Increasing Student Success in STEM: A Guide to Systemic Institutional Change
A Workbook for Campus Teams

By Susan Elrod and Adrianna Kezar

A Keck/PKAL Project at the Association of American Colleges & Universities (AAC&U)

Pre-publication DRAFT
Executive Summary

This workbook provides campus teams and leaders practical guidance on how to apply the newly developed systemic guide to effective institutional change for planning, implementing and sustaining reforms that improve STEM student learning and success, particularly for students who come from underrepresented minority (URM) populations. Many change efforts have been started but few have reached the transformational level of entire programs, departments, or colleges in the STEM disciplines. The guide describes a model that begins with the establishment of a vision and goals for the change project. After this step, then the model guides teams through an analysis phase to gather data and collect information about the current STEM learning and student success landscape. This analysis leads to the identification of specific campus challenges defined by the data and couched in the context, mission, and priorities of the campus. These challenges help teams establish the outcomes of the change project and lead them to choose, implement and evaluate specific strategies that will address the challenges and improve STEM student learning and success. Any change process is dynamic and nonlinear so this model is described as a flow, much like a river where there are multiple points of entry (and exit!) as well as obstacles that might be encountered along the way that create eddies in the flow. This workbook is a compilation of tools provided in the more detailed Guidebook (Elrod and Kezar, in press). The specific tools are as follows:

- Key questions, timeline considerations and challenge alerts for teams to consider at each phase of the process.
- Resources to help teams determine how to get started, conduct data analyses, avoid common pitfalls, build effective teams, address leadership, and sustain change.
- Example interventions and highlights from campus case studies.
- A readiness survey will also help teams determine whether they are prepared to move forward with implementation of their chosen strategies and interventions.
- A rubric to help campus teams gauge their progress in the model phases.
Acknowledgements

The authors would like to acknowledge the generous support of the W.M. Keck Foundation and the contributions by the campuses that participated in the project:

- California State University, East Bay
- California State University, Fullerton
- California State University, Long Beach
- California State University, Los Angeles
- San Diego State University
- San Francisco State University
- 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

They 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 AAC&U for sponsoring the project, providing staff support and opportunities for presentation at national meetings.
I. Introduction

A. Background
For the past 20 years, countless reports have been issued calling for change and reform of undergraduate education to improve student learning, persistence and graduation rates for students in STEM; however, by many measures recommendations in these reports have not been widely implemented (Seymour 2002; Handelsman, et al. 2004; Fairweather 2008; Borrego, Froyd and Hall 2010). Aspirational student success goals in STEM have been set most recently by the President’s Office of Science and Technology (PCAST) recent report, 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% to meet this goal, and the greatest opportunity for improvement is in the graduation rates of under-represented minority (URM) students 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 a foundation of conceptual learning goals and use of the most effective research-based teaching, learning and assessment strategies (AAAS, 2012; AAMC/HHMI, 2012). The meta analysis that Scott Freeman and his colleagues conducted of recent science education research papers and conclusively confirms that by using 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 21st century and the global challenges our society faces require that students be engaged in learning that will prepare them to address and solve these problems (National Academies 2009, 2010a, 2011, and 2012). Still other research and program development has shown that changing the learning environment toward more interactive and engaging teaching methods is only one factor that leads to improved student success.

In addition to improvements in pedagogy and curriculum, STEM leaders are also recognizing the multifaceted changes needed in order to create student success. Student advising, faculty professional development, student research mentoring, academic support programs, clear STEM-focused institutional articulation agreements, external partnerships with business and industry related to internships and other research experiences, among other critical areas are often overlooked within reform efforts and have been identified as central to student success. These programs are particularly important for students who are typically underrepresented in STEM disciplines, the group with the largest potential to contribute to the PCAST report’s lofty degree production goals. These multifaceted changes that include partnerships with student affairs and other support programs as well as entities outside the institution suggests an institutional rather than departmental approach to
change. Also key instructional and curricular reforms also need support from the institution in terms of altering promotion and tenure and reward structures or getting enough support for professional development. There is gaining recognition that reform in STEM 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 minority STEM students (Lee and Harmon, 2013).

In addition, research suggests that changes made to improve student engagement, such as implementation of high impact practices, has a benefit for all students, but has a greater impact 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, approaches to change in STEM higher education require a systemic and comprehensive approach that engages all levels of the institution, from department faculty to student affairs professionals to deans, provosts and presidents. As a result, this model focuses on institutional change in the way that STEM change agents 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. It 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 generous support of the W.M. Keck Foundation over a three-year project period.
B. Fostering Change

In order to make progress toward more institutional reform efforts, a comprehensive guide to systemic institutional change in STEM has been developed. This guide describes a model that is geared toward helping campus leaders plan, implement and assess systemic change strategies that improve recruitment, access, retention, learning, and completion for all students in all STEM disciplines. This includes the breadth of ways that students engage in STEM learning on our campuses, from students in STEM majors to those taking science and mathematics general education program requirements, meeting quantitative reasoning requirements, and taking science or mathematics prerequisite courses required for applied majors such as agriculture or those in the health professions.

As noted above, most prior initiatives or reports have been aimed at altering individual faculty or departmental activities, and there is little research that has helped leaders to understand the various interventions that might be implemented that extend beyond departments creating 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 faculty workload adjustments to provide them with the time to devote to redesigning courses or participating in the required professional development.

There are many different approaches to creating change within colleges and universities. A typical model is often of strategic planning and this model 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 practices of organizational learning. Within this approach to change, information gathering and data analysis play a central role in helping individuals to identify directions and appropriate interventions for making strategic forward progress. Participants in any organizational learning planning process foreground the data, reflection, dialogue, and non-hierarchical teams learning and developing innovative approaches. This means having campus teams look at data related to student success in order to determine the specific challenges and problems and to orient themselves towards a vision for change. But an organizational learning model also focuses on learning throughout the change process.

“New insights gained from the ongoing interactions have contributed to an iterative design process and to the non-linear nature of our work. The constant need and desire to adjust plans and actions based on new knowledge and insights acquired makes it challenging to develop a single plan.”
- CSU East Bay
The model is focused on facilitating organizational learning, but it also incorporates key ideas from other research on change, such as the need to address politics, developing buy-in and a shared vision, understanding the power of organizational culture, and helping campus leaders unearth underlying assumptions and values that might create resistance to change. It should be noted that almost all these processes — organizational learning, addressing politics, creating a shared vision and unearthing cultural assumptions — were extremely hard for STEM leaders in the project to embrace. These processes are often messy and non-linear. However, strategic planning approaches that are linear and less messy were often preferred by the leaders we worked with, which suggests that teams are not naturally inclined to use the strategies that work to create change. We describe this challenge in more detail later under implicit theories of change (Section II.B.2).

The Framework, described below, articulates both the practical steps and logistics of the work of STEM reform as well as the key phases for leading, supporting, implementing and sustaining program interventions that result in improved student learning and success, particularly for under-represented 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 various factors identified in the model process (e.g., leverage points, existing expertise, capacity, etc).
II. Keck/PKAL Model for Systemic Institutional Change in STEM

A. The Model

The model process is illustrated as a river to illustrate the dynamic, flowing nature of change (Figure 1).

Figure 1. The Model
It begins at the upper left and proceeds toward the lower right with the colored boxes representing the practical steps that need to occur along the way. Leadership is critical for starting the process. The process also requires a significant readiness assessment component to gauge campus climate, capacity for change and resources required for program development. And, finally the process leads to action of the planned strategies that leads to desired results.

The river analogy is most apt, not only because of the flowing nature of a river, but because a river is a dynamic, changing structure. The flow (change process) encounters obstacles (challenges presented by certain aspects of the change process) that may result in an eddy where the flow circles around the obstacle until it can break free. Travelers on the river may enter at various points or put out at certain locations to rest. New travelers may enter and 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 out for periods of time because other campus priorities emerge, team members take on other duties, campus leadership changes, etc.

The eddies in the model diagram indicate where effort has a tendency to loop back in an iterative process. For example, in the visioning process, the data landscape analysis informs and refines the vision. It is not a linear, stepwise process, but one that is more dynamic like a flowing river that produces occasional eddies off to the side as it encounters obstacles. The resulting eddy motion is an apt analogy for the circular swirl, or iterative process, that campus teams experience when they encounter resistance, challenges along their path toward reform. They must work through the issue, determine the nature of the challenge and figure out how to get the flow going again in the desired direction. In a “reform eddy” teams “peel out” or pause while the obstacle is investigated and further analyzed before they are able to get out of 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 of the problem, existing expertise, campus leadership capacity, etc. Teams can also swim up or downstream, although the general flow will be ultimately to go downstream toward action and success. Deploying the model using these elements can be painful and challenging but it is extremely helpful to envision what you think will work for you and to identify where you are, based on campus context, expertise, leadership, etc. Wherever you start, we believe you must somehow address all the elements at some point or time.

Throughout the flow, leadership is required, readiness must be assessed and, ultimately, action is taken (represented in the upper part of the diagram). Leaders must be identified early in the process. These leaders may be from the central
administration, departmental, division, or college. External experts and/or partners may also play a critical early leadership role (board of trustee member, K-12 partner). Early adopters/disrupters who are faculty that are already engaged in course redesign or DBER (discipline-based educational research) or are champions (influential faculty leaders) are common early leaders for change in STEM. These individuals make up important members of an initial team to get the project started. Some resources (particularly time for faculty leaders to devote to planning and initial analysis) are extremely helpful during this phase. Funding from special project funding pools or external grants can seed initial efforts.

There are eight elements of the model:

1. **Vision** -- The vision represents the direction that the campus is aimed in terms of altering the STEM experience to support student success. We encourage a vision that is clear and shared.

2. **Landscape and capacity** -- A direction forward is typically best created through an analysis of the existing landscape (internal campus data as well as external reports on STEM reform) as well as a review of current capacity to engage in change generally -- such as history of reform, leadership, and buy in and ownership among faculty. This stage focuses on the collecting of data and information to conduct analysis.

3. **Identify and analyze challenges** -- The landscape and capacity information needs to be analyzed in order to identify both challenges and opportunities for the campus. This phase often brings in aspects of both politics and culture that might be sources of both opportunities and challenges.

4. **Choose strategies/ interventions/opportunities** -- Campuses need to familiarize themselves with a host of strategies or interventions that they might choose from to address the challenges identified. They can examine these strategies in light of the capacity of the campus as well as opportunities identified earlier.

5. **Determine readiness for action** -- In addition to reviewing the capacity and opportunities, there are key issues that emerge when implementing specific strategies such as resources, workload, institutional commitment, facilities, timeline and other areas that should be reviewed in order to effectively implement the strategy and to ensure that the campus is ready to move forward with that particular strategy. Campuses will be able to identify
opportunities, such as a newly established special campus projects fund, a new faculty hire with appropriate expertise, etc. that can be leveraged in support of effective implementation. Besides ensuring that a solid plan for action has been developed, this phase also involves exploring campus politics and culture.

6. Implementation - Implementation involves drafting a plan for putting the intervention or strategies in place. The plan builds off of the ideas from the readiness for action, capacity of the campus, and opportunities identified. All of these will be built into the plan as well as a process for understanding challenges as they emerge. In addition to a well laid out plan, campuses may decide to pilot an initiative first and then consider how to modify and scale it after an initial trial.

7. Measure results -- Campuses will also create an assessment plan to inform whether the intervention is working and ways they can be changed over time to work better.

8. Disseminate and plan next steps – In order to prevent the continued siloization of our work, it is important for campuses to think about dissemination opportunities on campus as well as off campus, either regionally, statewide or nationally. Also, keeping the momentum going will require deliberate planning for next steps.

Figure 2 below represents the elements of the model arranged in the stages of the scientific method. Science faculty may find this version more approachable because it represents the change process in terms of the development of scientific knowledge, from hypothesis development to experimental design and testing. The model elements are placed in this context to show the parallels between these two processes. Through our work, we identified that faculty may resonate better at least initially with this representation of the framework. A similar framing has previously been used by Handelsman et al., (2004) and Weiman (2007) to help science faculty see the connections between their disciplinary mindset of discovery and experimentation, and that of educational research and reform. What we found is that one way to orient or approach change often does not work, so we offer this different vantage point that may more strongly resonate.
Figure 2. A Scientific Version of the Model
Step 1. Determine where to enter the Model

It needs to be emphasized that each campus must construct its own “framework” process. Our experience is that this model provides a general outline that can be used by individual campuses and customized to help them institutionalize and sustain STEM reform efforts. Individual campus processes vary tremendously, navigating through the model in very different ways. However, campuses will eventually hit on all of the aspects of the Framework. From our experience with the participating campuses, if a particular area was ignored they found themselves drawn back to that issue because it became a barrier to their forward movement. As a result, most campuses did not move through the model in a linear fashion. Sometimes it took teams 2 to 3 years to reassess goals and to experience enough roadblocks that they finally returned to the initial steps. When they did, there was a new clarity of purpose. But at the end of the project, each team noted that had they been open to following the model from the beginning they would have saved themselves a lot of stops and starts, resistance and headaches, and likely time and resources. So it’s important for campuses to identify what steps they have already taken and then help consider next steps moving forward. However, it is important to keep the model in the background to identify specific barriers and help teams return to issues they had ignored.

The entire process takes leadership. Leadership can take a variety of forms, from informal faculty leaders to formal institutional administrators. Regardless, though, 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 the best entry point and the questions in Table 1 are designed to help.

Activity: Answer the questions provided in Table 1 (yes/no) column.
### Table 1. Getting Started

<table>
<thead>
<tr>
<th>Key Questions</th>
<th>Yes, Some, No?</th>
<th>If yes, then …</th>
<th>If no, then …</th>
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<tr>
<td><strong>Vision</strong>: Is there a campus vision and/or goal statement that is specific to STEM learning goals and/or STEM student success (recruitment, persistence, graduation rates)? Do STEM programs, departments and/or Colleges have articulated goals for STEM student learning and success?</td>
<td>… use this as a lever to bring people together to discuss common goals and specific outcomes.</td>
<td>… this may be a good place to start. Present this as an opportunity to start a conversation about what is important regarding STEM student learning and success.</td>
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<td><strong>Landscape Analysis</strong>: 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.?</td>
<td>… tie the data to your vision if that hasn’t already been done. Data can be an important lever for change and an opportunity for conversations with faculty and staff. Interview faculty, attend department meetings, leverage educational experts.</td>
<td>… 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 may need to consider how it will obtain the expertise needed either through staffing or use of consultants.</td>
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<tr>
<td><strong>Identify and analyze challenges</strong>: Has the campus identified student attributes, programmatic bottlenecks, policy, scheduling or other factors that impeded STEM student learning, retention and/or graduation?</td>
<td>… leverage this analysis for a focused discussion on specific areas where interventions might be fruitful.</td>
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<tr>
<td><strong>Choose strategies and interventions</strong>: Does the campus have any experience with implementation of evidence-based practices in STEM education (e.g., studio courses, problem-based learning, peer-led team learning (PLTL), etc.), STEM-focused summer bridge programs, supplemental instruction, learning communities, etc.?</td>
<td>… bring the people who have this experience together to share their knowledge and assess results; tie results back to vision and landscape analysis to see how they fit together, identify where gaps exist and them create a plan for how to move forward that addresses concerns.</td>
<td>… conduct a review of the relevant literature (see section on strategies and interventions) as well as devoting resources to professional development opportunities for faculty and staff is warranted.</td>
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Questions:
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 have to leverage for starting at this point? What challenges do you think might face?
Step 2. Team and Leadership Development
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 projects to take the time to create high functioning teams. Once teams are created they also need time to get to know each other, create a common language and vision around the change, and 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. Everyone must feel welcome and that they are in a safe environment for discussion of potentially controversial ideas or data and for free expression of opinions as well as experimentation with innovative interventions.

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 be able act as liaison this is helpful in gaining 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—some one 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. We provide questions that can be used by leaders 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 were uncovered?
• 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 their 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?
Questions:

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

<table>
<thead>
<tr>
<th>Types of Expertise</th>
<th>Name(s)</th>
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</thead>
<tbody>
<tr>
<td>Faculty</td>
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</tr>
<tr>
<td>Staff</td>
<td></td>
</tr>
<tr>
<td>Student Affairs</td>
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<tr>
<td>Office of Institutional Research</td>
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<tr>
<td>Administration</td>
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<tr>
<td>Students</td>
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<tr>
<td>Other</td>
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<td>Other</td>
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<td>Other</td>
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</tbody>
</table>
2. Who will lead the team? You will need faculty leaders and institutional champions.

   a. Faculty leaders:

   b. Institutional champions:

3. How will the team work and communicate?
Team Development Resources: For more guidance on working as a team, please 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). Close to 2,000 faculty have gone through the training and found it extremely important to assisting them in leading change efforts on campus as well as advancing in their careers and to roles as department chair, dean and provost. Many disciplinary societies offer leadership training at their annual meetings. Other faculty 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; http://www.sencer.net), BioQUEST (http://bioquest.org), and POGIL (Process Oriented Guided Inquiry Learning; https://pogil.org). Each of these networks provides different opportunities for developing leadership skills, mostly through the lens of mounting projects related to undergraduate STEM reform. Campuses that are successful in reforming STEM typically send faculty to these various professional development opportunities to gain the skills required to lead processes like we describe in this guidebook. Faculty leaders, chair and deans may also realize greater success when they “lead up” by creating short talking points for higher level leaders so they can speak with authority about STEM education and/or campus projects. Additionally, senior leaders are needed to change reward structures, help with resources, and provide the 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 determined institutional priorities and aligns their STEM reform efforts with institutional goals.
Step 3. Establish your Model Baseline.
Before you get started, rate your campus’ current status on the elements of the model below. Use this rubric to check in on your progress periodically.

Activity: Determine the status of your campus along each element of the model in the rubric below. Identify the benchmark description that best fits your campus right now and tally your score.

Table 2. Model Rubric

<table>
<thead>
<tr>
<th>Model Element</th>
<th>Developed (3 points)</th>
<th>Emerging (2 points)</th>
<th>Initial (1 point)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>The campus has a well-defined statement that describes their collective vision for improving STEM student learning and success (which may include overarching outcomes like quantitative reasoning). The vision includes clear goals for your efforts as well as specific outcomes and measures, and is linked to institutional mission and priorities.</td>
<td>Individual units may have statements that relate to STEM student learning and success; however, they are not coherent across relevant units or tied to institutional mission and priorities.</td>
<td>The campus has not developed a vision or goals for STEM student learning and success, although isolated courses may have these goals. There may also not be a campus-wide vision for student learning and success.</td>
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<tr>
<td>Landscape and Capacity Analysis</td>
<td>The campus has a clear picture of how students are performing in classes and programs, as well as their attainment of STEM degrees by examining who is coming in, staying, graduating; how and what are they learning;</td>
<td>The campus has capacity for collecting and analyzing data but has not fully analyzed or disaggregated for STEM programs and courses, has not included STEM faculty and administrators in discussion of data.</td>
<td>The campus has not yet collected or analyzed data on student learning or success; may not have the staff or other resources to collect and analyze data.</td>
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<td>Identify and Analyze Challenges</td>
<td>Specific challenges regarding STEM student success have been articulated and supported by evidence. Pointers to particular programmatic or institutional opportunities that might be leveraged have been recognized.</td>
<td>The campus 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.</td>
<td>There is a general lack of awareness among faculty and/or administrators regarding effective practices for promoting STEM student success; the campus has not identified any opportunities that might be leveraged.</td>
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<tr>
<td>Strategy and Intervention Choice</td>
<td>Specific strategies or programmatic interventions have been identified that address the gaps or needs identified by the landscape analysis and are focused on the vision.</td>
<td>Programmatic strategies or interventions are not fully developed or do not address needs identified by landscape and capacity analysis.</td>
<td>Strategies have not been identified or developed.</td>
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<tr>
<td>Determine Readiness</td>
<td>The campus has identified and obtained the faculty, staff, financial, physical and cultural resources to implement the identified strategies.</td>
<td>Some resources have been identified, although the campus may not have obtained all the needed resources.</td>
<td>No analysis or identification of resources has been completed.</td>
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<tr>
<td>Implementation</td>
<td>The campus has carried out at least one pilot or small-scale implementation of their planned strategy and collected adequate assessment data to</td>
<td>Plans are not complete; scattered or isolated attempts at strategies may have been made by individuals or in single courses.</td>
<td>No plans to implement exist.</td>
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<tr>
<td>Measuring Impact</td>
<td>Dissemination and Next Steps</td>
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<td>Key data will have been collected and analyzed to help campuses evaluate how well their plan worked, where it may have failed and how you might improve it for the next round of implementation and eventual scale up.</td>
<td>Descriptions of project purpose, methods and results will be documented in various formats and venues, such as websites and newsletters, social media sites, campus presentations, community news articles, conference presentations, published papers. Plans are in place for modification, improvement and/or scale up.</td>
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<td>Implementation has occurred; however, little or no data has been collected; dataset may be incomplete; if data has been collected it may not have been analyzed.</td>
<td>Some descriptions of project goals and results may be available in project, department or college reports or campus website but 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.</td>
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<td>No data has been collected or analyzed.</td>
<td>Very little information about the project is available beyond those engaged in the process. No plan exists for applying lessons learned to future program implementation.</td>
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**TOTAL**

Scoring: A score of 8 indicates you are at the very beginning stages; a score of 24 indicates you are at a very advanced stage of work.
Questions:
1. Was your score expected, unexpected? Why?

2. What strengths, weaknesses and opportunities can you identify as a result of your rubric analysis?

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Opportunities</th>
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3. What are your three next steps for moving forward?

<table>
<thead>
<tr>
<th>What</th>
<th>Who</th>
<th>When</th>
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It is important to start with a clear vision of the purpose for improving undergraduate STEM education. This vision may be better framed as goals for reform, depending on how your campus works best. This vision is most powerful when it is constructed by a diverse team of leaders, faculty and staff from STEM departments and throughout the institution and is 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.

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

Many campuses started their work believing they had created a vision, but as they encountered other information, for example, learning about past efforts that were revealed by new data, or learning from others across campus, they either broadened or reconsidered their vision. 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. In the case studies there are examples of campuses that altered their initial vision, often because they did not conduct a careful enough landscape analysis. Ultimately, the vision process is not just about developing the direction but also a common language that everyone understands. This is important so that people can communicate clearly and teams can create buy in that helps build enthusiasm for the change. It is also useful to consider the many opportunities there are to improve STEM education and to consider a range of issues that might help to inform their vision of STEM student success. Some examples of opportunities and issues are listed below.

Most campuses also learned that vision creation comes from a careful landscape and capacity analysis. Many of our campus teams utilized national reports and research to help create their vision, such as the *Vision and Change in Biology Education* report (AAAS, 2012) or the Expanding Underrepresented Minority Participation report (National Academies, 2010a). Understanding current work that exists related to supporting student success as well as gaps, exploring data that might help understand problems or successes, and understanding the history related to STEM reform efforts. The landscape and
capacity analysis helps teams to consider an appropriate vision given their history, current efforts, and data that identified trends they may be unaware of. Thus it is important to see the landscape analysis and vision process very much tied together. The interplay of the landscape analysis and vision is described in the case study highlights below.

Opportunities:

- K-12 partnerships and outreach that might assist with recruitment
- Developments in evidence-based teaching practices (e.g., POGIL, PLTL, SCALE-UP, Classroom-Based Undergraduate Research Experiences (CUREs), etc.; see Project Kaleidoscope’s Pedagogies of Engagement website, National Academies, 2012); 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 approach
- Mentoring opportunities, both peer and faculty
- Peer learning opportunities, study groups and clubs
- Remediation, both English and Math; also considering Math requirements
- Partnerships with industry or business for research but also career connections
- Internships and co-ops
- Differential tuition policies
- Reverse transfer policies
- Facilities that support active learning; hybrid classrooms and uses of technology
Issues:

- Inclusiveness and stereotype threat
- Student self efficacy and development of scientist identity
- Departmental culture(s)
- Campus curricular policies
- Consideration of policies and procedures that affect student major progression or 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 that show interest in STEM but are leaving 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 as helpful for URM students. Learning more about practices/opportunities that are in support of these populations is an important step as part of the vision and later when considering interventions.

Also, another issue to address under vision is whether this is for STEM reform for STEM majors or STEM reform for all majors. We encourage campuses to think broadly because STEM literacy is low nationally and working to improve STEM knowledge among all college graduates is called for in most national reports. Some campuses as part of this project focused reforms on STEM majors only and others had a broader vision that included non-majors. But, it is important to at least have your campus team consider the multiple levels at which STEM reform might take place. In terms of considering non-majors – projects such as SENCER have resources for thinking about reforming general education science courses:


Here are a few examples of ways campuses facilitated their vision process:

- University of La Verne took the opportunity to align their STEM vision with an emerging strategic plan and a new campus president. This allowed them to be able to get institutional resources and support for their ideas.
- CSU East Bay created an institute that brought together educational researchers and STEM faculty to develop a common vision. Bringing together diverse voices was helpful. They also developed an advisory board to help them
with their vision development and were successful in obtaining both external and internal resources to support their vision.

• The CSU system team held an all-day retreat and brought in a consultant to help them in developing and defining the vision statement.

• The W.M. Keck Science Department and other campus teams took advantage of grant funding to provide the time and resources to solidify a common vision.

**Timeline:** The vision process typically takes 6 months to a year, but can take longer if data on STEM student success is lacking. We recommend waiting until a careful data landscape analysis can be conducted, otherwise the change process will likely return to the vision process anyway once the landscape analysis is finalized.

**Questions to ask when considering this step:**

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 do you 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?
Step 5. Landscape and capacity analysis related to vision

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, pedagogical approaches; and, 2) an external review of national reports, science education literature and/or projects reported by other campuses at conferences on STEM education. This step helps campuses hone 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 that address gaps and problem areas that may lie at the root of the problem they are trying to solve. This step is important to help the campus figure out what its specific issues and challenges are but also to gather data that will generate motivation for change, obtain buy-in from faculty members, and garner support from administrators. It will also require a continual process of gathering resources and information often in order to establish a good baseline and monitor progress.

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

The first step is data gathering and analysis. Table 4 lists types of data that campuses may find useful in conducting their landscape analysis to better characterize the terrain of STEM education on your campus. Other examples are listed on the AAC&U’s STEM Assessments website (http://www.aacu.org/resources/assessment/STEMAssessments.cfm). The most successful teams partnered with institutional researchers and assessment experts early on to collect, mine and analyze relevant data. Is important to obtain senior leadership support to get appropriate data to help examine the issue of student success. A successful example of this outside of the project is the 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. Commonly used types of data for conducting a thorough landscape analysis

<table>
<thead>
<tr>
<th>Type of data</th>
<th>Example</th>
<th>Purpose</th>
</tr>
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<tbody>
<tr>
<td>Student demographic data</td>
<td>High school attended, high school GPA, SAT/ACT, remedial Math &amp; English test scores/placements, cumulative college GPA, major GPA, URM (underrepresented minority) and/or first-generation status, Pell eligibility, etc.</td>
<td>Understand basic characteristics of students who enter the program, where they come from, their backgrounds, etc. to identify possible target populations or risk factors.</td>
</tr>
<tr>
<td>STEM major retention and graduation data</td>
<td>Data on enrollment, retention, graduation by ethnicity, gender, other factors of interest</td>
<td>Understand nuances of student success, differences among populations, progression, etc. to identify gaps.</td>
</tr>
<tr>
<td>Introductory course completion and progression data</td>
<td>Average course grades, DWF percentages (D grades, withdrawals, F grades), analysis of student enrollment in subsequent courses in series, etc.</td>
<td>Identify course-specific issues to determine specific roadblock populations, gaps in courses, etc.</td>
</tr>
<tr>
<td>Direct assessment of student learning in courses and programs (formative or summative)</td>
<td>Personal response systems used in class (i.e., “clickers); concept inventories and corresponding learning gains calculations (see for example, Hake, 1998; <a href="https://cihub.org">https://cihub.org</a>), including the Science Literacy Concept Inventory (Williams, Atkins and Schellenberg, 2013); Educational Testing Service (ETS) Major Field Tests, scoring of embedded exam questions or common exams; large-scale review of signature assignments using AAC&amp;U’s VALUE or other rubrics; use of rubrics to assess poster presentations of research projects</td>
<td>Probe student learning at a deeper level, programmatic level based on agreed upon outcomes to identify gaps in learning, particularly for important prerequisite knowledge.</td>
</tr>
<tr>
<td>Indirect assessment of student learning</td>
<td>Institutional surveys, such as National Survey of Student Engagement (NSSE), CIRP Freshman Survey; end of</td>
<td>Gather student or alumni feedback on their experiences in the program to</td>
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<tr>
<td>or experiences</td>
<td>Program effectiveness documentation</td>
<td>Student participation in special programs (summer bridge, advising programs, research, etc.)</td>
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<tr>
<td>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), IDEA surveys; alumni surveys</td>
<td>Program review documents, accreditation self-studies; curriculum maps; outcomes assessment plans; faculty workload analysis; alumni interviews &amp; tracking</td>
<td>Program tracking and evaluation reports; student surveys, interviews, focus groups</td>
</tr>
<tr>
<td>identify positive practices or those that may need improvement.</td>
<td>Determine program effectiveness; demonstrate how students move through the curriculum and faculty workload issues; connect program outcomes and assessments to institutional priorities.</td>
<td>Understand who is participating, how often, and whether participation makes a difference; also understand program effectiveness to make improvements.</td>
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</table>
(Reformed Teaching Observation Protocol; see NAGT, 2012) or COPUS (Classroom Observation Protocol for Undergraduate STEM; Smith, et al., 2013); other methods described in Describing and Measuring Undergraduate STEM Teaching Practices (AAAS, 2014)

| DBER (Discipline-Based Education Research) activity | Documentation of faculty members who have publications in science education journals, federal or other grants obtained for science education research and development projects, 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 – URM (under-represented minority) status, first-generation student status, gender, Pell eligibility, first-time full-time freshmen, transfer students, etc. to obtain the clearest picture of student success. Cohort studies are the best for over-time comparisons of populations.

These landscape analyses that campuses carried out included looking at data from their own campus as well as considering external stakeholder issues, such as high school and community college preparation or matriculation, and broader trends about STEM student success, strategies and ideas for change, and important trends for the future from national reports, such as the Engage to Excel report (PCAST, 2011). As noted above, it is important that data 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 that may help your efforts in this area are: The Equity Scorecard -- [http://cue.usc.edu/our_tools/the_equity_scorecard.html](http://cue.usc.edu/our_tools/the_equity_scorecard.html); Campus Diversity Project -- [http://irvine.org/evaluation/program-evaluations/campus_diversity_initiative](http://irvine.org/evaluation/program-evaluations/campus_diversity_initiative) and Achieving the Dream -- [http://achievingthedream.org/](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 (Partners for Undergraduate Life Science Education; [http://www.pulsecommunity.org](http://www.pulsecommunity.org)) initiative among other topics. The website created for this project ([http://aacu.org/pkal/educationframework/index.cfm](http://aacu.org/pkal/educationframework/index.cfm)) has links to presentations, reports, meeting resources and webinars used in the project that might be informative to your efforts.
In order to fully understand campus capacity for change, campuses 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, TAs, and departments for change. There are several approaches to determine receptivity, such as characterizing current STEM education grant activity, publications, participation of faculty in campus-based faculty development workshops and activities. Some of the campus teams that we worked with conducted surveys of faculty to determine their use or awareness of a STEM reform. The campus teams that we worked with found that past efforts at change help signal readiness and could be a source for understanding problems and moving forward.

- **Gauging faculty receptivity and achieving buy-in.** Creating faculty learning communities, or groups that meet regularly to discuss a common area of practice -- for example utilizing active learning or service learning in the classroom (maybe link to some resources on learning communities), is a powerful practice for obtaining buy-in. Many campuses have used learning communities in order to create readiness for reform or have created a speaker series, STEM education-focused workshops, faculty mini grants, conducted surveys on faculty practice (or have mined existing – Faculty Survey of Student Engagement (FSSE), Higher Education Research Institute’s (HERI) Faculty Survey, etc.).

- **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 who will be champions in the effort. If there is little leadership for the effort, it is unlikely to move forward and so determining who is willing to play a leadership role is critical. It is often helpful if there are senior faculty who 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 SLOs, service learning initiatives, tablet/technology initiative, graduation rate initiatives, university freshmen book reading, etc.) that could be aligned with their STEM vision and effort. For example, 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 picture when faculty and administrators are planning new initiatives or programs from which they will benefit. 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.

**Timeline:** The landscape analysis is ideally conducted in concert with discussions related to vision (shown as the first reform eddy in Figure 1) and is therefore best conducted in the first 6 months to a year of an initiative. Yet, if a campus is low on 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 get the right interpretation. Analysis of initial data may also reveal the need for other data, which may take time to obtain. It is important to create environment that allows for mistakes and trial and error as well as risk-taking.

**Questions:**
1. What data does the campus regularly collect and analyze (e.g., retention and graduation rates, National Survey of Student Engagement, CIRP Freshman Survey, Higher Education Research Institute (HERI) faculty survey)? Can this data be leveraged for learning more about the challenges regarding STEM student learning and/or success?

2. Looking at Table 4, what data/analysis might you consider adding to expand your understanding?

3. Are faculty (and relevant staff/administration) aware of the issues revealed by the data and landscape analysis? Are they interested in discussing them? Do they see the problem(s) the data reveal?
4. What is the existing climate for change? Have other change processes (e.g., general education reform, outcomes assessment initiatives) been carried out on campus? If so, how successful were they or what challenges did they face?

5. With respect to capacity for change:
   a. What kind of learning environments and opportunities do students currently experience?
   b. What structures are in place to support curricular revisions and pedagogical innovations?
   c. Are there faculty who are already engaged in STEM education research or faculty development?
   d. Are there existing initiatives devoted to student success on campus?
   e. Are there grant or other proposal opportunities to leverage in obtaining seed funding for STEM reform?
   f. Has the student affairs division created programs that target student success more broadly or for STEM students (e.g., summer bridge, early start)? How can their expertise be leveraged?

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?
Step 6. Identify and analyze challenges and opportunities emerging from Landscape and Capacity Analysis

Using the data analysis, campuses can specifically identify where the problems and challenges lie in recruitment, retention, program offerings (course sequencing, prerequisite requirements), teaching and learning spaces, pedagogy, advising, academic support, etc. This step will help teams evaluate the best possible strategies and interventions to implement in order to address the identified issues. Common challenges relate to:

- Recruitment of students into STEM majors.
- Retention of URM and/or first-generation students after the first and/or second years.
- High levels of remediation and/or lack of student success in remedial courses.
- Outmoded pedagogy in introductory/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 levels of course repeats leading to stalling of student progression through degree.
- Transfer shock of community college students matriculating into four-year universities.
- Lower than desired graduation rates.

_Benchmark:_ Specific challenges regarding STEM student success have been articulated and supported by evidence. Pointers to particular programmatic or institutional opportunities that might be leveraged have been recognized.

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

**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.

**Questions:**

1. Do you have enough data to draw conclusions? What additional information might you need? Do you have the data disaggregated appropriately enough to see all the populations (race, gender, socio-economic status, etc.)?

2. What assumptions have been made regarding student learning and success that are revealed by the data analysis?

3. What conclusions can be drawn from the data? What part of the program (pre-college, particular gateway course, math skills, advising, etc.) is implicated from the analysis?

4. Where and for whom are there gaps in student success?

5. What opportunities might you leverage to address the challenge? Existing campus programs, grant opportunities, institutional priorities?

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?
Step 7. Strategies and interventions that address challenges and leverage opportunities

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. For more general consideration of high-impact practices, see AAC&U’s reports (Kuh, 2008; Brownell and Swaner, 2010; Kuh and O’Donnell, 2013; McNair and Finley, 2013). There is also a new Discipline-Based Educational Research (DBER) Practitioner’s Guide forthcoming from the National Academies that should be an extremely resource for researching and implementing evidence-based reforms (http://www.nap.edu). The National Science Foundation’s STEP Central Website is also a useful resource (http://stepcentral.net/projects/).

Benchmark: Specific strategies or programmatic interventions have been identified that address the gaps or needs identified by the landscape analysis and are focused on the vision.

We found that campus teams developed better strategies when they were aware of a host of different approaches to addressing common STEM student success problems of retention, interest in STEM, success and coursework, math aversion, student isolation, or poor understanding of careers in STEM. For example, to address the issue of student isolation, students might be put into linked freshman courses, place in formal mentoring programs, or involved in undergraduate research. Larger campuses might have more success with the linked freshman courses and smaller institutions might be able to mentor each student. So being aware of several different interventions that might be used to address a problem allowed the institutions to decide on the intervention that best fit their context and capacity. Furthermore, there is a tendency to choose one intervention rather than think about a linked set of interventions that can best support student success. Retention is usually not impacted by one issue - for example poor instruction or lack of authentic STEM experience, but is usually impacted by several issues from transition to college (addressed by bridge program), success in early gateway courses (active learning), and identification of self as a scientist (undergraduate research experience/ authentic STEM experience). But it is important for campus teams to think broadly about a variety of necessary interventions that are needed to address a particular challenge. There are also interventions aimed specifically on supporting

“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
URM students that have been supported through research. The 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; or The Institute for Higher Education Policy’s (IHEP) project on diversifying the STEM pipeline -- http://www.ihep.org/Publications/publications-detail.cfm?id=132.

We also provide a caution that most teams wanted to jump directly to implementing interventions or strategies without fully understanding challenges within their campus environment. If it is difficult to obtain data or get faculty to read national reports or literature, project leaders may tend to jump into interventions as a way to garner attention and focus. To identify opportunities that 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 they are aware of all possible connections. For example, if your intervention involves starting a STEM summer bridge program, the campus may already offer a summer bridge program for the general student population into which you can connect and possibly save resources and time. This means there are outreach, staffing and program experts on campus that may be able to help plan and execute the new program. We also found a tendency for STEM reform efforts to be isolated from the general efforts to support student success and less likely to leverage existing resources. Often STEM leaders felt the need to obtain external grants and resources that slowed their process and possibilities, rather than examine existing resources.

Table 5. Summary of challenges and possible interventions (from the literature and reports)

<table>
<thead>
<tr>
<th>Identified Challenge</th>
<th>Some interventions to consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low levels of incoming freshmen</td>
<td>K-12 school outreach programs, engagement with local industry to sponsor robotics camps or other mechanisms to get students excited about STEM.</td>
</tr>
<tr>
<td>Low retention and/or graduation rates</td>
<td>Summer Bridge, freshmen STEM orientation programs, introductory/gateway course redesign to improve student engagement and success, freshmen learning communities, undergraduate research programs (e.g., the Freshman Research Initiative; <a href="http://cns.utexas.edu/fri">http://cns.utexas.edu/fri</a>), and other High-Impact Practices (Kuh, 2008).</td>
</tr>
<tr>
<td>High levels of remediation and/or lack of student success in remedial</td>
<td>Course redesign using more interactive-engaging pedagogies, focus on quantitative reasoning and/or statistics (see Statway and/or Quantway;</td>
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<td>------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>URM student persistence and graduation gaps; outmoded pedagogy in introductory/core/gateway courses; less than desirable learning in STEM at any level</td>
<td>Use of evidence-based pedagogies (see National Academies, 2012; Freeman et al., 2014) and other High-Impact Practices (Kuh, 2008; Brownell and Swaner, 2010; Kuh and O'Donnell, 2013; McNair and Finley, 2013); use of peer mentors, peer advisors or creation of a Learning Assistant program (<a href="http://laprogram.colorado.edu">http://laprogram.colorado.edu</a>).</td>
</tr>
<tr>
<td>Low levels of student engagement in or understanding of the process of science</td>
<td>Undergraduate research experiences (e.g., summer research programs, freshmen research initiative), including Classroom-based Undergraduate Research Experiences (CUREs).</td>
</tr>
<tr>
<td>Low sense of community/belonging among students; transfer shock of community college students</td>
<td>Learning communities and cohort programs that include linked courses, such as introductory science courses plus writing/critical thinking and/or other general education courses; implementation of service learning or community-based programs; partnerships with Student Affairs or other units on campus that interact with students outside the classroom.</td>
</tr>
<tr>
<td>Need for development of faculty expertise, development of a culture of evidence-based teaching; wider scale implementation of evidence-based methods.</td>
<td>Creation of targeted faculty development programs on campus, such as faculty learning communities; programs that provide opportunities for faculty to attend national faculty development workshops or institutes; consider hiring science faculty with education specialties (SFES; Bush et al., 2013)</td>
</tr>
<tr>
<td>Lack of support for students outside the department or program</td>
<td>Creation of partnerships with Student Affairs, advising or other units on campus that interface with students outside the classroom.</td>
</tr>
<tr>
<td>Problems with student scheduling patterns/course sequencing or high levels of repeat courses</td>
<td>Articulation and publication of student pathways for graduation, monitoring systems to identify at risk students for advising, tutoring, or other interventions.</td>
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</tbody>
</table>
Faculty will be a central resource in delivering the new program; therefore, faculty development is a critical factor to consider early. This is important in two regards: 1) ensuring faculty have the knowledge and skills to implement the teaching strategies shown above, and 2) developing faculty leadership capacity (discussed earlier). Faculty development programs on campuses vary in terms of size, offerings and engagement. Most campuses have a centralized office or center that often includes workshops and instructional design with respect to incorporation of technology. Another model is discipline-based faculty development that is housed in a College, such as that described by Marbach-Ad and her colleagues at the University of Maryland, College Park (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), the National Effective Teaching Institutes offered by the Association for Engineering Education (http://www.asee.org/conferences-and-events/conferences/neti). This is in addition to SENCER (Science Education for New Civic Engagement and Responsibilities; http://www.sencer.net), BioQUEST (http://bioquest.org), and POGIL (Process Oriented Guided Inquiry Learning; https://pogil.org) that were mentioned earlier (Section II.B.10).

**Timeline:** Like the analysis phase, identification of strategy or interventions typically happens quite quickly as the team investigates possible strategies that are focused on solving the identified problems.
Questions:

1. Have you examined the interventions needed comprehensively and holistically so that implementation is not thwarted by issues we did not consider but that are needed for support? Are the interventions supported by data and directed at solving the issues or challenges we have identified? See also Table 5 for some ideas about interventions.

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. What timeline is required to pilot test, evaluate and scale up?

5. Does your chosen intervention leverage existing resources, programs, 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 human subjects research? 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?
Step 8. Determine readiness

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. This in depth survey intentionally prompts teams to consider all the stages up to this point. This is because we found that campuses often proceeded without fully completing prior steps. So, this is a good point to assess progress and make any needed adjustments.

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

Once a particular strategy/intervention has been chosen, then the campus can identify what is their readiness for implementing a summer bridge program and revising introductory STEM courses to be more engaging and active. Determining specific readiness will be unique based on the interventions that are chosen, yet there are some common areas that we recommend teams examine including timelines, resources, institutional commitment, incentives and rewards, leadership, staffing, faculty development, incentive structures, buy-in, and data collection and analysis support.

**Timeline:** Determining readiness may take more time, like the landscape and capacity analysis phase, because it requires obtaining information about campus context, resources and culture. Political issues are particularly important to address. We found that campus teams had a tendency to move directly to implementation rather than take the time to assess readiness. However, the collection of readiness data was instrumental in overcoming resistance and moving forward with change more smoothly. If this phase isn’t addressed adequately, roadblocks may be encountered down the road that may create significant delays that could have been avoided.
Table 6. Readiness Survey

<table>
<thead>
<tr>
<th>Readiness Factor</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Not Sure</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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<tbody>
<tr>
<td>Planning:</td>
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<tr>
<td>1. The team has a clearly articulated and shared vision for the project.</td>
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<tr>
<td>2. Our vision is linked to key institutional priorities.</td>
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<td>3. We have scanned the campus for other STEM projects, programs and initiatives that already exist to which the new project might connect or leverage.</td>
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<td>4. We have created a project plan with identified actions, milestones and an achievable timeline. The plan involves a pilot project that will allow for initial testing and experimentation before scale up.</td>
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<td>5. We have identified possible pitfalls and roadblocks.</td>
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<td>6. We have a plan for helping students understand what is happening, the purpose and desired outcomes.</td>
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<td>7. We have an assessment plan and the capacity (including needed expertise in institutional research offices) to measure and analyze results.</td>
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<td>8. Our assessment plan builds from our landscape analysis, is linked to project outcomes and leverages existing data sources.</td>
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<td>9. We have received appropriate approval from campus Institutional Review Board for human subject research (if needed).</td>
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<td>10. We have identified appropriate facilities required to carry out the project.</td>
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<td>11. We have created a project budget.</td>
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<td>12. We have identified sources of support, both internal and external (grants, gifts, in-kind donations).</td>
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</table>
13. We have a plan for how we will communicate and celebrate project results. The plan should include both on and off campus sources as well as dissemination opportunities (e.g., published papers, conference presentations).

**People:**

14. We a team comprised of the appropriate faculty 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 help with the project or use it as a research/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 (e.g., advising, outreach, admissions), institutional research, the faculty development center, PIs of related funded projects, the President’s Office, advisory boards, committees or task forces dealing with student success. Off campus stakeholders may include K-12 educational, community and/or industry partners.)

**Politics:**

21. The project has the support of the dean, provost, president and other
key administrators.

22. We have identified the political issues we might 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.

| TOTAL |

Questions to ask when considering this step:

1. How ready are you?

2. In what areas are you least ready? What do you think you need to do to get more ready?

3. In what areas are you most ready? How can you leverage your readiness in these areas?
Step 9. Implementation

Implementation is a critical step and works best in when a pilot or small-scale test mode is used first to work out the bugs, do an initial assessment and try the implementation with minimal impact on faculty, staff and students. Pilot results can be used to assess how well the program met the goals and objectives, make adjustments, seek additional resources, garner other participant buy-in, etc. 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.

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

It is expected that innovations may not work as intended initially and this should not be seen as a failure. Instead, 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 years may fail to do so later because they may alleviate the situation, so solutions need to be seen as potentially contingent. Our previous project on Facilitating Interdisciplinary Learning (Kezar and Elrod, 2011; Project Kaleidoscope, 2011), also generously sponsored by the W.M. Keck Foundation, also has additional resources regarding infrastructure (policy/procedures), helpful funding sources/levels, faculty and staff workload management suggestions for resources to be developed and garnering support from administration, and other useful approaches that may be applicable.

**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/calendar schedule.
Questions:
  1. What is your plan for testing your strategy in a pilot process?

  2. Who will be involved?

  3. Do you have the resources you need?

  4. How will you measure success?

  5. How will assessment of the pilot program be used to make program improvements?

  6. How will the pilot program inform a larger scale implementation process?
Step 10. Measuring impact

This step goes hand-in-hand with implementation, forming the final “reform eddy” illustrated in the model diagram (Figure 1). A plan for measuring impact of your actions should have been built in to the implementation plan. These measures should be tightly linked to the outcomes you are trying to achieve. They could involve 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 often conducted, campus leaders should also consider focus groups or interviews with students when appropriate or portfolios and other qualitative demonstrations of competence. The earlier section on Landscape Analysis can serve as a guide for putting together this plan. For an example from the literature, Goldey et al. (2012) carried out a comprehensive reform of introductory biology courses and developed a comprehensive matrix of assessment tools to determine if their reforms were successful. You can use a few simple measures or create a complex plan. Be sure to be focused on measures that tie back to your desired outcomes as well as realistic about time and expertise required to carry out an effective analysis.

**Benchmark:** Key data will have been collected and analyzed to help campuses evaluate how well their plan worked, where it may have failed and how you might improve it for the next round of implementation and eventual scale up.

There are many resources on conducting evaluations of programs, curriculum, teaching and measuring impact that can be found in the science education literature and the reports that have been cited in this book, including the relatively new report from the AAAS (2014) on Describing and Measuring Undergraduate STEM Teaching Practices. But many of our campus teams found that rather than seeking a publication, they could hone expertise of social scientist and education faculty on their own campus to help with measuring the impact. While in the past they had tried to conduct this work on their own, they struggled and often results were subpar. When they partnered with colleagues in other fields that regularly do this kind of research, it was much easier to conduct this work.

Most commonly, campus teams didn’t collect enough data and were left wondering if what they just did had the desired impact. They had some data but not enough. Careful planning can help avoid this pitfall. Finally, the initial results from measuring impact can be used to alter aspects of the intervention to make it more successful in a second trial or as you scale up from a pilot test to broader implementation.
Timeline: Evaluation of results should occur both formatively, during the process, and summatively, at the end of the pilot or implementation phase. Generally, results should be collected semester by semester to monitor progress along the way and to have a bank of comparative data to see trends over time.

Questions:
1. Were you able to collect enough data to measure impact? Were there some data that were 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?
Step 11. Plans for dissemination and next steps

It is important to communicate your results, particularly to colleagues on campus but also to the broader community. This helps spread the word and create broader buy-in. It may bring new stakeholders or partners to the table as well, 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. There are several conferences and publication opportunities as well. Remember that to publish results of your work, a well-planned study must have received Institutional Review Board approval. Below is a listing of STEM-specific conferences and publication venues to consider:

- AAC&U/PKAL annual “Network for Academic Renewal” conference on transforming undergraduate STEM education or AAC&U’s annual meeting
- AAC&U publications (Liberal Education, Peer Review) or AAC&U’s monthly newsletter
- Scientific society annual meetings, some of which have special education conferences (e.g., American Society for Microbiology’s Conference on Undergraduate Education)
- Scientific journals that publish science education results (e.g., Science)
- Peer reviewed science education journals, such as Journal of College Science Teaching, or Journal of Research on Science Teaching.

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

Dissemination isn’t the end. It is just a milepost along the way that marks progress along the continuum of continual program development, planning, implementation and evaluation. Once the campus team has completed a full cycle of the model process, they should use the information collected and lessons learned to make improvements, create a new plan (if

“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
necessary) and/or prepare for scale up. A first step in this process is revisiting the vision that was initially created for the program to see if what you accomplished is aligned with the original goals. It is easy to lose sight of the original goal, especially when these projects typically 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.

**Timeline:** Preparing for presentation on campus can take a relatively short amount of time but planning for conference presentations or writing a paper takes more planning and organization. For example, many conferences call for proposals 6-8 months in advance. Preparing a manuscript takes discipline and time of a primary author to draft the paper and solicit contributions from the team. The process of peer review may also take up to 6 months.

**Questions:**
1. What on campus dissemination opportunities do we have, 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?
Conclusion

We will not meet the ambitious goals set out national 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 programs and departments to an institutional effort. A soon to be released (2015) National Research Council Report will describe the imperative for institutional efforts at STEM reform – the clarion calls for new approaches will continue to ring.

The Keck/PKAL model offers the first tool for helping campuses work on this broader vision. It offers concrete suggestions for process and content while also providing campus teams with tools they can use to steer their boat through the waters of STEM reform, and for advise for leaders to navigate the sometimes tricky political terrain involved in complex change processes. We appreciate the efforts of our pioneering campuses that explored new territory – literally going where few colleges have gone before. We are convinced that campuses that are open to a broader vision for student success and that allow themselves to engage in what can be a messy process of change can create high value, 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 for URM students. Perhaps programs implemented to improve STEM student learning and success can serve as models for other programs to advance equity and engagement in other disciplines.
IV. References cited


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