find this guidebook helpful in framing conversations with campuses regarding shared STEM education goals, priorities, and actions.

Each of the aforementioned groups brings a different perspective to a project's vision and analysis. Having faculty fully invested in the process helps guard against the project's stalling when campus leaders leave. Therefore, we hope that institutional leaders will see the value in teams that include members with a broad array of expertise to develop the vision, analyze data, understand campus capacity, and identify strategies for meaningful change.

While this guide can be used to create departmental-level and smaller-scale changes, student success in STEM depends on institutional variables as well as those at the department level. For example, the promotion and tenure process and its focus on scientific research are often cited as reasons why faculty members don't engage in changing their teaching methods. While this is a likely barrier, it cannot be addressed only at the departmental level; stakeholders at all levels of the institution own the tenure process, and changes to it must engage department faculty, department chairs, deans, provosts, and presidents. Alternatively, a campus team's strategy may involve student support programs that typically are not part of departmental responsibilities, requiring coordination of vision, expertise, and resources with offices outside the department and perhaps even in a different division of the university (i.e., student affairs). Therefore, as noted in the introduction, we recommend working with an institution-wide team to address STEM reform.

We have written this guidebook to help those leading these efforts, but we have formulated it as a step-by-step planning and practical guide that can be used by campus teams. In workshops and presentations to a variety of audiences, we found that faculty and staff who may be new to institutional or systems-level thinking, such as new faculty members, often found the overall model overwhelming. We therefore believe that this guidebook will work best if a single leader or a small team of leaders becomes familiar with the whole model and then facilitates the work of others on specific aspects of it. Each section of the guidebook includes tools designed to help teams navigate the dynamic process of change, and an appendix of focused questions further guides campus team work. These tools and the appendix are intended to break down complex ideas for novice change agents. We suggest that leaders begin by looking at the outline of stages, focusing on only one stage at a time. While the stages are iterative and affect each other, thinking about all stages at once can be frustrating for team members. By focusing on selected stages of the model, leaders will be better able to manage the complexity of the change process. As our campus teams often pointed out, leaders should assume the roles of teachers or mentors who can guide and support people who are new to change processes.

Part 1

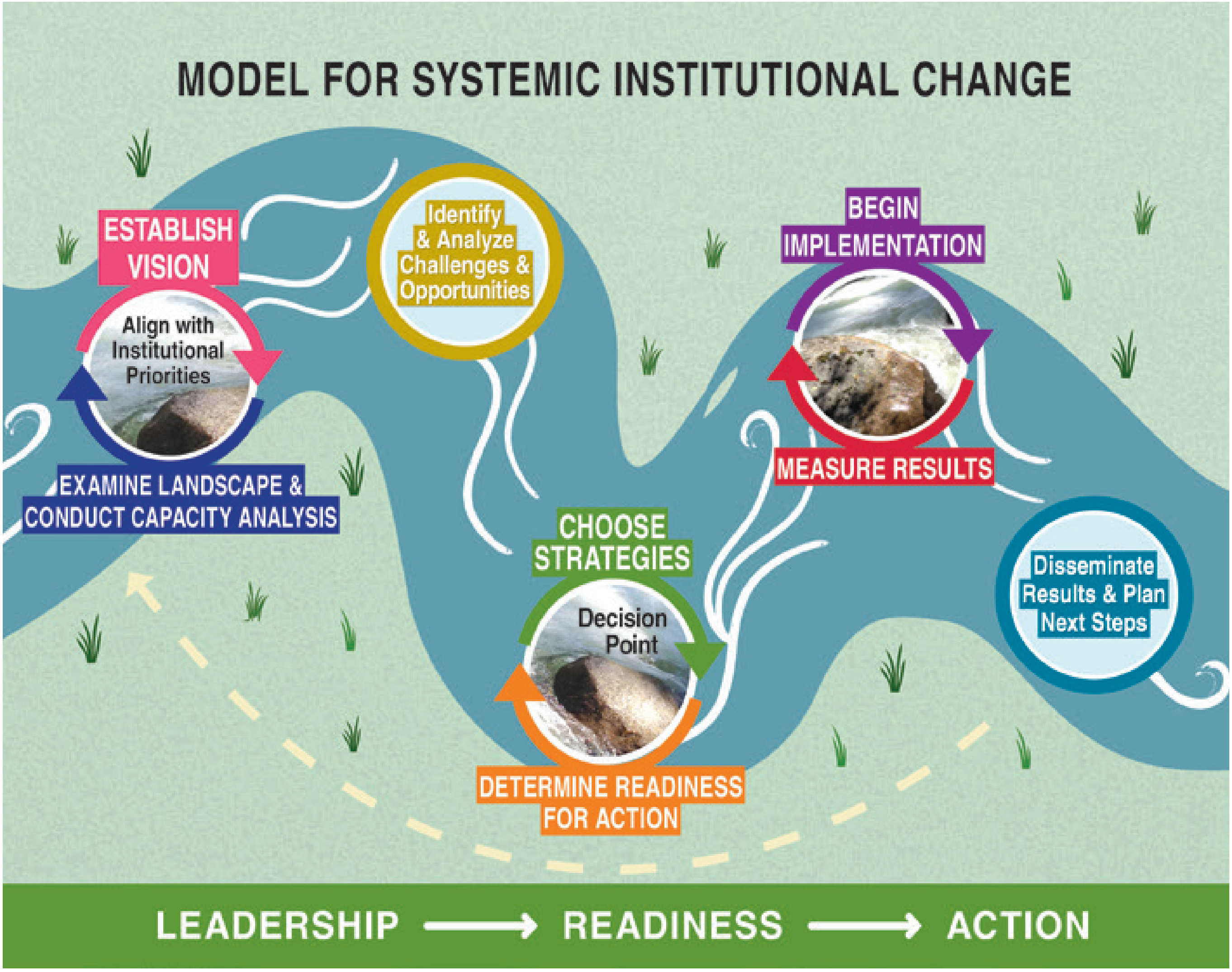
THE KECK/PKAL MODEL FOR SYSTEMIC INSTITUTIONAL CHANGE IN STEM EDUCATION

Leadership is critical from the start of the institutional change process. The process also requires campus teams to assess their readiness by gauging campus climate, measuring capacity for change, and identifying resources required for program development. Finally, by carrying out their planned strategies, project teams can achieve desired results. Below, we have presented the model for systemic institutional change as a river to show the dynamic, flowing nature of change (see fig. 1, page 9).

The river analogy is especially apt, not only because of the flowing nature of a river, but because, like institutional change, a river is dynamic and changing. The flow (change process) encounters obstacles (challenges presented by certain aspects of the change process) that may result in eddies where the flow circles around the obstacle until it can break free. Travelers on the river may enter at various points or stop at certain locations to rest. New travelers may join a party already on a journey down the river. Indeed, teams working on system change may start at different points, change membership, or even stop for periods of time because other campus priorities emerge, team members take on other duties, campus leadership changes, or other conditions shift.

The eddies in the model illustration indicate the points at which efforts often loop back in an iterative process. For example, in the visioning process, the data

Figure 1. The Keck/PKAL Model for Systemic Institutional Change in STEM Education



landscape analysis informs and refines the vision. The process is not always predictable and linear, but is dynamic like a flowing river that produces occasional eddies as it encounters obstacles. The resulting eddy motion also is an apt analogy for the circular swirl, or iterative process, that campus teams experience when they encounter resistance and other challenges along the path toward reform. They must work through each issue, determine the nature of the challenge(s), and figure out how to get the flow going in the desired direction again. In a "reform eddy," teams may need to "peel out" or pause while they investigate and further analyze the obstacle before they can escape the circular flow and continue further downstream. Teams may also enter the river at different points, depending on where they are in terms of understanding the problem, existing expertise, campus leadership capacity, and other factors. Teams can also swim up- or downstream, although the general flow will ultimately lead downstream toward action and success. Deploying the model can be painful and challenging, but it is extremely helpful in prompting campus teams to envision what will work for them and to identify where they are based on campus context, expertise, leadership, and additional considerations. Wherever each campus team starts, we believe that each team must address all the model's elements at some point or time in the change effort.

As stated at the bottom of the river diagram, progress through the flow requires leadership, assessment of readiness and, ultimately, action. Initial leaders must be identified early in the process. These leaders may be from the central administration, department, division, or elsewhere in the college. External experts or partners (e.g., board of trustees members, K–12 partners) may also play critical early leadership roles. Common early leaders for change in STEM are often early adopters or disrupters (such as faculty members who are already engaged in course redesign or discipline-based educational research (DBER) or champions (that is, influential faculty leaders). These individuals are important members of an initial team. Some resources (particularly time for faculty leaders to devote to planning and early analysis) are extremely helpful during this phase. Funding from special project funding pools or external grants can seed initial efforts.

In the sections that follow, we review the stages defined in the model:

1. **Establish Vision.** The vision represents the direction in which the campus is aimed in terms of altering its STEM experiences to support success for all students with a focus on inclusive excellence. We encourage teams to develop a vision that is comprehensive, clear, and shared.
2. **Examine Landscape and Conduct a Capacity Analysis.** Campus teams can typically best find a direction forward by analyzing existing data and information about STEM student learning and success (internal campus data as well as external reports on STEM reform), and by reviewing current capacity to engage in change generally (e.g., the history of reform, leadership, and buy-in and ownership among faculty members). These baseline data offer a picture of the current landscape. At this stage, teams focus on collecting data and information with which to conduct a capacity analysis.
3. **Identify and Analyze Challenges and Opportunities.** Campus teams need to analyze the information about landscape and capacity in order to identify both challenges and opportunities for the campus. This phase often involves aspects of both politics and culture that might be sources of both opportunities and challenges.
4. **Choose Strategies/Interventions, Leverage Opportunities.** Campus teams need to familiarize themselves with a host of high-impact practices or student-centered strategies from which they might choose to address the challenges they have identified. They can examine these strategies in light of the campus's capacity as well as in relation to opportunities identified in stage 3. At this stage, campus teams identify opportunities that they can leverage in support of their goals, such as a newly established special projects fund, a new faculty hire with appropriate expertise, or other points of leverage.
5. **Determine Readiness for Action.** Key issues will emerge as campus teams implement specific strategies. These may be related to resources, workload, institutional commitment, facilities, timelines, and other areas that the

team should review in order to effectively implement a particular strategy and ensure that the campus is ready to move forward with that strategy. In addition to ensuring that the team has developed a solid plan for action, this phase also involves exploring campus politics and culture and addressing these elements in the plan for action.

6. **Begin Implementation.** Implementation involves drafting a plan for putting the intervention or strategies in place using ideas the team developed when assessing readiness for action, campus capacity, and potential opportunities. The plan should include all of these elements as well as a process for understanding challenges as they emerge. After developing a plan, campus teams may decide to pilot an initiative first and then consider how to modify and scale it after a trial period.
7. **Measure Results.** Campus teams should create an assessment plan to inform whether the intervention is working and to establish ways to improve the initiative over time.
8. **Disseminate Results and Plan Next Steps.** In order to prevent the continued "siloization" of work, the project team should think about dissemination opportunities on campus as well as off campus, whether regionally, statewide, or nationally. To keep momentum going at this final stage, it is important that the team reflect on work done and begin deliberate planning of next steps.

Figure 2 (see page 12) represents the model elements arranged in the stages of the scientific method. Science faculty may find this version more approachable than earlier change models because it represents the change process in terms of the development of scientific knowledge, from hypothesis development to experimental design and testing. We have placed the model stages in this context to show the parallels between these two processes, having found through our work that this representation of the model may resonate better, at least initially, with faculty. Handelsman et al. (2004) and Wieman (2007) previously used similar framings to help science faculty see the connections between their disciplinary mindset of discovery and experimentation, and that of educational research and reform. We found that a single way of orienting or approaching change may not work, so we offer this different vantage point that may resonate more strongly with some faculty members.

PROJECT REFLECTIONS

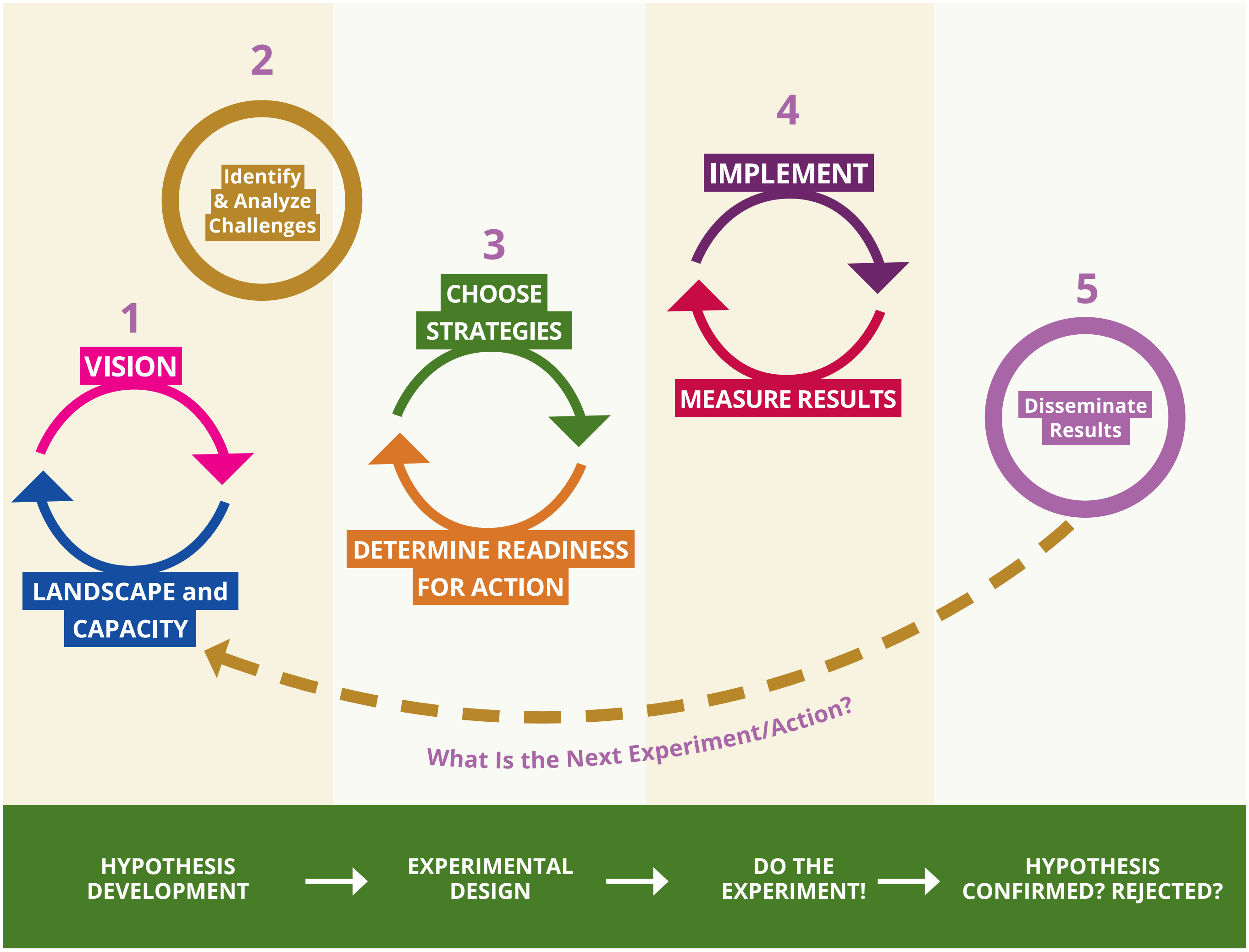
Wherever a campus starts, we believe that you must address all the model elements at some point or time in the change effort.

Practical Tips for Using the Model

Getting Started

It is important to remember that every campus must construct its own process. This model provides a general outline that individual campus teams can use and customize to help institutionalize and sustain their STEM reform efforts. As illustrated by the case studies, individual campus processes varied tremendously, and campus teams navigated through the model in very different ways. However, each campus team eventually addressed all of the aspects of the model. Campus teams often initially ignored a particular area, but then found themselves drawn to that area when it became a barrier to their forward movement. While most campus teams did not move through the model in a linear fashion, having the model in the

Figure 2. A Scientific Version of the Systemic Institutional Change Model



background as they conducted their work helped them identify why they were facing particular barriers and return to issues they had ignored.

We heard from the campus teams that they initially had a difficult time using the model because it ran counter to the direction they wanted to take or could get everyone on the team to consider. For example, many teams wanted to start first by developing strategies to get something going. Teams found it difficult to start with vision and landscape analysis for a variety of reasons, perhaps because they were anxious to put a solution in place, didn't feel that they could construct a collective vision, or perceived themselves as being on a short timeline. Sometimes it took teams two to three years to reassess their goals and experience enough roadblocks so that they finally returned to the model's initial steps. However, when they revisited those first steps, it was with a new sense of purpose. By the end of their projects, most teams reflected that if members had been open to following the model from the beginning, they would have saved themselves a lot of stops and starts, resistance and headaches, and time and resources.

We recognize that many readers will have done some of the work in the model's earlier stages, and will not start at the beginning. Therefore, it is important for campus teams to identify which steps they have already taken before moving forward.

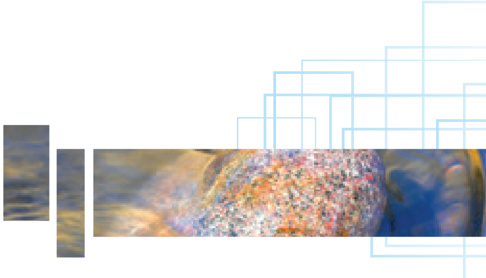
The entire change process requires leadership. Leadership can take a variety of forms, from informal leadership offered by faculty members to formal leadership by institutional administrators. Regardless of the form of leadership, though, all leaders must understand change processes and management issues in order to help the team stay the course down the river of change. Leaders must also help their teams determine their best entry point.

In the beginning stages, it is important for campus teams to discuss inclusive excellence—the Association of American Colleges and Universities' (AAC&U's) guiding principle describing the commitment to access, student success, and high-quality learning (http://www.aacu.org/programs-partnerships/making-excellence-inclusive). To support inclusive excellence, campus leaders and teams must address the core principles of diversity, inclusion, equity, and equity-mindedness as they relate to STEM program and learning goals. A key component of higher education programs that embrace inclusive excellence is implementation of high-impact practices (HIPs). These high-impact practices were originally defined by George D. Kuh (2008) based on results from the National Survey of Student Engagement (NSSE) as those practices that have a significant impact on student success, particularly for students from underserved populations. More recent studies have provided details regarding the impact of these practices on students from underrepresented minority (URM) populations, such as Hispanic, African American, or first-generation students (Kuh and O'Donnell 2013; Finley and McNair 2013). These publications provide detailed analysis on the impact of these practices as well as tools for planning, implementing, and assessing HIPs on campus. With creative planning by faculty members and campus leaders, all of these practices can be tailored to STEM learning environments and programs.

Table 1 provides some questions that leaders should ask to identify the most appropriate place to enter the process.

Identifying the Team's Implicit Change Theory

We found that the most significant reason teams struggled with the model is that they had their own implicit theories of how change happens. What we mean by theory in this section is not ideas that have been proven through research, but theory with a small "t" in that each person holds a working theory of how change occurs—a set of assumptions, not necessarily based on facts or evidence. For example, a common assumption among STEM faculty is that meaningful change can only happen in departments. If faculty members hold this belief, they will resist examining potential levers outside the department that may be important to address, such as mathematics preparation, success in a prerequisite course in another department, or interventions to help students with study skills or social supports. Another common assumption we found was that change can't happen without a large grant to support faculty buyouts. If teams have this assumption (and it is usually unspoken), then efforts to come together and analyze data will often be diminished by discussions about grant opportunities.



HIGH-IMPACT PRACTICES

- First-year experience/seminar
- Common intellectual experiences,
- Collaborative assignments and projects
- Diversity/global learning experiences
- Service learning/ community-based learning
- Learning communities
- Writing-intensive courses
- Internships
- Undergraduate research

Table 1. Getting Started Using the Systemic Institutional Change Model

Key Questions	If Yes, Then...	If No, Then...
Establish Vision Is there a campus vision and/or goal statement that is specific to STEM learning goals and/or the success of all STEM students, including underrepresented minorities? Does this statement include markers such as enrollment percentages, persistence data, and graduation rates? Do STEM programs, departments, and/or colleges have articulated goals for STEM student learning and success that embraces the principles of inclusive excellence?	...use this as a lever to bring people together to discuss common goals and specific outcomes regarding STEM education.	...this may be a good place to start, as it presents an opportunity to begin a conversation about what is important regarding STEM student learning and success.
Examine Landscape and Conduct Capacity Analysis Does the campus regularly collect and analyze data regarding STEM student learning, retention, and graduation? Is there faculty or staff expertise with respect to STEM learning, discipline-based education research (DBER), student support services, etc.?	...tie the data to your vision if you haven't already done so. Data can offer an important lever for change and an opportunity for conversations with faculty and staff. Interview campus experts that you have identified to see what they know, how their work relates to the data, and what they have accomplished. Use these interviews to begin constructing a map of campus issues and capacity to address these issues. Determine how to use these experts as team members and their work as levers for change.	... this may be a good place to start, assuming there are appropriate resources and expertise for performing this type of analysis. If not, the campus team may need to consider how it will obtain the expertise needed either through staffing or use of consultants.
Identify and Analyze Challenges and Opportunities Has the campus identified student attributes; programmatic bottlenecks; policy, scheduling, or other factors that impeded STEM student learning, retention, and/or graduation?	...leverage this analysis for a focused discussion on specific areas where interventions might be fruitful.	...begin by collecting data, to the extent you can, and put together a team that can analyze it. This will be an important analysis to carry out and is a critical step needed before moving forward to the next step.
Choose Strategies and Interventions, Leverage Opportunities Does the campus have any experience with implementing evidence-based practices in STEM education (e.g., studio courses; problem-based learning; peer-led team learning), STEM-focused summer bridge programs, supplemental instruction, learning communities, or other high-impact practices (HIPs)?	...bring the people who have these experiences together to share their knowledge and assess results. Tie results back to vision and landscape analysis to see how they fit together and identify where gaps exist, and then create a plan for moving forward that addresses concerns.	...conduct a review of the relevant literature (see Stage Four—Choose Strategies and Interventions, below) and determine whether devoting resources to professional development opportunities for faculty and staff is warranted.

Implicit biases can only be revealed through conversations about beliefs, values, and practices. Therefore, we encourage teams to make their first meeting a discussion about how change occurs and to make their implicit theories explicit. This process can be hard because implicit theories are often unconsciously held. Many people may not be able to articulate a theory of change or understand why they find the model difficult to work with. Just having candid discussions among team members can be helpful: for example, try asking, "What do you think it will take to start an undergraduate research program here?" We hope the case studies help to make the change process more real. By reflecting on cases and making implicit theories explicit, team members may become more open to examination and change.

If something is implicit, how does one begin the change process? First, we recommend that initial team discussions focus on how change occurs. This initial step allows implicit assumptions to emerge and be debated. Second, we found that using case studies to challenge assumptions can help stimulate useful discussions and change views. As a result, we have included case studies about change within this guidebook to help facilitate discussions about change processes so that team members can begin to articulate their own theories of change. Third, it can be helpful to start discussions about how change occurs by reviewing a publication or two about change theories or approaches. Kotter and Cohen's *The Heart of Change* (2002) or Kezar's *How Colleges Change* (2013) are two examples of books teams can use to prompt discussion. While participants have also jumped straight into engaging in the change process, efforts that began in this way were often derailed or delayed as a year of two of experience is usually necessary for most teams to come to a unified vision. For that reason, we encourage teams to hold early discussions using this guidebook and the case studies to reflect on implicit views.

"Our team members were initially reluctant to talk about organizational theory or formulate vision statements. For some teams involving university and program directors with varying exposure to strategic change initiatives, time spent taking about organizational change theory up front might be well spent."

—CSU Chancellor's Office Case Study

Scale of Change

The work of STEM education reform may be conducted at different levels of the institution. The most common level of work may be at the department level. One of our goals in developing this model was to assist campuses in moving from siloed departmental efforts to more broad institutional initiatives. While this model is aimed at institutional change, the same approach can also be used for departmental and program-level changes. All of the steps outlined here are also necessary when making changes at these more local levels. We also think it's important for campus leaders to recognize what is possible within a particular context. Some campuses are not ready for institutional changes. Starting at a departmental or program level is quite appropriate in these situations, and we advise use of the model in these instances.

Table 2 (see page 16) provides benchmarks regarding each of the phases of the model for work occurring at each of these levels. A national project focused on transformation of undergraduate biology education, the Partnership for Undergraduate Life Science Education (PULSE) project, has also created a rubric that is focused on department-level attributes, which may be of interest to those focused on this type of action (http://www.pulsecommunity.org). Another useful rubric that is focused on institutional level educational effectiveness is the WSCUCASC (Western Association of Schools and Colleges Senior Colleges and Universities Commission Western Association of Schools and Colleges) Framework for Assessing Educational Effectiveness, which is frequently used by campuses in their accreditation reviews (http://www.wascsenior.org/content/rubric-assessing-educational-effectiveness).

Process and Content of Change

One of the major challenges for campus teams using the model was to separate out the notion of what they wanted to change (vision and strategy) from the process of change (how to go about it, who was responsible, what political issues might arise), which also includes vision and strategy but involves many more elements. Campus teams were much more comfortable thinking about the content of the change than about the process. Our model focuses on both process and content. To be successful in achieving a vision, campus teams and leaders must follow a successful change process. A campus team may want to focus on just the content of change (such as undergraduate research programs) and move directly to particular strategies or interventions. But to carefully

Table 2. Department-Level Reform versus Institution-Level Reform.

	Program-Level Reform or Department-Level Reform	College-Level Reform, Division-Level Reform, or University-Level Reform*
Establish Vision	Vision encompasses program-level goals that may be limited to a single discipline	Vision encompasses all students and sets institution-level priorities that relate to STEM student learning, persistence, and graduation goals
Examine Landscape and Conduct Capacity Analysis	Data and capacity analysis is focused on data collected regarding students and faculty members in a limited number of courses or a program	Data and capacity analysis is focused across multiple courses, programs, and/or disciplines
Identify and Analyze Challenges	Challenges are specific to courses/programs analyzed (e.g., higher course failure rate for URM students)	Challenges are more systemic in nature and may be common across departments and programs (e.g., similar dropout rates for students in several STEM majors after the first two years)
Choose Strategies/ Interventions, Leverage Opportunities	Strategies are focused only at the course or program level (e.g., implementation of evidence-based teaching methods) and do not require everyone to be on board, especially initially	Strategies include course transformation but go beyond the classroom (e.g., creation of an early alert system that pulls data from student records regarding course grades, course progression, change of major, etc.) and require engagement of other campus departments and divisions, such as student affairs
Determine Readiness for Action	Readiness metrics are focused on faculty expertise, faculty interest, faculty development opportunities, workload, department resources, and teaching spaces	Readiness metrics also include those focused across the institution, linking departmental, programmatic, and institutional expertise, resources, and initiatives
Begin Implementation	Implementation occurs at the course or program level	Implementation occurs across multiple courses, programs, or departments
Measure Results	Assessment methods focus on measurable outcomes of single courses or programs (e.g., specific learning outcomes, course pass rates)	Assessment methods focus on measurable outcomes across programs (e.g., overall retention rates, graduation rates, persistence into upper-division courses)

**This language is meant to indicate a reform initiative that goes beyond a single department or unit and, to the extent possible, engages multiple entities across the college or university.*

select the intervention, the team will need to follow a process of reviewing data, examining external resources, and reviewing internal capacity. There should be a strong interconnection between process and content rather than a separation.

"While sharing details about a proven strategy may help to motivate change, it is important to go through the process of conducting a vision and landscape analysis before jumping into implementation."

Mistakes to Avoid

Campus leaders tend to begin the change process by suggesting that the campus implement a particular student success strategy that they read about in a report or publication. While sharing details about a proven strategy may help to motivate change, it is important to go through the process of conducting a vision and landscape analysis before jumping into implementation, as the latest published strategy may not fit every campus's situation or resources. Also, it is important to understand each campus's capacity to implement a strategy, and to evaluate whether the strategy will address team challenges and is consistent with campus resources, mission, and priorities. Obtaining buy-in from key faculty and staff is also important for a solid start. Campuses that started with a strategy found that, while they sometimes made progress, they often struggled with purpose, outcomes, buy-in, implementation, and measuring success and impact. Team members ended up going back to their vision, refining it, and doing more landscape analyses. Often, this meant bringing more people into the dialogue to achieve broader buy-in and support. After trying a proposed strategy and running into trouble, some campus teams were forced to backtrack to conduct a readiness assessment. Other common barriers encountered were

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

Not considering these barriers can be a mistake; if not anticipated, they can cause serious project delays. The team can identify some barriers as they get started and thus can deal with these barriers early; however, some barriers occur unexpectedly during the process. Having a committed campus leader at the helm as well as a diverse and high-functioning team (see "Program Management" below) can alleviate potential setbacks and interruptions. Leaders, though, must be flexible and adaptable to respond to these developments and must continue to focus the team on the goals and desired outcomes.

Timeline

It is important to understand that moving through an institutional change process usually takes at least five years. In fact, research suggests that institutional change is a long and messy process that may take as long as five to ten years. Part of the leader's role is to help pace people in the process and to maintain momentum. Project leaders can assure their teams that taking the time (from six months to more than a year) to develop a vision is not wasted and is essential to create buy-in that sustains change. Leaders play an important role as constant champions for change when the team starts to get fatigued. Project leaders should stay focused on the overall goal but identify smaller steps that the team can accomplish in relatively short periods of time. For example, having each team member work on a specific data set, as opposed to having the whole team review all the data, may help reduce fatigue. Creating a chart or document that catalogs these accomplishments will demonstrate to the team that they are making progress toward the larger goal.

There are many barriers that extend the timeline for the process, such as leaders leaving, teams taking time to develop their own capacity for data analysis, difficulty getting data, team member turn-over, or workload issues that prevent people from having the time to participate fully in the effort. When teams are composed of leaders from all levels of the university, including faculty and staff, they can avoid the stalling that may occur when top leaders leave, because there are many invested in keeping the project going. Having several leaders involved and focused at multiple levels may also speed up the change process.

Facilitation

Many project campus teams used an external consultant to help them move through a particular part of the change process. Several of our campus teams suggested that they would never have made progress without the help of a consultant. Being open to the necessity of an external person at different points in the change process can help campus teams navigate troubled waters in the river. Here are some ways a consultant may be helpful:

- **Meeting facilitation** for the initial vision conversation can help smooth power dynamics caused by certain individuals who may have strong feelings that will drown out the voices of more timid or junior members of the team. If there are several strong individuals or agendas, an external facilitator may be useful for the entire process, managing all major team conversations to ensure collaboration.

- **Assessment experts** can help identify existing data and important new data the team needs to collect and analyze; they can also validate methods or provide feedback on benchmarks or results.
- **STEM education leaders** who have been successful in reform projects can help the team see how the process worked for another campus, making it seem less intimidating. This may be particularly useful if the other campus has similar characteristics or faced similar challenges.
- **Mediation** may be needed to overcome roadblocks at any point in the process. Skeptics may agree initially to go along with the plan, but when results don't yield the desired gains immediately (as can be expected for most change projects), they can become vocal detractors, and the project may stall. An external evaluator or expert can come in to look at the process, listen to people's concerns, and help overcome the roadblock.

"Spending adequate time on team development is extremely important to a change initiative because the team is the engine that creates forward momentum of the project."

Project Management

Project management is another important consideration. Teams greatly enhanced their progress by identifying a faculty or staff member and assigning that person time to manage logistics, such as tracking timelines, scheduling meetings, documenting progress, managing team communications, and organizing project materials and outputs. Depending on the size and scale of the project as well as available resources, a project manager may be enlisted either part-time or full-time.

Team Development

Spending adequate time on team development is extremely important to a change initiative because the team is the engine that creates forward momentum of the project. Assembling the best team can take several months, and we encourage institutions to take the time to create high-functioning teams. Once teams are created, members also need time to get to know each other, create a common language and vision around change, and build trust. Regular meetings or an in-depth annual retreat also can facilitate team building. Before moving into the detailed work of data analysis and identifying interventions, team members need to trust each other, gain respect, understand each other's expertise, and develop relationships. All team members must feel that they are welcome and in an environment where they can safely discuss potentially controversial ideas or data, freely express opinions, and experiment with innovative interventions.

Teams will inevitably face turnover of membership over time. While this often stalls their efforts, it is important that the team identifies new members and continues to move forward. Our campus teams did better when they met regularly and asked themselves questions such as, *Is our team working well together? Does it have representation from necessary groups*?

Some teams found that they needed different individuals once they chose a particular intervention. For example, a team that opts to focus on linked first-year courses might want to involve more faculty teaching introductory courses, and even key general education courses (e.g., writing). Often, those faculty members are not on the tenure track and may not have been considered initially for the team. Another example may be a team that decides a summer bridge program is necessary. To avoid reinventing the wheel, creating such a program may require including staff from outreach and recruiting offices as well as student affairs offices who have expertise in these types of programs. Alumni may also be a useful resource. Therefore, the team may need to expand or alter its composition over time to include the expertise needed to execute the change.

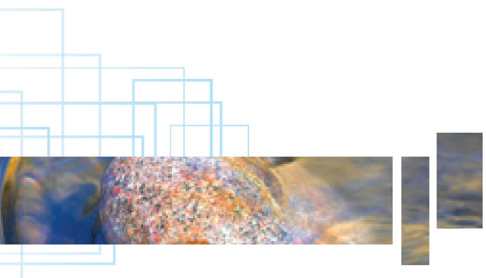
For more guidance on working as a team, see Bensimon and Neumann (1993) and also introductory information on the Equity Scorecard for campus evidence teams (http://cue.usc.edu/our_tools/the_equity_scorecard.html).

Leaders and Leadership Development

Having a team leader who can keep the team focused and on track is critical. Having one or two senior leaders on the team or serving as liaisons may be helpful in gaining the type of leadership needed for institution-wide change. Some teams found that they got better thinking by identifying unexpected people to put on the team (i.e., someone from technology services or other disciplines such as the humanities). It is also important for team leaders to continually reflect on the process to monitor team effectiveness as well as project progress. Below, we provide questions that leaders can use to be mindful of team process and practice.

As noted in the introduction and elsewhere above, research has indicated that a distributed or shared leadership model works best to institutionalize changes. In order to enact institutional change, the project team will require engagement from leaders across campus, such as grassroots faculty leaders, midlevel leaders (such as department chairs and deans), and senior leaders in the administration. (For details, see “Using This Guidebook” on page 4). An important lesson learned from our project was that faculty members often need to develop the leadership skills necessary to facilitate a STEM reform project. While faculty members generally receive excellent training in their disciplines, they are not necessarily trained to lead change processes.

Many different opportunities for developing faculty’s leadership skills now exist. Some of these programs are described in a 2014 symposium issue of the *Journal of Leadership Studies* (Elrod and Kezar 2014b). For example, Project Kaleidoscope offers a yearly summer leadership Institute (see https://www.aacu.org/summerinstitutes/sli; also described in Elrod and Kezar 2014a). More than two thousand faculty members have participated in the Project Kaleidoscope training and many found it important in assisting their campus change efforts and advancing their careers to roles such as department chair, dean, and provost. Many disciplinary societies offer leadership training at their annual meetings. Some faculty members have developed their leadership skills by participating in regional and national STEM reform networks such as SENCER (Science Education for New Civic Engagements and Responsibilities; see http://www.sencer.net), BioQUEST (http://bioquest.org), and POGIL (Process Oriented Guided Inquiry Learning; see https://pogil.org). Each of these networks provides different opportunities for developing leadership skills, mostly through the lens of projects related to undergraduate STEM reform.



LEADER REFLECTION QUESTIONS

- What aspects of this stage went well? Where did you encounter challenges? Were you able to overcome them? If so, how? If not, why not?
- What important team and/or institutional values did you uncover?
- What did you learn about what your campus does well and can further leverage?
- How well is your team functioning? How are you empowering and rewarding the team’s work? Are there any issues—communication, collaboration, commitment, capacity? How are you addressing these challenges?
- What were your leadership challenges? What were your leadership successes?
- Overall, how well do you think the team executed this stage of the process? What might you do next time to improve?

Campuses that are successful in reforming STEM typically send faculty members to professional development opportunities to gain the skills required to lead change processes. Faculty leaders, department chairs, and deans may also realize greater success when they "lead up" by creating short talking points to help higher-level leaders speak with authority about STEM education and/or campus projects. Additionally, senior leaders are needed to change reward structures, help with resources, and provide infrastructure, such as professional development or outcomes assessment to support long-term changes. Senior leaders are more likely to be supportive when they see the initiative is aligned with institutional goals. We found that campus teams were much more successful when they identified institutional priorities and aligned their STEM reform efforts with institutional goals.

Sustaining Change

In the long term, the goal is to build programs that have an impact and can be sustained using campus resources. Grants and other one-time funding opportunities provide useful catalysts for planning and pilot testing, but the goal is to move toward systemic programmatic and cultural changes that result in improved outcomes for students, particularly those from underrepresented minority groups. Sustaining change requires institutions to address infrastructural issues—policies, procedures, funding models, faculty and staff capacity, incentives and rewards—that will either impede or enable the desired changes. For example, in promoting interdisciplinary curriculum development, the team needs to examine policies and committee processes that govern curriculum review procedures to ensure that cross-departmental proposals won't be held up in committee for lack of a process to seek proper input and consultation (Kezar and Elrod 2011; Project Kaleidoscope 2011b). An often-cited barrier to STEM reform is the lack of attention paid to this type of work in the faculty promotion and tenure review process, which is largely determined by university policies but allows for departmental influences and specificity. Creative campus leaders must find ways to encourage, empower, and reward faculty members who engage in efforts to improve undergraduate STEM education.

Continued faculty engagement is key because change processes are never complete. Student success issues are continually shifting as new groups of students come to campus, new research on learning is published, new curricula are developed, and advances are made in our understanding of the factors that affect student success. Campuses need to review the data on an ongoing basis as the barriers to student success may change or the best resources to create a quality education may evolve. Sustaining change also requires constant learning about student success. In recent years, there has been a shift in higher education circles from seeing change as a one-time event to seeing it as an ongoing process of improvement. We encourage leaders to see the process described here as something to revisit over time, not something to use in a single instance.

Case Studies

Case studies from participating campuses are featured in the next section, which describes the stages of the Keck/PKAL Systemic Institutional Change Model in detail. We use examples from the case studies to illustrate the process and outcomes. Full case studies are available as a downloadable PDF at www.aacu.org/pkal/keck/case-studies.

In order to set the context for readers, we briefly provide an overview of each of the cases, which we have presented in order of increasing institutional engagement and complexity:

- The team from the **University of La Verne**, a private Hispanic-Serving Institution in the Los Angeles area, focused on improving the preparation of biology majors for capstone experiences and increasing retention rates in the major. These efforts resulted in specific first-year course and program revisions that leveraged a university-wide program for underprepared students.
- Participants from the **W. M. Keck Science Department**—a joint science department of Claremont McKenna, Pitzer, and Scripps Colleges in Southern California—concentrated their efforts on improving underrepresented science student success by establishing a one-week summer bridge program that introduced students to the excitement of science and to the expectations and demands of college-level science coursework.
- The goal of the **California State University–Fullerton** (CSU Fullerton) team was to develop and institutionalize professional development programs for all faculty in the College of Natural Sciences and Mathematics. These programs focused on engaging faculty members in the use of methods referred to as "scientific teaching" in order to catalyze reform.
- Participants from **San Diego State University** focused their efforts on scientific literacy in general education courses. They used a concept inventory instrument to measure learning and then correlated their findings to a variety of variables in an effort to understand what factors were contributing to students' completion of the scientific literacy requirement. Using this new understanding, they redesigned courses in ways that improved general education learning outcomes.
- **California State University–East Bay (CSU East Bay)** faced demand from the local community to create more STEM graduates. In 2009, CSU East Bay launched a new initiative and vision to become a quality STEM-centered institution. This vision extends to enhancing K–16 STEM education by working with schools and community colleges. Their case involved creating an Institute for STEM Education.
- The **University of California–Davis** established their iAMSTEM office as a center that would focus on improving undergraduate STEM education. The project team focused their landscape analysis on the development and use of new tools for analyzing the placement and progress of students in introductory courses. These data informed the development of teaching assistant training, faculty development programming, and additional content-based assessments that would improve introductory students' outcomes.
- **The California State University Chancellor's Office** developed a shared vision focused on promoting effective STEM education across the twenty-three campus system that would better prepare their diverse student body to meet the challenges and opportunities in our global society. Project participants implemented a strategy that resulted in increased resources and programs to support the vision.

Descriptions of the Model Stages

This section describes each stage of the Keck/PKAL Model for Systemic Institutional Change in STEM Education in detail and provides key benchmarks, planning questions, highlights from campus case studies, tools specific to each stage, challenge alerts to help leaders anticipate common roadblocks, timeline considerations, and leader reflection questions. Other tools for facilitating teamwork appear in the appendix. Here, we remind team leaders that they should begin their work at the most appropriate place within the model (see "Getting Started," page 11). Remember to start small and build to scale.

We have also provided all the benchmarks in rubric form (see table 3) to guide project development using the model. A score of eight indicates that a campus team is at the very beginning stages; a score of twenty-four indicates that the team is already at a very advanced stage of work.

Table 3. Systemic Institutional Change Rubric

Model Stage	Benchmark			Score
	Developed (3 points)	**Emerging (2 points)**	**Initial (1 point)**	
Establish Vision	The campus has a well-defined statement that describes a collective vision for improving STEM student learning and success (which may include overarching outcomes like quantitative reasoning). The vision includes clear goals for efforts as well as specific outcomes and measures, and is linked to institutional mission and priorities.	Individual units may have statements that relate to STEM student learning and success; however, these statements are not coherent across relevant units or tied to institutional mission and priorities.	The campus has not developed a vision or goals for STEM student learning and success, although isolated courses may have these goals. There also may not be a campus-wide vision for student learning and success.	
Examine Landscape and Conduct Capacity Analysis	The campus team has developed a clear picture of how students are performing in classes and programs, as well as of their STEM degree attainment, by examining who is coming in, staying, and graduating; what students are learning; how faculty members are teaching and how students are learning; how students are moving into and through the institution; how students are interacting with faculty members; what roadblocks students are facing; and what programs or other factors facilitate students' progression.	The campus has capacity for collecting and analyzing data but has not fully analyzed or disaggregated for STEM programs and courses, and has not included STEM faculty and administrators in discussion of data.	The campus has not yet collected or analyzed data on student learning or success; it may not have the staff or other resources to collect and analyze data.	
Identify and Analyze Challenges and Opportunities	There may be specific challenges regarding STEM student success have been articulated and supported by evidence. Particular programmatic or institutional opportunities that might be leveraged have been recognized.	Campus leadership may have a desire to implement one or more strategies, but these are not connected to the evidence regarding student learning and success indicators; a few opportunities have been identified, although some may not be directly applicable.	There is a general lack of awareness among faculty members and/or administrators regarding effective practices for promoting STEM student success; the campus has not identified any opportunities that might be leveraged.	
Choose Strategies and Interventions, Leverage Opportunities	There may be specific strategies or programmatic interventions have been identified. These strategies or interventions address the gaps or needs clarified through the landscape analysis and are focused on the vision.	Programmatic strategies or interventions are not fully developed or do not address needs identified through the landscape and capacity analysis.	Strategies have not been identified or developed.	
Determine Readiness for Action	The campus has identified and obtained the faculty, staff, financial, physical, and cultural resources to implement the selected strategies.	Some resources have been identified, although the campus may not have obtained all the needed resources.	No analysis or identification of resources has been completed.	

Model Stage	Benchmark			Score
	Developed (3 points)	**Emerging (2 points)**	**Initial (1 point)**	
Begin Implementation	The campus has carried out at least one pilot or small-scale implementation of the planned strategy and has collected adequate assessment data to monitor effectiveness, make improvements, and inform scale-up.	Plans are not complete; scattered or isolated attempts at strategies may have been made by individuals or in single courses.	No plans to implement exist.	
Measure Results	Key data have been collected and analyzed to help the campus evaluate how well the plan worked, where it may have failed, and how it might be improved for the next round of implementation and eventual scale-up.	Implementation has occurred; however, little or no data has been collected. The dataset may be incomplete; if data has been collected, it may not have been analyzed.	No data has been collected or analyzed.	
Disseminate Results and Plan Next Steps	Descriptions of project purpose, methods, and results have been documented in various formats and venues, such as websites and newsletters, social media sites, campus presentations, community news articles, conference presentations, and published papers. Plans are in place for modification, improvement, and/or scale-up.	Some descriptions of project goals and results may be available in project, department, or college reports or campus website, but these descriptions are not widely available across campus or beyond. Planning for next steps may be incomplete, missing assessment data or other details, including those required for scale-up.	Very little information about the project is available to campus stakeholders beyond those engaged in the process. No plan exists for applying lessons learned to future program implementation.	
TOTAL (Sum Score Column)				

Part 2

ACHIEVING SYSTEMIC INSTITUTIONAL CHANGE

This section describes each stage of the Keck/PKAL Model for Systemic Institutional Change in STEM Education in detail and provides key benchmarks, planning questions, highlights from campus case studies, tools specific to each stage, challenge alerts to help leaders anticipate common roadblocks, timeline considerations, and leader reflection questions. We have also provided other tools to facilitate teamwork in the appendix. Full case studies are available as a downloadable PDF at www.aacu.org/pkal/keck/case-studies.

Here, we remind team leaders that they should start from the most appropriate place within the model (see page 11 for information about "Getting Started") and should start small and build to scale. The systemic institutional change rubric (table 3, page 24) describes the benchmarks for each stage of the Keck/PKAL model.

◆ STAGE ONE: ESTABLISH VISION

Benchmark

The campus has a well-defined statement that describes a collective vision for improving STEM student learning and success. The vision includes clear goals as well as specific outcomes and measures, and is linked to institutional mission and priorities.

Questions to Ask When Considering This Step

1. Is the vision articulated in a way that will be clear to internal and external stakeholder groups?
2. Is the vision aligned with institutional goals?
3. What current leaders does the campus have with respect to STEM education and what ideas are they enthusiastic about moving forward?
4. What are the key trends that should guide the vision of student success?
5. What assets does the campus have that can be capitalized on for creating a vision?

It is important to start with a clear vision of the campus's purpose for improving undergraduate STEM education. Depending on how the campus works, it may be better to frame the vision in terms of goals for reform. The vision is most powerful when it is constructed by a diverse team of leaders, faculty, and staff from STEM departments and throughout the institution. It should also be aligned with campus priorities or initiatives for undergraduate learning or success that are connected to and have support from the central administration, deans, and department chairs.

From listening to observations shared by the eleven campus teams in the project, we learned that developing a vision or goals takes longer than expected and that it typically cannot be done in isolation from a landscape analysis. A team can define an initial vision, but it may have to return to and alter that vision after data gathering and analysis. Spending the time to talk as a team and develop a common understanding of (or set of descriptors for) the issues surrounding a project is an important part of vision development. Most teams believed that they could develop a vision in a couple of meetings, but this turned out to be a false assumption. Creating a vision, particularly if campus constituents have not had conversations about STEM student success, usually requires shared, deep exploration of the issues where team members read some common documents, reports, or research on the issue and explore campus data together. Exploration during an extended period of conversation (six to eight months) or in several focused retreats where people engage in these activities can be effective. However, it is critical that this process not be so long or intense that team members lose focus. All the case studies illustrate this point, but the California State University (CSU) Chancellor's Office and the CSU Fullerton case studies in particular illustrate the importance of taking time to create a vision.

Most campus teams also learned that creating a strong vision comes from conducting a careful landscape and capacity analysis. One of our major goals was to introduce ideas from broad national efforts to inform campus teams participating in the project. Many of our campus teams used national reports and research, such *Vision and Change in Biology Education* (American Association for the Advancement of Science 2011) or *Expanding Underrepresented Minority Participation* (National Academies 2010a), to help create their visions.

"Understanding current work related to supporting student success as well as existing gaps, exploring data that might help campus teams understand problems or successes, and understanding the history related to STEM reform efforts are all necessary steps in creating a meaningful landscape and capacity analysis."

Understanding current work related to supporting student success as well as existing gaps, exploring data that might help campus teams understand problems or successes, and understanding the history related to STEM reform efforts are all necessary steps in creating a meaningful landscape and capacity analysis. The landscape and capacity analysis helps teams consider an appropriate vision given their history, current efforts, and data identifying trends of which they may have been unaware. Thus it is important to see the landscape analysis and vision process as very much tied together. The interplay of the landscape analysis and vision is described in the case study highlights below.

Many campuses started their work believing that they had created a vision, but as they encountered other information (i.e., learning about past efforts or learning from others across campus) they either broadened or reconsidered their visions. Faculty members may have different perspectives on student success because they are focused on a narrower bandwidth of programs than the dean of undergraduate studies, who looks across all programs. The case studies include examples of campuses that altered their initial visions, often because they did not conduct a careful enough initial landscape analysis. That is why the model emphasizes the iterative process between the landscape analysis and vision.

Ultimately, the vision process is about developing not just a direction, but also a common language that everyone understands. A common language is important so that people can communicate clearly and teams can create buy-in that helps build enthusiasm for the change. Campus teams mentioned that being flexible with the vision and allowing it to change over time as new ideas or opportunities emerged was important.

Building a larger vision that went beyond the typical focus on looking for one or two best practices was also a challenge for our eleven teams. Getting team members to think beyond a narrow vision where something like undergraduate research was the sole intervention took time. We asked teams to consider the many opportunities to improve STEM education and to consider a range of issues that might help inform their vision of STEM student success. Some examples of opportunities and issues are listed below.

Examples of opportunities to improve STEM education include

- K–12 partnerships and outreach that might assist with recruitment;
- developments in evidence-based teaching practices (e.g., Process Oriented Guided Inquiry Learning (POGIL), Peer Led Team Learning (PLTL), Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP), Classroom-Based Undergraduate Research Experiences (CUREs);
- use of other high-impact practices (Kuh 2008), such as learning communities, service learning, and undergraduate research;
- STEM-specific orientations, summer bridge programs, and other summer programs;
- advising practices and partnerships with student affairs;
- tutoring and supplemental instruction programs;
- analysis of introductory course learning and student persistence data;
- curricular goals alignment and mapping;
- assessment of student learning and progress;

- faculty professional development;
- transfer agreements and approaches;
- mentoring opportunities from both peers and faculty;
- peer learning opportunities (e.g., study groups and clubs);
- remediation in both English and math, and consideration of math requirements;
- partnerships with industry or business for research but also career connections;
- internships and co-ops;
- differential tuition policies for different STEM disciplines;
- reverse transfer policies;
- facilities that support active learning, including through hybrid learning environments and uses of technology.

Selected issues that might inform a vision of STEM success include:

- inclusiveness and stereotype threat;
- student self-efficacy and development of scientist identity;
- departmental culture(s);
- campus curricular policies;
- policies and procedures that affect students' progression through a major or transfer articulation.

We noted in the introduction that most national STEM reform reports speak to the importance of supporting all students, with particular attention to URM students who show interest in STEM but are leaving STEM disciplines at much higher rates than other populations. When thinking through a STEM vision, it is important to consider how many of the opportunities—summer bridge programs, intensive advising, mentoring, high-impact practices—have been identified through national studies as helpful for URM students. Learning more about practices and opportunities that support these populations is an important step when developing the vision and later when considering interventions.

Another issue to address when establishing vision is whether the goal is STEM reform for STEM majors or STEM reform for all majors. We encourage campus teams to think broadly, because STEM literacy is low nationally and most national reports addressing the topic call for work to improve STEM knowledge among all college graduates. Some campuses participating in this project focused reforms on STEM majors only, while others had a broader vision that included nonmajors. But it is important for campus teams to at least consider the multiple levels at which STEM reform might take place. For efforts focused on nonmajors, projects such as SENCER (Science Education for New Civic Engagements and Responsibilities) (http://www.sencer.net/) offer resources for reforming general education science courses.

"Most national STEM reform reports speak to the importance of supporting all students, with particular attention to URM students who show interest in STEM but are leaving STEM disciplines at much higher rates than other populations."

Case Study Highlights

The campus case studies included the following example vision statements:

- "The vision for the…project is to develop a culture in which instructors use evidence-based, scientific approaches to teaching and student learning in classroom, online and laboratory instruction in courses across the curriculum." (**CSU Fullerton**)
- "Our goal for the project was to properly scaffold these skills (learning how to ask questions, formulate hypotheses, carry out experimentation, analyze data, and present research in lower-stakes environments) to improve retention and help prepare our students for the capstone and beyond." (**University of La Verne**)
- "Our vision is to contribute 'to the advancement of effective STEM education across the CSU, so 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.'" (**CSU Chancellor's Office**)

Campus teams facilitated their vision process through some of the following practices:

- The **University of La Verne** team aligned their STEM vision with an emerging strategic plan and the priorities of a new campus president. This allowed them to acquire institutional resources and support for their ideas.
- The **CSU East Bay** team created an institute that brought together educational researchers and STEM faculty members to develop a common vision. Team members also developed an advisory board to help with vision development and obtained both external and internal resources to support their vision.
- The **CSU Chancellor's Office** team held an all-day retreat and brought in a consultant to help them develop and define the vision statement.
- The **W. M. Keck Science Department** team and other campus teams took advantage of grant funding to provide the time and resources needed to solidify a common vision.

Challenge Alert

- **Manage leadership turnover.** Leadership turnover in the early phases can be particularly disruptive and needs to be engaged with care. At the CSU Chancellor's office, the initial team leader left after the project started. This loss left the team without a champion to lead the vision discussions. Team members resolved the issue by continuing to meet and share the leadership role until another leader came on board.
- **Move toward a shared vision.** For many institutions, members of the team will have different ideas for a vision, and these may be implicit or not yet articulated. The CSU Chancellor's office experienced difficult initial meetings until team members discovered one issue upon which they could all agree—the value of high-impact practices. Once they had agreement around that issue, they decided to look at data related to it, which helped them move toward a collective vision.
- **Refresh a stale or static vision.** The CSU Fullerton case study demonstrates that even though campus stakeholders had been working in STEM reform for fifteen years, the project team did not have an updated vision to guide them forward in their current work. The visions that campus stakeholders had developed for past projects led team members to falsely believe they knew where to go next, but in reality they had to stop and develop a new vision.

- **Avoid a singular or top-down vision.** The CSU Fullerton case also illustrates that when a vision is largely driven by a single individual, such as a dean or a department chair, it may not gain traction until others on the team have the time to understand and buy into it. The UC Davis vision emerged from the provost's office and, despite support from the administration, the project team had less faculty buy-in than anticipated at the beginning, which resulted in slow initial progress.

Timeline

The vision process typically takes six months to a year, but it can take longer if data on STEM student success is lacking. We recommend tying this phase to a careful data landscape analysis; otherwise, the team will likely need to return to the vision process anyway after finalizing the landscape analysis.

STAGE TWO: EXAMINE LANDSCAPE AND CONDUCT CAPACITY ANALYSIS

Benchmark

The campus team has developed a clear picture of how students are performing in classes and programs, as well as of their STEM degree attainment, by examining who is coming in, staying, and graduating; what students are learning; how faculty members are teaching and how students are learning; how students are moving into and through the institution; how students are interacting with faculty members; what roadblocks students are facing; and what programs or other factors facilitate students' progression.

Questions to Ask When Considering This Stage

1. What data do the campus regularly collect and analyze (e.g., retention and graduation rates, National Survey of Student Engagement results, Cooperative Institutional Research Program Freshman Survey data, Higher Education Research Institute faculty survey responses), disaggregated for various populations, particularly underrepresented minorities and first-generation students? Can these data be leveraged for learning more about the challenges regarding STEM student learning and/or success?
2. Are faculty (and relevant staff and administrators) aware of the issues revealed by the data and landscape analysis? Are they interested in discussing these issues? Do they see the problem(s) the data reveal?
3. What kind of learning environments and opportunities do students currently experience?
4. What structures are in place to support curricular revisions and pedagogical innovations?
5. Are there faculty members who are already engaged in STEM education research or faculty development?

“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’ and ‘research-based instructional strategies.’ 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.”

—CSU Fullerton Cases Study

6. Are there existing initiatives devoted to student success initiatives on campus? Are there grant or other proposal opportunities that the team can leverage to obtain seed funding for STEM reform?
7. Has the student affairs division created programs that target student success more broadly (e.g., summer bridge or early start programs)? How can the division’s expertise be leveraged?
8. What is the existing climate for change? Have other change processes (e.g., general education reforms, outcomes assessment initiatives) been carried out on campus? If so, how successful were they, and what challenges did they face?

The two primary stages in examining the landscape are (1) a review of institutional, program, and/or course data, including analysis of existing curriculum maps, learning environments, and pedagogical approaches; and (2) an external review of national reports, science education literature, and/or projects reported by representatives from other campuses at conferences on STEM education. This stage helps campuses home in on specific problem areas (e.g., first-year retention, transfer student isolation, matriculation through introductory course series, etc.) in order to focus implementation strategies on addressing gaps and problem areas that may lie at the root of the problem to be solved. This stage is important to help the campus team identify the campus’s specific issues and challenges, but also to help the team gather data that will generate motivation for change, result in buy-in from faculty members, and garner support from administrators. This stage also requires a continual process of gathering resources and information in order to establish a good baseline and monitor progress.

The first stage is data gathering and analysis. Table 4 lists types of data that campus teams may find useful in conducting a landscape analysis to better characterize the terrain of STEM education on the campus. Other examples are listed on AAC&U’s STEM Assessments website (https://www.aacu.org/node/5623). The most successful teams partnered with institutional researchers and assessment experts early on to collect, mine, and analyze relevant data. It is important to obtain senior leadership support in order to get access to appropriate data for examining student success. An example of a successful data-driven effort from outside the project is an introductory course redesign effort at Wofford College, where a department champion used both departmental and institutional data to catalyze and evaluate efforts (Goldey et al. 2012).

Table 4. Types of Data Commonly Used for Conducting a Thorough Landscape Analysis

Type of Data	Example	Purpose
Student demographic data	High school attended, high school GPA, SAT/ACT score, remedial math and English test scores/placements, cumulative college GPA, major GPA, URM (underrepresented minority) and/or first-generation status, Pell eligibility	Understand basic characteristics of students who enter the program (where they come from, their backgrounds, etc.) to identify possible target populations or risk factors
STEM major retention and graduation data	Data on enrollment, retention, and graduation by ethnicity, gender, and other factors of interest	Understand nuances of student success, differences among populations, progression, etc. to identify gaps
Introductory course completion and progression data	Average course grades, DWF (D grades, Withdrawals, F grades) percentages, analysis of student enrollment in subsequent courses in series	Identify course-specific issues to determine specific roadblock populations, gaps in courses, etc.
Direct assessment of student learning in courses and programs (formative or summative)	Personal response systems used in class (i.e., "clickers"); concept inventories and corresponding learning gains calculations (see, for example, Hake 1998); Educational Testing Service (ETS) Major Field Tests, using scoring of embedded exam questions or common exams; large-scale review of signature assignments using AAC&U's VALUE or other rubrics; use of rubrics to assess poster presentations of research projects	Probe student learning at a deeper, programmatic level, using agreed-upon outcomes to identify gaps in learning, particularly related to important prerequisite knowledge
Indirect assessment of student learning or experiences	Institutional surveys, such as the National Survey of Student Engagement (NSSE) and the Cooperative Institutional Research Program (CIRP) Freshman Survey; end-of-course surveys such as Classroom-based Undergraduate Research Experience (CURE), Summer Undergraduate Research Experience (SURE), Colorado Learning Attitudes about Science Survey (CLASS), Student Assessment of Learning Gains (SALG), and IDEA surveys; alumni surveys	Gather student or alumni feedback on their experiences in the program to identify positive practices or those that may need improvement
Program effectiveness documentation	Program review documents, accreditation self-studies, curriculum maps, outcomes assessment plans, faculty workload analysis, and alumni interviews and tracking	Determine program effectiveness; demonstrate how students move through the curriculum; evaluate faculty workload issues; connect program outcomes and assessments to institutional priorities.
Student participation in special programs (summer bridge, advising, research, etc.)	Program tracking and evaluation reports, student surveys, interviews, and focus groups	Understand who is participating, how often, and whether participation makes a difference; also understand program effectiveness to make improvements
Data on faculty attitudes and teaching practices	Faculty Survey of Student Engagement (FSSE), HERI Faculty Survey, Attitudes about Teaching Inventory (Trigwell and Prosser 2004), and others (e.g., Marbach-Ad, Schaefer, and Thompson 2012)	Use as an indicator of receptivity or readiness of faculty to participate in a change project; determine gaps between faculty expectations and student experiences, especially when paired with student surveys such as NSSE; determine the types of professional development programs necessary to develop faculty expertise needed for change
Measures of effective teaching	Course portfolios created by faculty members; classroom observations of instruction, such as RTOP (Reformed Teaching Observation Protocol); resources such as the National Association of Geoscience Teachers' *What Is Reformed Teaching?* (NAGT 2012), COPUS (Classroom Observation Protocol for Undergraduate STEM, described by Smith et al. 2013) or the Teaching Dimensions Observation Protocol (http://tdop.wceruw.org); other methods described in *Describing and Measuring Undergraduate STEM Teaching Practices* (American Association for the Advancement of Science 2014)	Determine if faculty are employing the most effective evidence-based teaching practices
DBER (Discipline-Based Education Research) activity	Documentation of faculty publications in science education journals, federal or other grants obtained for science education research and development projects, and presentations at science education conferences	Use as an indicator of faculty capacity, receptivity, and readiness for change

Note: For all of the above, data should be disaggregated using various parameters—underrepresented minority status, first-generation student status, gender, Pell eligibility, first-time full-time student status, transfer student status, etc.—to obtain the clearest picture of student success. Cohort studies provide the best data for comparisons of populations over time.

PROJECT REFLECTIONS

Faculty buy-in, ownership, and commitment are required for long-term implementation and continuous improvement. One of the ways to create greater buy-in, leadership, and ownership is to create a learning community on campus among faculty.

In their landscape analyses, campus teams looked at data from their own campuses while also considering external stakeholder issues, such as high school and community college preparation or matriculation, as well as broader trends in STEM student success, strategies and ideas for change, and important trends for the future identified in national reports, such as the *Engage to Excel* report (PCAST 2011). As noted above, the data should be disaggregated by race, gender, ethnic, and first-generation status in order to best support students. Examples of processes and projects that have broken out data by race, ethnicity, and gender are the Equity Scorecard (http://cue.usc.edu/our_tools/the_equity_scorecard.html), the Campus Diversity Initiative (http://irvine.org/evaluation/program-evaluations/campus_diversity_initiative), and Achieving the Dream (http://achievingthedream.org/). We also invited speakers to the annual project meetings and conducted webinars where experts shared data on STEM assessment, student success, improving support for URM students, data analytics, and the national PULSE initiative (Partners for Undergraduate Life Science Education, http://www.pulsecommunity.org), among other topics. Our project website (http://aacu.org/pkal/educationframework/index.cfm) includes links to presentations, reports, meeting resources, and webinars that might inform a campus's efforts.

In order to fully understand the campus capacity for change, campus teams should consider the following issues:

- **Identification of expertise.** An important aspect of landscape and capacity analysis is gauging the receptivity and capacity of faculty, staff, teaching assistants, and departments for change. There are several approaches to determining receptivity, such as characterizing current STEM education grant activity, publications, or participation of faculty members in campus-based faculty development workshops and activities. Some of the campus teams conducted faculty surveys to determine the faculty's use and awareness of STEM reform resources. Most campus teams found that past change efforts helped signal readiness and could assist the teams in understanding problems and moving forward. Campus expertise can be found through researching a variety of resources, including previous STEM education grants (NSF's past programs, such as Course, Curriculum, and Laboratory Improvement; Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics; and Improving Undergraduate STEM education) publications, discipline-based education researcher faculty, science faculty with education specialties faculty, and collaborations with education faculty regarding K–12 teacher preparation. In addition, the current landscape of faculty leadership can also affect readiness for change. Some campus teams held informal discussions with faculty about their views of an initiative. By identifying receptive faculty, campus teams can help establish a broader foundation for more successful and sustainable reforms.
- **Gauging faculty receptivity and achieving buy-in.** Creating faculty learning communities, or groups that meet regularly to discuss a common area of practice (e.g., using active learning or service learning in the classroom), is a powerful practice for obtaining buy-in. In these communities, faculty members meet monthly to discuss a new report, published paper, or other resource and apply the new knowledge to their classrooms and programs. They share advice and learn from each other. Many campuses have used learning communities to create readiness for reform. Other approaches include creating a speaker series, offering STEM education–focused workshops, providing faculty minigrants, and conducting surveys on faculty practice or

mining existing surveys such as the Faculty Survey of Student Engagement (FSSE), the Higher Education Research Institute (HERI) Faculty Survey, and others.

- **Inviting and empowering the willing.** In addition to determining awareness or buy-in, it is also important to understand who might be willing to take a leadership role or be a champion in the effort. Without leadership, the effort is unlikely to move forward—so determining who is willing to play a leadership role is critical. It is often helpful if senior faculty will support junior faculty who are experimenting with their teaching, for example.
- **Leveraging campus-wide initiatives.** Furthermore, as part of the landscape analysis, STEM leaders reviewed university initiatives (accreditation efforts, campus-wide commitments to establish and review service-learning objectives, service-learning initiatives, tablet/technology initiatives, graduation rate initiatives, university first-year readings, etc.) that could be aligned with their STEM vision and effort. For example, the University of La Verne leveraged a campus-wide initiative, the La Verne Experience, which focuses on engaging students across the entire campus.
- **Partnering with students.** Too often, students are left out of the planning process when faculty members and administrators are designing new initiatives or programs. But students may have some of the best insights and ideas for reform. When new programs are launched, students also need to be informed about the goals and approach of the new venture so they understand why it is important and how they might best perform in the new environment.

Case Study Highlights

Almost all of the teams noted that review of data and information was limited, and that building buy-in, leadership capacity, and momentum for change was the most significant aspect of the work.

- Both **San Diego State University** and **CSU East Bay** had their deans of undergraduate studies act as administrator on their respective teams. These individuals played key roles in helping faculty understand the breadth of data sources available to them and the meaning of the data, and they assisted with additional data collection. Faculty members also helped administrators better understand their concerns and the specific issues related to STEM student success (as opposed to general student success).
- **UC Davis** was a very strong case study for landscape and capacity analysis. The campus team examined a very broad spectrum of data, ranging from incoming student characteristics, placement exam scores, retention rates, and time to graduation, disaggregated by ethnicity and first-generation student status. The team also found that faculty members were skeptical of the trends that their data analysis revealed because these trends were antithetical to their existing beliefs about how well students were progressing. Therefore, the team had to work harder to develop understanding and gain buy-in. Through their analysis of capacity, team members identified the need for better data and tools for sharing data, a lack of accountability for using data, and little communication about data. Their revised vision returned to focus on data tools because they recognized that was where they had weaknesses. They also realized that having robust data would be essential for obtaining faculty buy-in.
- The **CSU Chancellor's Office** engaged in the landscape and capacity analysis by getting feedback from system-wide stakeholders via survey, by drawing on system-

wide graduation initiative data, and by analyzing data on high-impact practices. The team held a retreat to review all the data; this event helped them reach their ultimate vision, which did not emerge until after landscape analysis. Team leaders brought in a consultant for the retreat to help participants navigate the discussion and to engage divergent voices. The strategies the team eventually developed came out of the data they collected from stakeholders. One of the team's capacity challenges was engaging faculty members and administrators on a diverse set of campuses across the state while also respecting their individual campus missions and cultures.

- Due to the breadth of the STEM vision and challenge they took on, the **CSU East Bay** team conducted an extensive landscape analysis that included the review of high school and community college data on student preparation in math, remedial education needs; graduation rates and data from their own institution; course pass rates in pre-algebra and remediation in English. This helped team members refine their vision and focus funding requests.
- The **CSU Fullerton** team used faculty surveys to identify what teaching practices—particularly those described as evidence-based—the faculty were using. These data helped the team understand their campus's specific needs for faculty development. The team also looked at DWF rates for bottleneck courses (classes that students need to graduate but cannot get into easily because of enrollment demands), as well as student demographics.
- The **University of La Verne's** campus team conducted an extensive landscape analysis that involved analyzing retention rates in biology. After finding that attrition was higher than expected, the team developed a new understanding of their challenges.
- The **W. M. Keck Science Department** collected extensive math- and science-course retention data that they examined for all of their science students. They disaggregated the data by race and gender, which is an important stage for any campus. They found, among other things, that SAT scores correlated with chemistry performance and retention and thus were a good predictor of student success in this discipline.

Challenge Alert

- **Avoid rushing ahead despite lack of buy-in or capacity.** A common pitfall was moving ahead with a new program or project with only a few engaged faculty members. While this may be sufficient to conduct a small pilot, without broader buy-in, a pilot may be as far as the project goes—especially on small campuses. In addition, one very vocal champion with expertise may overwhelm newcomers to the work. Spending time developing a common language and vision for the project can help expand faculty buy-in and project capacity.
- **Include diverse perspectives on data.** Diverse teams can develop complex interventions and solutions, but the presence of diverse perspectives can also make it difficult to interpret and make sense of the data. After encountering such difficulties during the vision process, the CSU Chancellor's Office team decided to bring in a consultant to help them interpret the data they had collected.
- **Fill in the data vacuum.** Several institutions realized that the data they wanted was not being collected. For example, CSU Fullerton realized they did not have data on faculty teaching practices, so they conducted a faculty survey. Most science and mathematics faculty members have little experience with institutional data or social science research methods. Therefore, it's important to develop a relationship with

the institutional research office or a social scientist on campus who is more familiar with data collection.

- **Beware data overload.** It is easy to get bogged down in the process of exhaustively collecting data, especially if the team isn't focused on clear goals. This can paralyze the team, so be strategic when choosing analyses.
- **Prepare for data threat.** The landscape analysis can be political when the time comes to identify problems. Nobody wants to be singled out as the problem when data on high-failure-rate courses is presented. Sensitivity must be used when presenting data so that it does not pose a threat to people. Most faculty members care deeply about student success and should be respected for their dedication. If people personalize the data, it can paralyze the process. The data may also contradict what people anecdotally think or believe, so leaders must be prepared for dissonance to arise in the group around discussions of data.
- **Get team members' heads out of the sand.** Ignoring what the data say in favor of commonly held beliefs was another stumbling block. The data often tell truths that are difficult to accept. However, remaining objective and open to the problems that the data analysis reveals is important for creating a realistic view of the situation on campus.
- **Disclose secret data.** Some campus leaders are reluctant to share data, either because they fear that data will be disseminated beyond campus or because they don't want to reveal weaknesses beyond a small group of insiders on campus. There may be good reasons for their fears; however, more and more campuses are making data public in an effort to demonstrate that they are addressing problems. Some accreditation processes may also require data disclosure.
- **Manage the data.** Once data has been collected, it needs to be organized, managed, and prepared for presentation. Again, teaming up with institutional research offices or social scientists who are more experienced with data organization and management can be helpful. This is also were a project manager may be helpful.
- **Build a robust institutional research infrastructure.** Many teams recognized that their institutions had poor data infrastructures with respect to STEM-specific data. Institutions typically collect and analyze data across the entire campus, not on specific programs. The UC Davis team realized that their campus had a poor data infrastructure regarding STEM-specific data. Finding that they could not do the landscape analysis they thought would be most useful, they built a more robust system. This isn't always possible, but engaging institutional research offices early may help team members see how they can best help the STEM reform project. For example, the CSU Chancellor's Office is developing a system-wide data dashboard that will now contain a STEM-specific dashboard.

"The data often tell truths that are difficult to accept. However, remaining objective and open to the problems that the data analysis reveals is important for creating a realistic view of the situation on campus."

Timeline

The landscape analysis ideally occurs in concert with discussions related to vision (shown as the first reform eddy in figure 1 on page 9) and is therefore best conducted in the first six to twelve months of an initiative. If a campus has low data capacity, the landscape analysis and vision process can take up to two years. If the data environment is rich, it will help move the vision process forward faster. It is also important to leave time for experimentation and analysis as sometimes data has to be analyzed in several different ways to arrive at the right interpretation. Analysis of initial data may also reveal the need for other data, which may take time to obtain. Create an environment that allows for mistakes and trial and error as well as risk-taking.

◆ STAGE THREE: IDENTIFY AND ANALYZE CHALLENGES AND OPPORTUNITIES

Benchmark

The campus team's specific challenges regarding STEM student success have been articulated and supported by evidence. Particular programmatic or institutional opportunities that might be leveraged have been recognized.

Questions to Ask When Considering This Stage

1. Does the campus team have enough data to draw conclusions? What additional information might be needed? Are the data disaggregated by all relevant student characteristics (race, gender, socioeconomic status, etc.)?
2. What assumptions does the data analysis reveal regarding student learning and success?
3. What conclusions can be drawn from the data? What part of the program (precollege, particular gateway courses, developmental math courses, advising, etc.) is implicated by the analysis?
4. Where and for whom are there gaps in student success?
5. What opportunities (such as existing campus programs, grant opportunities, or institutional priorities) might be leveraged to address the challenges?

Using the data analysis, campus teams can identify specifically where problems and challenges lie in recruitment and retention efforts, program offerings (e.g., in course sequencing or prerequisite requirements), teaching and learning spaces, pedagogy, advising, academic support, and other areas. This stage will help teams evaluate the best possible strategies and interventions to implement in order to address the identified issues. Common challenges often relate to

- recruitment of students into STEM majors;
- retention of URM and/or first-generation students after the first and/or second years;
- the large number of students requiring remediation and/or lack of student success in remedial courses;
- outmoded pedagogy in introductory or core courses and/or spaces for active learning;
- lack of faculty development opportunities to improve STEM teaching;
- students taking courses out of sequence, leading to longer and more convoluted paths to graduation;
- unsatisfactory student learning in introductory or other core courses;
- lack of adequate academic support services;
- high course repeat levels leading to stalling of student progression through degree;
- transfer shock of community college students matriculating at four-year universities; and
- graduation rates that are lower than desired.

In addition to identifying particular challenges when analyzing campus data, campus teams can also look at the external landscape and their campuses' internal capacity for opportunities. In reviewing the external landscape, for example, the CSU Fullerton team identified the potential of intensive professional development by looking at models from the SPIN-UP/TYC (Strategic Programs for Innovations in Undergraduate Physics at Two-Year Colleges) program in physics (http://www.aapt.org/Programs/projects/spinup/). In terms of reviewing internal capacity, San Diego State recognized that regional accreditation requirements provided a strong push toward student outcomes assessment, and they could use their work toward regional accreditation to develop student learning outcomes in STEM. The University of La Verne team identified courses their institution had begun to redevelop and realized that they could expand and build on this initial STEM reform effort that already had some support. Most campuses benefited from building on their internal capacities and opportunities. The vast majority of campus teams were able to take advantage of external grant funding to catalyze their efforts. Local philanthropic or federal STEM education opportunities may help galvanize campus efforts and provide needed seed funding.

"In addition to identifying particular challenges when analyzing campus data, campus teams can also look at the external landscape and their campuses' internal capacity for opportunities."

Case Study Highlights

- By analyzing STEM retention data, several campuses identified gaps that disadvantaged URM students compared to white students. Analyzing retention data for cohorts of students may also reveal specific years in which drops in retention are most prominent. The **University of La Verne** team identified a retention problem in the second year of study, and this helped them identify where to focus their efforts. In the past, based on anecdotal student reports, they had implemented changes in the first year that made results worse for students. By examining data, they discovered the need to focus on the second year, where retention problems actually existed. They also moved from a content-based to a concept-based curriculum by examining trends related to students' prior work in high school and post-graduate needs.
- The **CSU East Bay** team's landscape analysis helped them identify a lack of preparation and engagement among students. As a result, the team determined that a focus on the development of STEM majors' English and math capabilities, along with a focus on additional supports for student engagement and persistence in STEM majors, might be a good place to start.
- The **UC Davis** team's landscape analysis helped the team identify gaps in performance between URM and white students and confirmed that success in the first five quarters is significant to overall success. The team confirmed that URM and first-generation status were predictive of failure to persist. The data also helped them see transfer shock among community colleges students coming to a four-year institution, problems of curved grading in large introductory courses, challenges in teaching assistants training, and problems with placement test practices.
- At **CSU Fullerton**, review of internal data demonstrated the need to collect more specific data about faculty pedagogical practices. As this case illustrates, review of the data sometimes leads teams to identify further needs for data collection to inform strategy development.

Challenge Alert

- **Avoid favoring assumptions over evidence.** Even when campus teams collect data, they can find themselves creating interpretations based on previous biases or assumptions rather than on what the data have revealed. This may be because they don't want to face the reality that there are problems with instruction, student preparation, or other aspects of their programs. It is important for the team leader to help continuously direct people back to the data so that the interventions and strategies they develop reflect reality rather than perceptions. Be very aware that politics can emerge quite significantly at this phase. Several campus teams encountered individuals who questioned the team's interpretation because it suggested they would have to do their work differently or pointed to problems in pedagogical or curricular practices. Again, a consultant or outside set of eyes is often important at this phase.
- **Manage debates about data quality or interpretation.** As noted in the landscape analysis section, data can be interpreted differently by people who come to the problem from different perspectives, and data can also point out problems that are threatening. Trying to identify challenges and solutions can often mean managing many different perspectives and spending time to create a shared vision about what the data say. As noted earlier, bringing in a consultant can be very helpful at this phase. Even after people reach a consensus about the data, they can begin to debate the quality of the information itself as a way to detract from the emerging interpretation. It is often difficult to obtain perfect data on any issue, so leaders must help teams take a rational approach to the existing data or identify new data that needs to be collected. Campuses can also bring in speakers from other campuses (including those that participated in this project) as a way to help people understand the quality of the data needed. Furthermore, outside speakers can speak to the challenge and, often, distraction of the debate about data quality.

Timeline

This stage often proceeds quickly as it emerges from the landscape and capacity analysis. Trends, gaps, and problems are revealed by the data and conclusions can be drawn within a matter of months.

◆ STAGE FOUR: CHOOSE STRATEGIES AND INTERVENTIONS, LEVERAGE OPPORTUNITIES

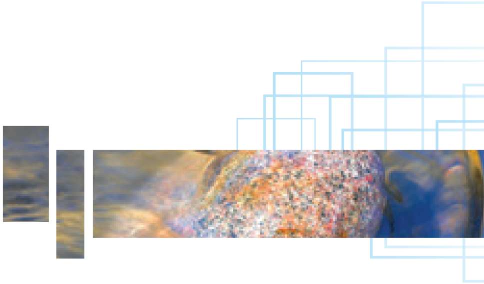
Benchmark

Specific strategies or programmatic interventions have been identified. These strategies or interventions address the gaps or needs clarified through the landscape analysis and are focused on the vision.

Questions to Ask When Considering This Stage

1. Has the campus team comprehensively and holistically examined the interventions needed so that unanticipated issues do not thwart the implementation? Are the interventions supported by data and directed at solving the issues or challenges the team has identified?
2. How does the chosen intervention map to the landscape and capacity analysis? How does it connect to the vision for STEM learning and student success?
3. What outcomes will be achieved as a result of the intervention? How will success be measured, based on data that has already been analyzed? What new data will need to be collected?
4. How much time is required to pilot, test, evaluate, and scale up?
5. Do the chosen interventions leverage existing resources, programs, and/or expertise?
6. How will the plan be communicated to internal and external stakeholders, including students?
7. Has approval from the school's institutional review board (or the appropriate campus ethics group) been attained for research involving human subjects? This is required if the team plans to publish results (see the box on "Institutional Review Board Approval" on this page).

This section describes documented, evidence-based strategies, programs, and interventions that have been described in the literature, national reports, or by campuses participating in this project. Table 5 (see page 42) provides a summary of common challenges encountered by campuses, along with associated interventions that address those challenges. For more general consideration of high-impact practices, see AAC&U's reports on the subject (Kuh 2008; Brownell and Swaner 2010; Kuh and O'Donnell 2013; Finley and McNair 2013). *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*, a 2012 report from the National Academies, is an extremely helpful resource for researching and implementing evidence-based reforms (http://www.nap.edu/read/13362/). The National Science Foundation's STEM Central website is also a useful resource (https://stem-central.net/projects/).



INSTITUTIONAL REVIEW BOARD APPROVAL

Almost all campuses have an institutional review board (IRB) that evaluates protocols for conducting research that involves human subjects. Most educational research that would be involved in STEM reform is typically categorized as exempt, although you should seek advice from the chair of your campus committee. *Approvals are generally required if you want to publish your results.* Committees typically have standardized templates and procedures that make the approval process straightforward. Many IRB committees work via e-mail and so can review protocols anytime.

Student data should be de-identified so it cannot be traced back to the student. To ensure anonymity, it is also best if a researcher external to the project or affiliated with your institutional research office collects and stores the data. Often, IRB procedures require students whose data will be analyzed to fill out a consent form that makes them aware of the type of data that will be collected and analyzed, and for what purpose. Students also have the option of opting out of the study if they have concerns.

Table 5. Summary of Challenges and Possible Interventions

Identified Challenge	Some Interventions to Consider
Low levels of incoming declared STEM majors	K–12 school outreach programs, engagement with local industry to sponsor robotics camps or other mechanisms to get students excited about STEM
Low retention and/or graduation rates	Summer bridge programs, first-year STEM orientation programs, introductory/gateway course redesign to improve student engagement and success, first-year learning communities, undergraduate research programs (e.g., the University of Texas at Austin Freshman Research Initiative, described at http://cns.utexas.edu/fri), other high-impact practices (Kuh 2008)
High levels of remediation and/or lack of student success in remedial courses	Course redesign using more interactive engaging pedagogies; focus on quantitative reasoning and/or statistics (see Statway and/or Quantway, described at http://www.carnegiefoundation.org/statway and http://www.carnegiefoundation.org/quantway); creation of intensive tutoring and/or supplemental instruction programs, such as the University of Missouri-Kansas City's International Center for Supplemental Instruction(http://www.umkc.edu/ASM/si/index.shtml)
URM student persistence and graduation gaps; outmoded pedagogy in introductory/core/gateway courses; less than desirable learning in STEM at any level	Evidence-based pedagogies (see National Academies 2012; Freeman et al. 2014) and other high-impact practices (see Kuh 2008; Brownell and Swaner 2010; Kuh and O'Donnell 2013; Finley and McNair 2013); peer mentors, peer advisors, or creation of a learning assistant program (see, for example, http://laprogram.colorado.edu); other resources, such as those found at the Carl Wieman Science Education Initiative website (http://www.cwsei.ubc.ca)
Low levels of student engagement in or understanding of the scientific process	Undergraduate research experiences (e.g., summer research programs, first-year research initiatives), including Classroom-based Undergraduate Research Experiences (CUREs)
Low sense of community/belonging among students; transfer shock among students matriculating from community colleges	Learning communities and cohort programs that include linked courses, such as introductory science courses plus writing/critical thinking and/or other general education courses; service-learning or community-based programs; partnerships with student affairs or other units on campus that interact with students outside the classroom
Need for development of faculty expertise and a culture of evidence-based teaching; wider scale implementation of evidence-based methods	Targeted faculty development programs on campus, such as faculty learning communities; programs that provide opportunities for faculty members to attend national faculty development workshops or institutes; hiring science faculty with education specialties (Bush et al. 2013)
Lack of support for students outside the department or program	Partnerships with student affairs, advising, or other units on campus that interface with students outside the classroom
Problems with student scheduling patterns/course sequencing or high numbers of repeat courses	Articulation and publication of student pathways to graduation, monitoring systems to identify at-risk students for advising, tutoring, or other interventions.

We found that campus teams developed better strategies when they were aware of a host of different approaches to addressing common STEM student success challenges such as retention, interest in STEM, success in coursework, math aversion, student isolation, or poor understanding of STEM careers. For example, to address the issue of student isolation, students might be enrolled in linked first-year courses, placed in formal mentoring programs, or involved in undergraduate research. Larger campuses might have more success with linked first-year courses, while smaller institutions might be able to mentor each student. Being aware of several different interventions that might address a problem allowed the institutions to choose the intervention that best fit their context and capacity. Furthermore, there is a tendency to choose only one intervention rather than think about a linked set of interventions that can best support student success. Retention is usually not affected by one issue (i.e., poor instruction or lack of authentic STEM experiences, such as undergraduate research opportunities) but is usually affected by several issues, such as transition to college (addressed by bridge programs), success in early gateway courses (addressed through active learning), and self-identification as a scientist (addressed through undergraduate research experiences authentic and STEM experiences). It is important for campus teams to think broadly about a variety of interventions that are needed to address a particular challenge.

Research on STEM student success has also validated interventions aimed specifically at supporting URM students, such as the University of Maryland, Baltimore County's Meyerhoff scholars programs (http://meyerhoff.umbc.edu/); the Association of Public and Land Grant Universities' Minority Male STEM Initiative (https://www.aplu.org/sslpage.aspx?pid=2274); and the Institute for Higher Education Policy's (IHEP's) project on diversifying the STEM pipeline (http://www.ihep.org/Publications/publications-detail.cfm?id=132). There is a growing body of research on interventions that work for URM students, which usually include an interconnected set of strategies such as K–12 readiness programs; summer bridge programs; undergraduate research opportunities; mentoring programs; student affairs partnerships; first-year experience interventions, particularly related to mathematics; revised gatekeeper or introductory courses; and internships and cooperative opportunities for students to practice STEM skills. IHEP studies found that programs that support URM students also tend to benefit the student body at large. As such, both goals can be reached through supporting URM.

Most teams wanted to jump directly to implementing interventions or strategies without fully understanding challenges within their campus environments. If it is difficult to obtain data or get faculty members to read national reports or literature, project leaders may jump into interventions as a way of garnering attention and achieving focus. But ultimately, campus teams that jumped directly to interventions usually had to move backward over time. The process outlined in this guidebook is designed to help campus leaders find the middle ground between thoughtful action (which takes time) and quick fixes that may or may not be appropriate or reasonable, but that have worked elsewhere.

To identify opportunities to leverage existing resources and programs, campus teams should talk with leaders in student affairs, undergraduate studies, offices of research, sponsored programs, outreach offices, and community engagement programs to be sure team members are aware of all possible connections. For example, if a team's intervention involves starting a STEM summer bridge program, the team may be

"The diverse array of initiatives put forth by faculty members in the three high needs areas demonstrates the high level of interest and desire to improve learning outcomes for our diverse student body. The variety 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."

—CSU East Bay Case Study

"Faculty members generally will be a central resource in delivering the new program; therefore, it is critical to consider faculty development at an early stage."

able to connect with the campus's existing summer bridge program for the general student population, possibly save resources and time. Campus outreach, staffing, and program experts may be able to help plan and execute the new program. We also found a tendency for STEM reform efforts to be isolated from general efforts to support student success, making them less likely to leverage existing resources. Instead of examining existing resources, STEM leaders often felt the need to obtain external grants and resources, a step that slowed their process and narrowed their possibilities.

Faculty members generally will be a central resource in delivering the new program; therefore, it is critical to consider faculty development at an early stage. This is important (1) to ensure that faculty members have the knowledge and skills necessary to implement the teaching strategies shown above, and (2) to develop faculty leadership capacity. Faculty development programs on campuses vary in size, offerings, and engagement. Most campuses have a center or centralized office that may offer workshops and instructional design assistance with respect to incorporating technology. Discipline-based faculty development housed in a college is another model (see Marbach-Ad et al. 2007).

There are several national opportunities for STEM faculty development, such as the National Academies Summer Institute (http://www.academiessummerinstitute.org), the American Association of Physics Teachers' New Physics and Astronomy Faculty Workshop (http://www.aapt.org/Conferences/newfaculty/nfw.cfm), Center for Astronomy Education workshops (http://astronomy101.jpl.nasa.gov), the Mathematical Association of America's PREP and Project NExT programs (http://www.maa.org/programs/faculty-and-departments), and the National Effective Teaching Institutes offered by the American Society for Engineering Education (http://www.asee.org/conferences-and-events/conferences/neti). SENCER (Science Education for New Civic Engagement and Responsibilities, described at http://www.sencer.net), BioQUEST (http://bioquest.org), and POGIL (Process Oriented Guided Inquiry Learning, described at https://pogil.org) offer additional resources.

Campus leaders may find it useful to prepare a logic model for their project. There are many types of logic models (and many references for building one), but leaders can start simple with the basic model illustrated below.

Simple Campus Project Logic Model

Inputs	Activities	Outputs	Outcomes/ Impacts
What resources or information do you have that will help you plan and implement the project?	What specific activities will be implemented?	What tangible products will the project produce (e.g., new curricular materials, workshop materials, policies, etc.)?	What measurable outcomes or impacts will be realized as a result of the project?

Case Study Highlights

- At **CSU Fullerton**, survey data provided concrete ideas for professional development strategies for faculty.
- **UC Davis's** data analysis confirmed the need for target gateway STEM courses and prompted the development of data dashboards for faculty members' use in

revising courses. The analysis also identified the need for a teaching assistant training program.

- The **W. M. Keck Science Department** decided to implement a summer bridge program based on their analysis of retention and preparation data for incoming science students.
- The **CSU Chancellor's Office** decided to focus on two strategies that emerged directly from their landscape analysis: (1) increasing resources and partnerships for advancing STEM educational effectiveness, and (2) developing a highly visible system-wide entity to coordinate, convene, and advise for effective STEM education.

Challenge Alert

- **Leverage existing resources.** Most new initiatives or projects require resources. However, new resources may be difficult to obtain, so team members' mindset that they are necessary may create a significant roadblock. Campus leaders must find ways to leverage or redirect existing resources by aligning projects with campus priorities. Additionally, creative partnerships or collaborations with other colleges or universities, community organizations, industry partners, or other stakeholders should also be considered. These types of relationships not only bring resources (financial contributions, expertise, equipment, etc.), but also provide a broader base of support and engagement that might be more sustainable. While sometimes additional resources are needed, it is worth considering whether efforts can be moved forward without new resources because these are not always available, particularly in the current environment of retrenchment and continued budget limitations.
- **Keep it simple.** Fully addressing some of the challenges to STEM student success will not be easy and may require several strategies that map across the campus. But a plan involving multiple strategies may be too complicated to implement well, especially initially. Also, some strategies (e.g., undergraduate research) may be complicated and more resource intensive than others. While effective, they may drain personnel, cultural, and other resources and may result in a stumbling block for teams. By starting with a simpler strategy, teams may achieve early success that can help build momentum and establish a track record that may result in additional resources.
- **Don't forget about existing assets or opportunities.** Even after examining their assets and potential opportunities during the landscape and capacity analysis, campus teams may forget about these opportunities when choosing strategies and interventions. It is important to go back to the landscape and capacity analysis to ensure that strategies make the most of existing resources and connections to other campus programs. One of the biggest assets that campus teams identified was their institutional research office and the treasure trove of data that could be marshaled for STEM reform efforts. It is also now quite common for campuses to have global student success initiatives that can provide leverage points for STEM-specific projects.

Timeline

Like in the analysis phase, after launching a focused investigation, teams tended to quickly identify appropriate strategies and interventions to their specific problems.

◆ STAGE FIVE: DETERMINE READINESS FOR ACTION

Benchmark

The campus has identified and obtained the faculty, staff, financial, physical, and cultural resources to implement the selected strategies.

This section outlines key "readiness" factors that need to be considered and in place in order to facilitate successful implementation and longer term sustainability of program interventions. Key readiness factors are outlined in the readiness survey tool shown in table 6. Because we found that campus teams often proceeded without fully completing prior stages, we intentionally designed this in-depth survey to prompt teams to consider all the previous stages. This is a good point to assess progress and make any needed adjustments.

Once a particular strategy or intervention has been chosen, a campus team can evaluate its readiness is for implementing that intervention. The process for determining specific readiness will be unique based on the interventions each team chooses, yet we recommend that teams examine some common areas, including timelines, resources, institutional commitment, incentives and rewards, leadership, staffing, faculty development, buy-in, and support for data collection and analysis.

Table 6. Readiness Survey

Readiness Factor	Strongly Agree (5)	Agree (4)	Not Sure (3)	Disagree (2)	Strongly Disagree (1)
Planning					
1. The team has a clearly articulated and shared a vision for the project.					
2. Our vision is linked to key institutional priorities.					
3. We have scanned the campus for other STEM projects, programs, and initiatives that already exist to which the new project might connect for leverage.					
4. We have created a project plan with anticipated actions, milestones, and an achievable timeline. The plan involves a pilot project that will allow for initial testing and experimentation before scaling up.					
5. We have identified possible pitfalls and roadblocks.					
6. We have a strategy to help students understand the intended plan, its purpose, and the desired outcomes.					
7. We have an assessment plan and the capacity (including needed expertise from institutional research offices) to measure and analyze results.					
8. Our assessment plan builds from our landscape analysis, is linked to project outcomes, and leverages existing data sources.					
9. We have received appropriate approval from our campus institutional review board for human subject research (if needed).					
10. We have identified appropriate facilities required to carry out the project.					
11. We have created a project budget.					
12. We have identified sources of support, both internal and external (grants, gifts, in-kind donations).					

Readiness Factor	Strongly Agree (5)	Agree (4)	Not Sure (3)	Disagree (2)	Strongly Disagree (1)
13. We have a plan for communicating and celebrating project results. The plan includes both on- and off-campus dissemination opportunities (e.g., published papers, conference presentations).					
People					
14. We have a team comprised of the appropriate faculty members and staff.					
15. The project has one or more leaders.					
16. We have identified and hired a project manager who has the time and expertise required.					
17. People involved in the project have the time, incentives, motivation, and expertise to successfully carry out project objectives. (Consider graduate assistants, postdocs, or undergraduate students who can help with the project or use it as a research or thesis project. Reach out to educational researchers for additional research support.)					
18. If additional training is required, we have identified what is needed and have a plan for providing it to project faculty, staff, and students.					
19. We have identified external experts required to help campus leaders, faculty, and staff build plans, develop needed expertise, and/or evaluate results.					
20. We have identified and informed key on- and off-campus stakeholders. (On-campus stakeholders include other academic departments or offices within academic affairs; relevant units within student affairs, such as advising, outreach, and admissions; the institutional research office; the faculty development center; principal investigators of related funded projects; the president's office; and advisory boards, committees, or task forces dealing with student success. Off-campus stakeholders may include partners in K–12 education, the community, and/or industry.)					
Politics					
21. The project has the support of the dean, provost, president, and other key administrators.					
22. We have identified the political issues we may encounter, including relevant policies or procedures, committee/departmental approval processes, incentives and rewards for faculty involvement, and allocation of resources and space.					
23. We have buy-in from key on-campus stakeholders.					
24. We have strategies for addressing the identified political issues.					
SUBTOTAL (Sum each column)					
TOTAL (Add all subtotals)					

Case Study Highlights

- The **CSU East Bay** team's early, clear vision of becoming a quality STEM-centered institution allowed the team to obtain grant funding quickly. In their case, obtaining the resources needed for readiness was facilitated by a strong vision. Furthermore, once the team developed a list of strategies to use such as improvement of developmental math courses, they then examined whether they had resources in those areas and determined what they might need to implement changes. Later, through thoughtful landscape analysis, the team demonstrated and obtained a commitment for permanent funding from the provost for an institute that was initially grant funded.

- Recognizing that they did not have available resources for professional development in STEM, the **CSU Fullerton** team mounted a grant-writing effort to fund a STEM-specific center for catalyzing these changes.
- The **UC Davis** team identified a series of important factors that affected their plans to address gateway course student success, increase faculty buy-in to improve teaching, and improve teaching assistant training. To move forward, the team realized that they needed more faculty expertise in using evidence-based pedagogies, as well as more buy-in and incentives to implement new strategies. They also were lacking an infrastructure to collect and analyze data over time to see if the team was making progress. Therefore, faculty development, buy-in, and data infrastructure became key to the success of their project.
- The **University of La Verne** team examined the workload implications of their curriculum restructuring and determined that they needed to hire adjunct faculty members. This strategy would help ease workload in the short term and could eventually lead to the dean's approval of new faculty lines if the reforms were successful. The team identified the need for other resources and obtained several grants to support their curricular revision work. They also created an improved data infrastructure so they could better monitor results and worked to better communicate the curricular changes to students.

Challenge Alert

- **Teams may not always get all they want.** Once campus teams determined the strategies/interventions and resources needed, they often were unable to get funds from the institution or grants to fund key areas. Campuses may need to scale back on plans in order to remain realistic and maintain enthusiastic and motivated involvement. It is important to determine what you can do with existing or leveraged resources from other projects. Taking on a large project without adequate funding can create burnout and may damage subsequent efforts. A small-scale, affordable pilot project may be what is needed to garner additional resources.
- **Don't start if the team isn't ready.** Responses to the readiness survey may suggest areas that need additional time and effort to address. For example, the UC Davis team identified professional development needs that would take quite a bit of time to implement and would slow down the change process. Despite the time commitment addressing these needs would require, they decided to invest the time necessary to develop faculty expertise. While campuses are reluctant to slow down, it is often necessary.

Timeline

Like landscape and capacity analysis, determining readiness may take more time than anticipated because it requires teams to obtain information about campus context, resources, and culture. Political issues are particularly important to address. We found that campus teams tended to move directly to implementation instead of taking the time to assess their readiness. However, campus teams found that the readiness data they had collected through completing the Readiness Survey was instrumental in overcoming resistance and moving forward with change more smoothly. If this phase isn't addressed adequately, teams may encounter roadblocks resulting in significant delays that could have been avoided.

◆ STAGE SIX: BEGIN IMPLEMENTATION

Benchmark

The campus has carried out at least one pilot or small-scale implementation of the planned strategy and has collected adequate assessment data to monitor effectiveness, make improvements, and inform scale-up.

"Implementation is a critical stage and works best when a pilot or small-scale test is used first to work out the bugs and do an initial assessment with minimal impact on faculty, staff, and students."

Questions to Ask When Considering This Stage

1. What were the results of the readiness survey?
    - If responses in most areas were either "agree" or "strongly agree," then the team is ready to proceed. For any areas where responses were "disagree" or "strongly disagree," what resources, time and expertise will be needed to become more confident in the team's readiness?
    - If most responses were "not sure," "disagree," or "strongly disagree," what corresponding areas does the team need to spend more time addressing to become better prepared for the work ahead?

Implementation is a critical stage and works best when a pilot or small-scale test is used first to work out the bugs and do an initial assessment with minimal impact on faculty, staff, and students. Campus teams can use pilot results to assess how well the program met the goals and objectives, make adjustments, seek additional resources, and garner participant buy-in. Several of the campuses in our project piloted programs, courses, or services to support students, and this turned out to be a very successful strategy.

However, innovations may not work as intended initially. Instead of seeing this as a failure, teams should return to the data to see if there is a mismatch or reflect on the implementation process to determine where there might have been problems. It is possible that the chosen strategy was not well matched with the data, so another intervention may need to be tried. Even an intervention that works for a couple of years may fail to work later because the situation may have changed. Solutions need to be seen as contingent.

Our previous project on Facilitating Interdisciplinary Learning (Kezar and Elrod 2011; Project Kaleidoscope 2011b), also sponsored by the W. M. Keck Foundation, has additional resources related to infrastructure (policy and procedures), helpful funding sources and levels, suggestions for managing faculty and staff workload while developing needed resources, garnering support from the administration, and other useful approaches.

Case Study Highlights

- The **CSU East Bay** team developed a plan for implementation that included faculty development and infrastructure support for their change strategies. They conducted a needs assessment and designed, piloted, and assessed interventions in order to eventually bring those interventions to scale.
- The **CSU Fullerton** team anticipated that addressing faculty development with respect to teaching would require ways to help faculty with assessment in their

classrooms. This illustrates the need to be aware that new issues are likely to emerge as the project gets started. A team must be agile and vigilant to address issues as they arise.

- The **UC Davis** team developed an implementation plan that engaged the institution at multiple levels, from instructor development to university-level actions, in improving gateway courses and student retention. The team also leveraged multiple funding sources, internal and external, to support implementation of their plan.

Challenge Alert

- **Be ready for resistance to emerge.** Resistance will emerge because change is a difficult process for most individuals. Sometimes resistant individuals on campus will allow a planning process to go on because they don't believe the plans will actually be implemented. Sometimes resistance does not emerge until the plan actually goes into place. Therefore, you can't assume that no resistance in early phases means that there is general buy-in. If resistance emerges at the time of implementation, return to the data, present the data to resisters, and carry out further discussions to garner buy-in.
- **Professional development is critical and takes time.** It may be difficult to identify specific professional development needs until you have started implementing the plan. Only then will certain problems emerge (e.g., the need for additional assessment training for faculty members). So stay alert for problems that emerge that may reflect needs for professional development. One way to ensure professional development along the way is to create a faculty learning community focused on the change being implemented. With a learning community in place, there is an ongoing mechanism for addressing learning and development.
- **Beware of team breakdown.** Teams need constant TLC. Members may come and go, especially over a project that lasts several years. Also, some team members may need a break to relieve burnout or attend to other professional activities. Sending the team to conferences or off-campus professional development opportunities (including leadership development workshops) may build team cohesion and boost energy levels. A midproject team retreat with an external facilitator may also help the team overcome barriers and build a new sense of community. Bringing newly hired faculty members or lecturers into the project is also a good way to keep momentum going.
- **Avoid promotion and tenure roadblocks.** It is essential for faculty members in the promotion and tenure pipeline to be able to count their work on the project in their promotion and tenure reviews. Campuses should address this issue early in the process to identify how this will work. This is another reason for getting administrative support and buy-in early in the process.

Timeline

Implementation varies depending on the complexity of the change itself. Most interventions can be implemented in a year or two, with trials occurring on the academic term or calendar schedule.

STAGE SEVEN: MEASURE RESULTS

Benchmark

Key data have been collected and analyzed to help the campus evaluate how well the plan worked, where it may have failed, and how it might be improved for the next round of implementation and eventual scale-up.

Questions to Ask When Considering This Stage

1. Was enough data collected to measure impact? Was some data redundant or unnecessary? Were there other pieces of information that should have been collected?
2. What was learned? Did the plan(s) yield anticipated results? What unexpected results occurred?
3. If desired results were achieved, what are the next steps? What resources will be needed to either mount another trial or scale up the program?
4. If desired results were not achieved, how will the campus team change course to address the problem?
5. What additional questions were raised by what was learned? What new data will need to be collected to address these questions?

This stage goes hand in hand with implementation, forming the final "reform eddy" illustrated in the model diagram (see fig. 1, page 9). A plan for measuring impact should have been built into the implementation plan. These measures should be tightly linked to the outcomes the team is trying to achieve and could include direct measures of student learning in courses or programs, surveys of student satisfaction or engagement, or analysis of course or program retention and completion rates. While quantitative assessments are popular, campus leaders should also consider conducting focus groups or interviews with students or evaluating portfolios and other qualitative demonstrations of competence. The earlier section on Landscape Analysis can serve as a guide for putting together an assessment plan. For an example from the literature, see Goldey et al. (2012), which describes how the authors carried out a comprehensive reform of introductory biology courses and developed a matrix of assessment tools to determine if their reforms were successful. You can use a few simple measures or create a complex plan, but be sure to focus on measures that connect with your desired outcomes and develop realistic expectations regarding the time and expertise that will be required to carry out an effective analysis.

There are many resources on evaluating programs, curriculum, and teaching and on measuring impact that can be found in the science education literature and the reports that have been cited in this book, including the recent American Association for the Advancement of Science report *Describing and Measuring Undergraduate STEM Teaching Practices* (2014). But many of our campus teams found that rather than consulting publications, they could engage the expertise of social scientists and education faculty on their own campuses to help measure impact. When they had tried to conduct this work on their own in the past, they struggled and often produced subpar results. When they instead partnered with colleagues in other fields who regularly do this kind of research, it was much easier to conduct the work.

"Measures should be tightly linked to the outcomes the team is trying to achieve and could include direct measures of student learning in courses or programs, surveys of student satisfaction or engagement, or analysis of course or program retention and completion rates."

Most commonly, campus teams didn't collect enough data and were left wondering whether what they just did had the desired impact. Often, they had some data but not enough. Careful planning can help campus teams avoid this pitfall. Finally, campus teams can use their initial results from measuring impact to alter aspects of the intervention and make it more successful in a second trial or to scale up from a pilot test to broader implementation.

Case Study Highlights

- The **UC Davis** team demonstrated that developing a data infrastructure up front makes measuring impacts at the end much easier.
- The **CSU Chancellor's Office** wanted to obtain a grant to fund a group to convene and advocate for effective STEM educational practices. The team obtained several grants, and that result validated their approach and demonstrated that they were making progress. They developed assessment plans as part of the individual grants and will be assessing impact over the next three years.
- The **CSU East Bay** team had a detailed and robust plan to measure impact that included analyzing course pass rates and other quantitative data, and conducting surveys and interviews of students to measure shifts in attitudes related to courses. Their plan included examining student work samples and analyzing instructor materials and practices. They plan to evaluate faculty and graduate teaching assistant actions through ethnographic analysis to better understand what happens in classes in terms of student engagement. They are also engaging students in research on the project.
- **CSU Fullerton** will continue to survey their faculty as a measure of impact. They will also use their thoughtful and targeted landscape analysis tools to set benchmarks and measure results.
- The **W. M. Keck Science Department** decided to create a video highlighting faculty and student engagement, which included footage from their summer program. This video was widely disseminated to provide exposure and to obtain buy-in from various stakeholders, including nonscience faculty and administrators; current students and alumni; and prospective students, trustees, and donors. The video has turned out to be a great tool for demonstrating success because it contains clips of activities as well as student and faculty testimonials. The host colleges' offices of communication were not aware of the department's numerous STEM workforce retention and development efforts, and this video allowed the department to connect to a broader public relations infrastructure.
- The **University of La Verne** team used the CURE (Course-based Undergraduate Research Experiences) survey, an informal measure of student learning and experience, to determine the impact of research experiences that are embedded in courses.

Challenge Alert

- **Create a detailed assessment plan up front.** Some campuses did not create explicit plans for measuring results over time, or did not create plans with enough measures. When they completed implementation, they were left wondering about the true impact. More focused projects developed appropriate measures, but more complex projects struggled to develop and complete multifaceted plans across many initiatives. So, be realistic but thorough.

- **Be patient!** Measuring student success, especially in the form of retention and graduation rates, takes several years. Many campuses found success by setting interim milestone measures on the way to long-term data gathering goals. For example, the W. M. Keck Science Department included footage from their summer immersion program in a publicity video as a preliminary way of documenting success prior to completing the full quantitative analysis of student success.
- **Don't be afraid to reach out to get the right expertise.** STEM faculty don't often look to social scientists or educational researchers for help creating assessment plans and measuring results.

Timeline

Evaluation of results should occur both formatively (during the process) and summatively (at the end of the pilot or implementation phase). Generally, teams should collect results each semester to monitor progress along the way and should create a comparative data bank to establish trends over time.

"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."

—CSU East Bay Case Study

STAGE EIGHT—DISSEMINATE RESULTS AND PLAN NEXT STEPS

Benchmark

Descriptions of project purpose, methods, and results have been documented in various formats and venues, such as websites and newsletters, social media sites, campus presentations, community news articles, conference presentations, and published papers. Plans are in place for modification, improvement, and/or scale-up.

Questions to Ask When Considering This Stage

1. What on-campus dissemination channels exist? These may include department meetings, college/division or institutional events, campus news outlets, and websites.
2. What regional or statewide venues might be appropriate?
3. What is the plan for national conference attendance/presentation?
4. What journals might be appropriate?
5. Have assessment data been fully reviewed? Has a plan been formulated for applying lessons learned to another iteration of the program or initiative?

It is important to communicate the results, particularly to colleagues on campus but also to the broader community. This helps spread the word and create broader buy-in. It may also bring to the table new stakeholders or partners, some of whom you may not have realized had an interest. Venues could include department, division, college, or university-wide meetings, or regional gatherings of community colleges and four-year institutions. Several conferences and publication opportunities also exist. Remember that in order to publish the results of your work, your study must receive institutional review board approval. Below is a listing of STEM-specific conferences and publication venues to consider for dissemination of your project's results:

- Annual AAC&U/PKAL Network for Academic Renewal conference on Transforming Undergraduate STEM Education, or AAC&U's Annual Meeting
- AAC&U quarterly publications (*Liberal Education*, *Peer Review*, and *Diversity & Democracy*) or AAC&U's monthly newsletter, *AAC&U News*.
- Meetings of scientific societies, some of which host special education conferences (e.g., American Society for Microbiology's Conference on Undergraduate Education)
- Scientific society journals (e.g., *BioScience*, *CBE—Life Sciences Education*, *Journal of Chemical Education*, *Journal of Geoscience Education*, *Physical Review Special Topics—Physics Education*)
- Scientific journals that publish science education results (e.g., *Science*)
- Peer-reviewed science education journals (e.g., *Journal of College Science Teaching* and *Journal of Research on Science Teaching*)

Dissemination isn't the end. It is just a milepost along the way that marks progress along the continuum of program development, planning, implementation, and evaluation. Once the campus team has completed a full cycle of the process, they should use the information collected and lessons learned to make improvements, create a new plan (if necessary), and/or prepare to scale up. A first step in this process is revisiting the vision that the team initially created for the program to see if what the team accomplished is aligned with the original goals. It is easy to lose sight of the original goals, especially when projects take several years and involve many people across the institution. Data that has been collected along the way will help determine if specific outcomes were met, and formative feedback from students and participating faculty and staff can inform future implementation.

Case Study Highlights

- Campus teams participating in the project had regular opportunities to present their progress and results to one another. Consider forming a working group with other regional campuses that can provide inputs for your program as well as feedback on your progress.
- The **CSU Chancellor's Office** developed a plan to report their progress and new opportunities at a system-wide STEM summit. They have received several grants that are helping them move forward with new and deeper plans for implementation.
- The **CSU East Bay** project leveraged several existing campus and local K–12 venues for increasing project visibility, such as a quarterly leadership conference for school district partners. Through the project, the team formed a cross-disciplinary and cross-institutional network to help them review project results and make future plans.
- The **W. M. Keck Science Department** used their promotional video and leveraged campus communication outlets to spread the word about the new summer program. They are using lessons learned to continue to obtain buy-in and improve the program to meet the needs of their incoming first-year students.
- The **UC Davis** team is planning to disseminate articles in a variety of society and science-based journals, as well as through other campus networks to which they belong (e.g., the Association of American Universities STEM education project). These cross-campus networks are also helping the team maintain momentum while keeping them accountable to the broader research university community dedicated to improving STEM student success.
- The **University of La Verne** team plans to present results at an upcoming AAC&U/PKAL Transforming Undergraduate STEM Education conference. Their project was so successful, it has inspired cross-campus engagement in similar planning efforts to improve student success more broadly.

Challenge Alert

- **Plan ahead for publication.** Communicating or publishing results is often an aspect of the work that campuses do not consider until they have completed a project. Then they realize that they do not have all the data they might need to create a compelling story. Thinking about dissemination opportunities in advance can help campus teams shape results and inform planning (for example, by prompting teams to obtain any institutional review board approvals that are necessary for publication).
- **Plan ahead for next steps.** It is easy to get caught up in the momentum of the pilot test or experimental implementation of a new program without thinking past

that stage to future implementation. The pilot program may contain elements that are unrealistic for larger scale implementation, so thinking ahead about realistic future planning is important.

Timeline

Preparing for presentation on campus can take a relatively short amount of time, but planning for conference presentations or writing papers takes more planning and organization. For example, many conferences call for proposals six to eight months in advance. Preparing a manuscript takes discipline and requires a primary author to spend time drafting the paper and soliciting contributions from the team. The process of peer review may also take up to six months.

CONCLUSION

US higher education will not meet the ambitious national goals for STEM reform by continuing existing efforts. Research has emerged that demonstrates the importance of a broader vision of STEM reform for student success–moving from reforms focused on programs and departments to institutional efforts.

The Keck/PKAL Model for Systemic Institutional Change in STEM Education offers a comprehensive guide for helping campuses work on this broader vision. The model's concrete suggestions for process and content provides campus teams with tools they can use to steer their respective boats through the waters of STEM reform, and to advise leaders on navigating the sometimes tricky political terrain involved in complex change processes. We appreciate the efforts of our pioneering campus teams, each of which explored new territory–literally going where few colleges have gone before. We are convinced that campus leaders who are open to a broader vision for student success and who allow themselves to engage in what can be a messy process of change can create highly valuable, sustained, and scaled efforts at STEM reform. In turn, these efforts will contribute to overall campus goals for improving the learning and success of all students, particularly URM students. Perhaps programs implemented to improve STEM student learning and success can serve as models for programs designed to advance equity and engagement in other disciplines.

"We appreciate the efforts of our pioneering campus teams, each of which explored new territory—literally going where few colleges have gone before. We are convinced that campus leaders who are open to a broader vision for student success and who allow themselves to engage in what can be a messy process of change."

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APPENDIX A. WORKING GUIDE FOR CAMPUS TEAMS

This appendix is a guide to help campus teams work through each stage of the systemic institutional change model. These stages include not only the eight elements previously outlined in the publication, but also three preliminary steps—"Practice Self Reflection," "Create Effective Teams and Leadership," and "Establish Your Baseline"—which should be carried out at the beginning of the process.

Practice Self Reflection

Using table 1 (see page 14), evaluate the areas of work related to the model that your campus may or may not have carried out in order to determine the best place to get started. The following questions will help you figure out an appropriate place to begin.

1. Based on your responses to the questions in table 1, map your project back to the model. Where are you? How can you use the model to create a process for continuing your change effort?
2. What opportunities might you possess to leverage for starting at this point? What challenges do you think might face?

Create Effective Teams and Leadership

Team development is extremely important because the team is the engine creating the forward momentum of the project. Assembling the best team can take several months and we encourage project leaders to take the time to create high-functioning teams. Once teams have been created, team members also need time to get to know each other, to create a common language and vision around the change, and to build trust. Regular meetings or an in-depth annual retreat can facilitate team building. Before moving into the detailed work of data analysis and identifying interventions, team members need to trust each other, gain respect, understand each other's expertise, and develop relationships. All team members must feel that they are welcome and in an environment where they can safely discuss potentially controversial ideas or data, freely express opinions, and experiment with innovative interventions. The following questions will help guide teamwork:

1. Who do you think you need on the team? Think about the expertise you might need and the expertise you have on campus from across the institution.

Types of Expertise	Name(s)
Faculty	
Staff	
Student Affairs	
Office of Institutional Research	
Administration	
Students	
Other	
Other	
Other	

2. Who will lead the team? You will need faculty leaders and institutional champions. Institutional champions may or may not have titles that give them leadership responsibility; however, they should be motivated and capable of leading the effort.
   a. Faculty leaders:
   b. Institutional champions:
3. How will the team work and communicate?

Leading an Effective Team. Having a team leader who can keep the team focused and on track is critical. If one or two senior leaders are willing to serve on the team or are able act as liaisons, this can help the team gain the type of leadership needed for institution-wide change. Some teams find that they get better thinking by identifying unexpected people to put on the team, such as someone from technology services or another discipline like the humanities. It is also important for team leaders to continually reflect on the process to monitor team effectiveness as well as project progress. We provide questions that leaders can use to be mindful of team process and practice:

Leader Reflection Questions

- What aspects of this stage went well? Where did you encounter challenges? Were you able to overcome them? If so, how? If not, why not?
- What important team and/or institutional values did you uncover?
- What did you learn about what your campus does well and can further leverage?
- How well is your team functioning? How are you empowering and rewarding the team's work? Are there any issues—communication, collaboration, commitment, capacity? How are you addressing these challenges?
- What were your leadership challenges? What were your leadership successes?
- Overall, how well do you think the team executed this stage of the process? What might you do next time to improve?

Team Development Resources. For more guidance on working as a team, see Bensimon and Neumann (1993) and also the Equity Scorecard Project's guides for campus teams (http://cue.usc.edu/our_tools/the_equity_scorecard.html).

Leadership Development Resources. Project Kaleidoscope offers a yearly summer leadership Institute (Elrod and Kezar 2014). More than two thousand faculty members have gone through the training and found it extremely important in assisting their campus change efforts advancing their careers to roles such as department chair, dean, and provost. Many disciplinary societies offer leadership training at their annual meetings. Some faculty members have developed their leadership skills by participating in regional and national STEM reform networks such as SENCER (Science Education for New Civic Engagement and Responsibilities; see http://www.sencer.net), BioQUEST (http://bioquest.org), and POGIL (Process Oriented Guided Inquiry Learning; see https://pogil.org). Each of these networks provides different opportunities for developing leadership skills, mostly through the lens of projects related to undergraduate STEM reform. Campuses that are successful in reforming STEM typically send faculty members to these various professional development opportunities to gain the skills required to lead processes like those described in this guidebook. Faculty leaders, department chairs, and deans may also realize greater success when they "lead up" by creating short talking points to help higher-level leaders speak with authority about STEM education and/or campus projects. Additionally, senior leaders are needed to change reward structures, help with resources, and provide infrastructure, such as professional development or outcomes assessment to support long-term changes. Senior leaders are more likely to be supportive when they see the initiative is aligned with institutional goals. We found that campus teams were much more successful when they identified institutional priorities and aligned their STEM reform efforts with institutional goals.

Establish Your Baseline

Before you get started, rate your campus's current status on the elements of the model below. Use this rubric to check in on your progress periodically. Using the rubric (see table 3 on page 24), determine the status of your campus along each element of the model. Identify the benchmark description that best fits your campus right now and tally your score.

1. Was your score expected or unexpected? Why?
2. What strengths, weaknesses, and opportunities can you identify as a result of your rubric analysis?

Strengths	Weaknesses	Opportunities

3. What are your three next steps for moving forward?

What	Who	When
1.		
2.		
3.		

Notes

Applying the Model to Your Campus Change Initiative

Stage One: Establish Vision

The first stage in the model is to create a shared vision among campus team members and additional campus stakeholders.

Questions

1. What is your vision for STEM education reform? Where are you in the visioning process?
2. How is your vision aligned with institutional goals?
3. What are the key trends that should guide your vision of student success?
4. What assets and expertise does the campus have that can be capitalized on for creating a vision?
5. What challenges do you anticipate encountering? How might you address these challenges up front?
6. What are your next steps?

Notes

Stage Two: Examine Landscape and Conduct Capacity Analysis

The two primary steps in examining the landscape are (1) a review of institutional, program, and/or course data, including analysis of existing curriculum maps, learning environments, and pedagogical approaches; and, (2) an external review of national reports, science education literature, and/or projects reported by representatives from other campuses at conferences on STEM education. This stage helps campuses home in on specific problem areas (e.g., first-year retention, transfer student isolation, matriculation through introductory course series, etc.) in order to focus implementation strategies on addressing gaps and problem areas that may lie at the root of the problem to be solved. The first step is data gathering and analysis. Table 4 (see page 33) lists types of data that campus teams may find useful in conducting a landscape analysis to better characterize the terrain of STEM education on campus.

Questions

1. What data do the campus regularly collect and analyze (e.g., retention and graduation rates, National Survey of Student Engagement results, CIRP Freshman Survey data, Higher Education Research Institute faculty survey responses)? Can these data be leveraged for learning more about the challenges regarding STEM student learning and/or success?
2. Looking at table 4 (see page 33), what data or analysis might you consider adding to expand your understanding? Are faculty (and relevant staff and administrators) aware of the issues revealed by the data and landscape analysis? Are they interested in discussing these issues? Do they see the problem(s) the data reveal?
3. What is the existing climate for change? Have other change processes (e.g., general education reforms, outcomes assessment initiatives) been carried out on campus? If so, how successful were they, and what challenges did they face?
4. With respect to capacity for change:
   - What kind of learning environments and opportunities do students currently experience?
   - What structures are in place to support curricular revisions and pedagogical innovations?
   - Are there faculty members who are already engaged in STEM education research or faculty development?
   - Are there existing initiatives devoted to student success on campus?
   - Are there grant or other proposal opportunities that the team can leverage to obtain seed funding for STEM reform?
   - Has the student affairs division created programs that target student success for STEM students or more broadly (e.g., summer bridge or early start programs)? How can the division's expertise be leveraged?
5. What resonated with you about approaches highlighted in the case studies?
6. What challenges do you anticipate encountering? How might you address these challenges up front?
7. What are your next steps?

Stage Three: Identify and Analyze Challenges and Opportunities

Using data analysis, campus teams can identify specifically where problems and challenges lie in recruitment and retention efforts, program offerings (e.g., in course sequencing or prerequisite requirements), teaching and learning spaces, pedagogy, advising, academic support, and other areas. This stage will help teams evaluate the best possible strategies and interventions to implement in order to address the identified issues.

Questions

1. Do you have enough data to draw conclusions? What additional information might you need? Are the data disaggregated by all relevant student characteristics (race, gender, socioeconomic status, etc.)?
2. What assumptions does the data analysis reveal regarding student learning and success?
3. What conclusions can be drawn from the data? What part of the program (precollege, particular gateway course, math skills, advising, etc.) is implicated by the analysis?
4. Where and for whom are there gaps in student success?
5. What opportunities (such as existing campus programs, grant opportunities, or institutional priorities) might you leverage to address the challenge?
6. What resonated with you about approaches highlighted in the case studies?
7. What challenges do you anticipate encountering? How might you address these challenges up front?
8. What are your next steps?

Notes

Stage Four: Chose Strategies and Interventions, Leverage Opportunities

Once they have identified specific challenges, campus teams are positioned to connect the data analysis and identify possible interventions that will address the issues. Table 5 (see page 42) provides some suggestions for consideration. Campus teams may also consider examples from other campuses, from the research and educational literature, from conference proceedings, or from other sources.

Questions

1. Have you examined, both comprehensively and holistically, the interventions needed so that unanticipated issues do not thwart the implementation? Are the interventions supported by data and directed at solving the issues or challenges you identified?
2. How does your chosen intervention map to the landscape and capacity analysis? How does it connect to your vision for STEM learning and student success?
3. What outcomes will you achieve as a result of the intervention? How will you measure success, based on data you have already analyzed? What new data will you need to collect?
4. How much time is required to pilot, test, evaluate, and scale up?
5. Does your chosen intervention leverage existing resources, programs, and expertise?
6. How will you communicate to internal and external stakeholders, including students, about your plan?
7. Do you need to obtain institutional review board approval for research involving human subjects? (This is required if you plan to publish your results.)
8. Will faculty development be an issue? If so, how will you address it?
9. What resonated with you about approaches highlighted in the case studies?
10. What challenges do you anticipate encountering? How might you address these challenges up front?
11. What are your next steps?

Notes

Stage Five: Determine Readiness for Action

An important step in the planning process is determining whether you have thought through all aspects that will affect the program's success. Table 6 (see page 46) provides a readiness survey that campus teams can use to delve into various aspects of institutional change projects that are important to consider as they prepare to launch new initiatives.

Questions

1. Based on the results of the readiness survey, how ready are you?
2. In what areas are you least ready? What do you think you need to do to be more ready?
3. In what areas are you most ready? How can you leverage your readiness in these areas?

Notes

Stage Six: Begin Implementation

After you have identified a course of action and planned to launch your program, these additional questions may help you prepare to begin implementation.

Questions

1. What is your plan for a pilot process to test your strategy?
2. Who will be involved?
3. Do you have the resources you need?
4. How will you measure success?
5. How will you use assessment of the pilot program to make improvements?
6. How will the pilot program inform a larger scale implementation process?

Notes

Stage Seven: Measure Results

Assessing progress is key to knowing whether or not you have been successful. Spend the time to reflect on and analyze the data you have collected in order to refine and improve your approach over time.

Questions

1. Were you able to collect enough data to measure impact? Were some data redundant or unnecessary? Are there other pieces of information you wished you had collected?
2. What did you learn? Did your plans yield anticipated results?
3. If so, what are the next steps? What resources do you need to either mount another trial or scale up the program?
4. If not, how will you change course to address the problem from a different angle?
5. What additional questions are raised by what you learned? What new data will you need to address these questions?

Notes

Stage Eight: Disseminate Results and Plan Next Steps

Sharing your experiences across campus, with other campuses, and with the broader community will help advance higher education's efforts to increase student success in STEM.

Questions

1. What on-campus dissemination opportunities exist, including department meetings, college/division or institutional events, campus news outlets, and websites?
2. What regional or statewide venues might be appropriate?
3. Do you have a plan for national conference attendance/presentation?
4. What journals might be appropriate?
5. Have you reviewed assessment data and formulated a plan for applying lessons learned to another iteration of your program or initiative?

Notes

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About AAC&U

The Association of American Colleges and Universities (AAC&U) is the leading national association concerned with the quality, vitality, and public standing of undergraduate liberal education. Its members are committed to extending the advantages of a liberal education to all students, regardless of academic specialization or intended career. Founded in 1915, AAC&U now comprises more than 1,300 member institutions—including accredited public and private colleges, community colleges, research universities, and comprehensive universities of every type and size. AAC&U functions as a catalyst and facilitator, forging links among presidents, administrators, and faculty members who are engaged in institutional and curricular planning. Its mission is to reinforce the collective commitment to liberal education and inclusive excellence at both the national and local levels, and to help individual institutions keep the quality of student learning at the core of their work as they evolve to meet new economic and social challenges.

Information about AAC&U membership, programs, and publications can be found at www.aacu.org.

About PKAL

Project Kaleidoscope (PKAL) is AAC&U's STEM higher education reform center dedicated to empowering STEM faculty, particularly those from underrepresented groups, to graduate more students in STEM fields who are competitively trained and liberally educated. PKAL also works to develop a scientifically literate citizenry as part of its commitment to principles and practices central to AAC&U's Liberal Education and America's Promise (LEAP) initiative. Since its founding in 1989, PKAL has been one of the leading advocates in the United States for transforming undergraduate STEM teaching and learning. It has to date empowered an extensive network of over 7,000 STEM faculty and administrators committed to the principles, practices, and partnerships that advance cutting-edge, integrative STEM higher education for all students. To that end, all PKAL undertakings are uniquely designed to foster quality, diversity, and social responsibility.

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