# Promoting Transformation of Undergraduate STEM Education

# Workshop Summary Report

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# Introduction

Research on teaching and learning has led to the development of instructional methods that are more effective in helping students learn. These evidence-based teaching practices, which encourage student engagement and active learning, as well as create inclusive learning environments, have been documented by high-level reports and policy papers. At the same time, the national policy environment is reflecting a more coordinated effort to improve undergraduate science, technology, engineering and mathematics (STEM) education across relevant organizations and actors. Several multi-institutional projects to improve undergraduate STEM education are underway, along with an even greater number of institutional-based projects aimed at addressing teaching and learning in STEM fields. Documenting the organizational change process and impact within and across these projects, developing mechanisms for sharing knowledge, and broadening the group of institutions engaged in this kind of reform is essential for realizing large-scale improvements in STEM education in colleges and universities across the country.

The National Science Foundation (NSF) plays an important leadership role in the development and implementation of efforts to enhance and improve STEM education in the United States. Through the Education and Human Resources, Division of Undergraduate Education's Improving Undergraduate STEM Education (IUSE) program, the NSF has made a substantial commitment to improve the quality and effectiveness of undergraduate STEM education for all students.

During a 2019 workshop, the American Association of Universities (AAU) convened experts involved in leading, researching, evaluating and funding efforts to transform undergraduate STEM teaching across all sectors of higher education. The goal was to synthesize essential issues and challenges in designing, leading, and researching institutional and multi-institutional transformation projects to improve undergraduate STEM education.

The workshop was designed to identify critical themes necessary to understand when examining the outcomes of a reform effort, and when examining the change process of a reform effort. In addition, the workshop created a forum to provide recommendations for the continued advancement of the IUSE program through the NSF's Education and Human Resources, Division of Undergraduate Education.

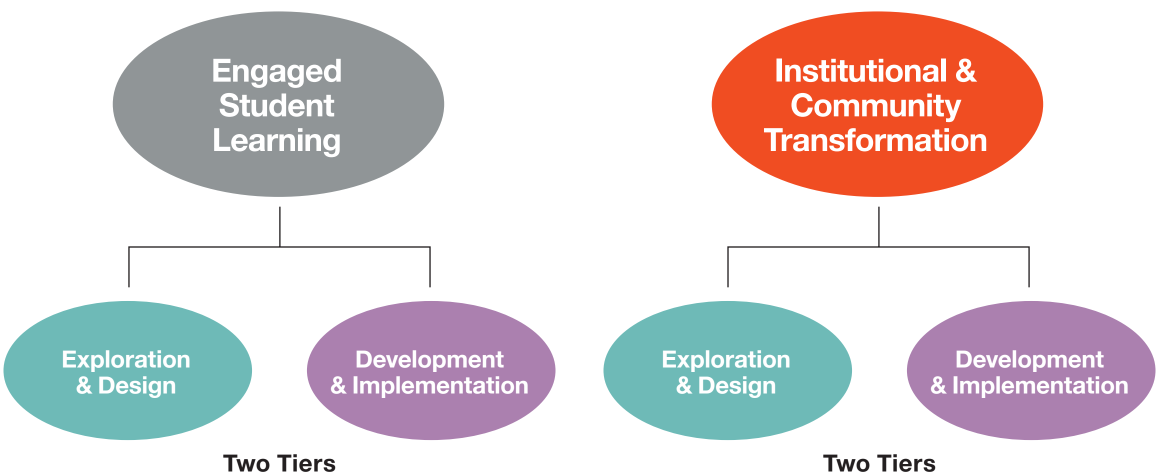
This workshop report serves as an executive summary of key findings and recommendations that emerged from an analysis of small-group activities and notes from whole-group discussions. We extend our thanks to the workshop participants. We also want to extend our appreciation to the academic leaders and scholars who wrote reflections to ensure the voices and perspectives of all sectors of higher education were represented in the summary report.

# Background on the NSF Improving Undergraduate STEM Education Program

The NSF plays a leadership role in the development and implementation of efforts to enhance and improve STEM education in the United States. Through the Education and Human Resources, Division of Undergraduate Education's IUSE program, the NSF has made a substantial commitment to the highest caliber undergraduate STEM education through an agencywide framework of investments. The goal of the IUSE program is to improve the effectiveness of undergraduate STEM education for both majors and nonmajors, educate students to be leaders and innovators in emerging and rapidly changing STEM fields, and educate a scientifically literate populace.

Within the IUSE program are two tracks: (1) Engage Student Learning and (2) Institutional and Community Transformation. Two tiers exist (Exploration and Design, and Development and Implementation) for each track. The tiers correspond to differences in scale and funding levels.

## NSF IUSE Program Tracks




The focus of the Engaged Student Learning track is on designing, developing, and implementing research studies on STEM learning models, approaches, and tools that show promise for increasing the engagement of undergraduate students in STEM learning and lead to measurable and lasting student learning gains. The expectation is that these research projects are evidence-based and build upon prior knowledge about how people learn.

The focus of the Institutional and Community Transformation track is on increasing the propagation of highly effective methods of STEM teaching and learning. Institutions or collaborations across multiple institutions are supported to use innovative approaches to increase the use of evidence-based teaching and learning practices. The expectation is that these research projects have identified a problem to be addressed, goals to be achieved and strategies to meet the established goals, and that they include an identified theory of change that is guiding the work. The projects are expected to have mechanisms to both assess the effectiveness of the project and examine the process of change.

The NSF's Division of Undergraduate Education has made approximately 60 institutional awards beginning with those made through the Widening Implementation and Demonstration of Evidence Based Reforms (WIDER) program (NSF 13-552) and continuing through the Institutional and Community Transformation IUSE program for the past four years (the current IUSE Solicitation is NSF 17-590). Change leaders, including leaders in funding agencies, need research-based guidance as they envision, organize, and facilitate major transformation efforts designed to advance change initiatives to improve the quality and effectiveness of undergraduate STEM education.

# Workshop

# Description and Goals

AAU hosted the Essential Questions and Measures: Assessing Institutional Transformation of Undergraduate STEM Education Workshop on February 6-7, 2019 in Washington, D.C. Twenty-seven experts involved in leading, researching, evaluating and funding efforts to transform undergraduate STEM teaching and learning practices were convened as participants. The workshop was facilitated by three AAU staff members, and six NSF staff members joined as observers (a list containing the names, institutional affiliations and titles of all workshop participants is found at the end of this report).

The workshop was grounded and guided in part by what has been learned and documented in prior research. In particular, research and engagement in national conversations undertaken by AAU and its research partners Adrianna Kezar, James Fairweather, Linda Slakey, and Mary Deane Sorcinelli provided a foundation for the workshop (see, Association of American Universities, 2013, 2017a, 2017b; Kezar, 2018; Miller, Fairweather, Slakey, Smith, & King, 2017). Research and project activities of the AAU Undergraduate STEM Education Initiative are currently supported by two active NSF awards (grant numbers 1432766 and 1625532), and through the support of non-NSF awards—most notably major grants from the Helmsley Charitable Trust, as well as the Northrop Grumman Foundation. In addition, AAU previously received an NSF WIDER award (grant number 1256221) which resulted in *Essential Questions & Data Sources for Continuous Improvement of Undergraduate STEM Teaching and Learning* (Association of American Universities, 2017a). That study provides a set of questions that can be used at multiple levels within a university to assess progress along the set of key institutional elements identified in AAU's *Framework for Systemic Change in Undergraduate STEM Teaching and Learning* (Association of American Universities, 2013).

**Is the intention of the investigation to examine what were the outcomes of the reform effort, or to examine how the reform effort was implemented?**

From this research emerges a critical consideration when designing questions to examine, and indicators to document, transformations to undergraduate STEM teaching and learning. It may be asked as follows: Is the intention of the investigation to examine ***what*** were the outcomes of the reform effort, or to examine ***how*** the reform effort was implemented? Articulation of the focus of study is critical because the research questions to examine a project's impact are different than the research questions to examine the change process of a project.

Within each of these two lines of inquiry are a number of complexities. For example, the scope and scale-size of transformation projects (e.g., institutional, multi-institutional, or association-wide) present a challenge to both enact change and to study the change process (Association of American Universities, 2017b; Coleman, Smith, & Miller, in press; Kezar, 2018). Additionally, the types of relevant measures to evaluate classroom-based, department- and institution-level, and multi-institutional project effects vary greatly (Fairweather, Trapani, & Paulson, 2016). At the same time, higher education is a complex system and achieving transformation in undergraduate STEM education involves examining the relevance and impact of critical organization factors that can impede or facilitate progress (Austin, 2011; Kezar, Miller, Bernstein-Serra, & Holcombe, 2019; Miller, Fairweather, Slakey, Smith, & King, 2017).

Ultimately, understanding the issues and challenges in designing, leading, and researching institutional and multi-institutional transformation projects to improve undergraduate STEM education is of practical and theoretical importance since an increasing number of these projects are underway. The workshop aimed to develop recommendations based on our collective knowledge in these areas that would enhance future solicitations for systemic institutional transformation projects.

# Activities

The format of the workshop included a design thinking activity as well as small-group and whole-group discussions. These activities engaged participants in two key exercises:

1. identifying essential questions and indicators of progress when studying the impact of a reform effort as compared to studying a reform effort's process of change, considering projects at multiple levels and;
2. providing recommendations for enhancing future solicitations aimed at systematic transformation of undergraduate STEM teaching and learning building on what is known about fostering change.

During the first segment of the workshop, participants worked together to identify important questions, forms of evidence and indicators of progress that should be considered when examining the impact of an implementation project, as well as when examining the change process that occurred in an implementation effort. Throughout this exercise workshop participants were mindful of the multiple levels at which project work can occur. Although they focused on institutional-level and multi-institutional level transformation efforts, workshop participants were asked to consider additional levels such as efforts that comprise funded portfolios and nationwide efforts (see the matrix grid developed by AAU to frame the workshop discussion and acknowledge existing research).

Building off the information that was gathered and discussed, workshop participants then worked together to create recommendations to improve future funding solicitations for projects aimed at systemic improvements to undergraduate STEM education.

| SYSTEM TYPE ENGAGED IN TRANSFORMING UNDERGRADUATE STEM EDUCATION | RESEARCH PROJECT FOCUS: **Examining the Impact of an Implementation Effort** — *What were the outcomes of the reform effort?* | RESEARCH PROJECT FOCUS: **Examining the Change Process of an Implementation Effort** — *How was the reform effort implemented?* |
|---|---|---|
| **Institutional Improvement** | Existing Resources: Within class faculty member research (National Research Council, 2012), cross-department or college evidence (e.g., institution-wide data analytics) | Existing Resources: Support for High-Impact Practices (Kezar & Holcombe, 2017); Promoting Evidence-Based Change (Austin, 2011) |
| **Multi-institutional Projects/Networks** | Existing Resources: AAU Undergraduate STEM Education Initiative 5-Year Status Report (Association of American Universities, 2017; Miller, et al., 2017) | Existing Resources: Increasing Student Success in STEM: A Guide to Systemic Institutional Change (Elrod & Kezar, 2016); Communities of Transformation and Their Work Scaling STEM Reform (Kezar & Gehrke, 2015); The Strategic Role of a National Organization (Kezar, 2018) |
| **Portfolio of Funding** (e.g., NSF IUSE, HHMI Inclusive Excellence) | | |
| **National-Level** | Existing Resources: Indicators for Monitoring Undergraduate STEM Education (National Academies of Science, Engineering and Medicine, 2018) | Existing Resource: Achieving Systemic Change (Coalition for Reform of Undergraduate STEM Education, 2014) |

# Data Analysis

Materials from small-group activities and notes from whole-group discussions were collected and analyzed. The analysis aimed to summarize information and to find patterns in the data that address the focus areas—factors related to essential questions and indicators for studying the impact of change and the process of change across multiple levels. The workshop design and analysis also generated suggestions for future solicitations to catalyze systemic transformation of undergraduate STEM teaching and learning.

Using computer-assisted qualitative data analysis software, a coding process was carried out to capture variety in the responses and to find commonalities across all of the data. Descriptive codes were developed to summarize information. Then, similar codes were grouped into categories and subcategories. Codes, categories, and subcategories were refined and codified to form considerations and recommendations. In total, 20 consideration areas and two major solicitation recommendations emerged from the data. The complete set of considerations are listed and described in the appendix. Additionally, the appendix contains tables showing the results of data analyses in more detail.

# Key Findings

# Institutional and Multi-Institutional Projects to Transform Undergraduate STEM Education

A critical component of the IUSE program is that it purposefully links the assessment of the stated goals and outcomes of the project with the comprehensive evaluation of the organizational change process. Such evaluations need to document successes and failures and identify critical elements necessary for change, all while considering the unique characteristics of the project goals and institutional contexts.

**A critical component of the IUSE program is that it purposefully links the assessment of the stated goals and outcomes of the project with the comprehensive evaluation of the organizational change process.**

Data from the workshop regarding factors that are important to consider when examining ***what*** were the outcomes of a reform effort and when examining ***how*** a reform effort was implemented, for both institutional and multi-institutional transformation projects, were analyzed by looking at the frequency of responses. The top three considerations in each of the four areas are seen in the matrix below. In the two instances where four categories are listed, examining the impact of institutional improvement efforts and examining the change process of multi-institutional efforts, there existed ties in counts for second and third places, respectively (see appendix data tables for more details).

Looking at the similarities and differences of the top considerations appearing down the rows and across the columns of this matrix yields the following key findings:

- **Conditions for sustained change** appears in each of the cells of the matrix. This indicates the importance of understanding and taking into consideration the conditions under which transformations to improve undergraduate teaching and learning are sustained—for both institutional and multi-institutional change projects, and also when looking at questions about the impact, as well as the change process of efforts.

- **Student and alumni learning outcomes** appeared as an important consideration for examining the outcomes of institutional and multi-institutional transformation projects, but it was not a top consideration when examining the change process of projects.

- **Faculty approaches to teaching and teaching improvement** was a top consideration for studying the change process in institutional and multi-institutional efforts, as well as for examining the outcomes of institutional change projects.

- Not surprisingly, **examining cross-institutional collaborations and peer networks** was a top consideration for studying both the impact and change process of multi-institutional efforts, but it was not applicable to studying the impact or change process of institutional improvement projects.

- Some considerations appeared in only one quadrant of the matrix. **Department commitment** emerged as a top consideration in studying the impact of institutional reform efforts. On the same row, **alignment of evidence-based practices with rewards, hiring and training** appeared as a top consideration for examining the change process of institutional reform efforts. Lastly, **common data** was a top consideration for examining the change process of multi-institutional reform efforts.

| | **Examining the Impact/Outcomes of the Reform Effort** | **Examining the Change Process of the Reform Effort** |
|---|---|---|
| **Institutional Improvement** | Conditions for sustained change<br>Student and alumni learning outcomes data<br>Faculty approaches to teaching and teaching improvement<br>Department commitment | Conditions for sustained change<br>Faculty approaches to teaching and teaching improvement<br>Alignment of evidence-based practices with rewards, hiring and training |
| **Multi-Institutional Projects/ Networks** | Conditions for sustained change<br>Student and alumni learning outcomes data<br>Examining cross-institutional collaborations and peer networks | Conditions for sustained change<br>Faculty approaches to teaching and teaching improvement<br>Examining cross-institutional collaborations and peer networks<br>Common Data |

***Alignment of evidence-based practices with rewards, hiring and training:*** Alignment of the use of evidence-based practices with policies, practices and discussions regarding faculty promotion and tenure, the evaluation of teaching, and recognition and rewards for exceptional teaching efforts. Additionally, this category includes the alignment of evidence-based practices with policies and practices around the hiring and development of new faculty and instructors, and the pedagogical training of graduate students.

***Common data:*** The importance of having common data sources and shared metrics, data approaches and analyses within and across projects.

***Conditions for sustained change:*** Examining the conditions under which changes to improve undergraduate teaching and learning are sustained. These include looking at and understanding the kinds of leadership and clout; the types of structures, strategies, and supports; the necessary amounts of readiness; the kinds of information and the nature of motivations necessary to create systemic change.

***Department commitment:*** The existence of a commitment to and shared ownership of student success and excellence in teaching within the department. This can be evident though departmental culture, practices and discussions; department-wide curricula reform efforts such as course section alignment; and the collection and use of within-department metrics and student data to inform educational improvement efforts.

***Examining cross-institutional collaborations and peer networks:*** Examining various characteristics of cross-institutional collaborations and peer networks, including their formation, nature, longevity and internal and external supports; their benefits and outcomes; and inquiries around the spread of effective practices and lessons learned across and beyond the networked institutions.

***Faculty approaches to teaching and teaching improvement:*** Looking at and understanding how faculty and instructors approach teaching, their engagement with developing their teaching, as well as the activities they do when they teach. This incorporates examining classroom practices; faculty and instructors' attitudes and beliefs about teaching, including their desire to improve or change their teaching; faculty and instructors' knowledge about, comfort with and buy-in to evidence-based teaching practices; their perceived sense of teaching support; their involvement in teaching professional development; and their engagement in educational research.

***Student and alumni learning outcomes data:*** Collecting and examining student learning, enrollment, experience, achievement and outcomes data. This category also includes collecting and examining learning and outcomes data of alumni.

# Portfolio and National Level Work to Transform Undergraduate STEM Education

At the portfolio level, the top considerations when examining the outcomes of reform efforts and the change processes of efforts were the same. They involved commitment to building upon what is already known; to understanding the conditions necessary to effect change, including the real implications of various institutional contexts; and to striving toward equity and inclusivity. Looking at the national level, the top considerations when examining the change process of efforts were similar. They included understanding the conditions needed to sustain change, as well as the indicators of progress.

When examining the impact of reform efforts at a national level it is important to acknowledge that the National Academies of Sciences, Engineering and Medicine (2018) convened a consensus study to develop a set of national-level indicators to measure the status and quality of undergraduate STEM education over multiple years. This focus was important because current undergraduate STEM education reform initiatives tend to gather detailed, local data that are useful and appropriate for local feedback and improvement at the individual, departmental, institutional, or system level. However, such detailed data are not adequate for providing a broad, national picture of STEM teaching and learning. This limitation was reinforced by the workshop. The top considerations for demonstrating the impact of transformation on undergraduate STEM education at the national level were how it affected the public understanding and attitudes toward science and higher education, as well as its documented student learning and alumni outcomes data.

# Recommendations

# Recommendations for the NSF Improving Undergraduate STEM Education Program Solicitation

Two main recommendations for refining future solicitations aimed at systemic transformation of undergraduate STEM education emerged from the workshop. The solicitation recommendations align with the key findings discussed above and offer a strategy for ensuring future funded projects address these critical elements.

The first recommendation is to provide more structure to the solicitation by explicitly articulating what is wanted and expected to be included in proposals, and by including detailed guidelines for successful proposals and successful proposal elements. The second is to increase the number of successful proposals submissions from more varied institutions and institutional types. Workshop participants provided concrete suggestions for ways to achieve the two recommendations, which can be seen in the two tables on the following page.

In discussions about the first recommendation that future solicitations include more structure and guidelines, workshop participants emphasized the importance of framing the call around systemic change, making clear the intention and goals of the solicitation, and being mindful of the language and attention to detail used in the call. Workshop participants said those improvements would make solicitations become better catalysts for change.

Workshop participants also stressed the need for solicitations to incorporate specific requests to help ensure that projects successfully enact and sustain change. Suggestions included requiring proposals to demonstrate institutional buy-in and contain well thought-out plans for evaluation. To help submissions meet the conditions of the more deliberately structured call, workshop participants indicated the need for the solicitation to provide more detailed guidance on required proposal elements and to offer examples of past proposals that have been successfully awarded.

When talking about the second recommendation to increase the number of successful proposal submissions from more varied institutions and institutional types, the analogy of "expanding the choir" emerged. Workshop participants noted that individuals from similar institution types, or in some cases from the same institutions, are most often principal investigators or project team members on NSF IUSE grants. Given this, there is a need to build across a wider variety of institutions a capacity to be prepared to engage in work toward systemic improvements in undergraduate STEM teaching and learning.

Workshop participants suggested several ways to scaffold readiness of institutions that are new to this work, as well as ways to support individuals who are submitting IUSE proposals for the first time. Some of the suggestions included offering planning grant or readiness grant opportunities to institutions beginning to engage in this work and providing resources, connections, and mentoring support to first-time proposal submitters. Additionally, it was suggested that mutually beneficial, cross-institutional capacity-building partnerships be encouraged to allow successful awardee institutions and institutions from underrepresented institutional types to collaborate to enact change.

In addition to the two main recommendations for future IUSE solicitations, some workshop participants discussed other types of funding calls or awards that NSF could make available to advance specific areas of work related to fostering change, or to incubate creative projects, such as "Idea Labs." A few workshop participants also raised some important considerations related to the award selection process, including the need to identify the gaps of work in the portfolio, and the importance of educating and training proposal reviewers.

**Recommendation 1** **Provide more structure, explicit wording and guidance in calls**

**Include more detailed expectations and guidelines for a successful proposal and successful proposal elements; make clear the intention of the solicitation; pay particular attention to the language used in the call**

### ▼ Focus calls around change

- Focus calls on a system view of change; include an articulation of alignment of institutional vision, change theory, leadership, and activities
- Explicitly fund research to understand and better implement processes to promote and spread change
- Require proposals to specify change theories and vision of change, and tie proposed strategies and actions to them
- Offer two distinct funding tracks: (1) Implementing, Scaling, or Transferring Change Track and (2) Studying, or Exploring Change Track

### ▼ Include specific asks in calls

- Require dissemination beyond publication, and the dissemination of both successes and failures
- Have proposals include an audit of existing efforts, needs, strengths and challenges
- Have proposals demonstrate connections with other institutional change projects
- Have proposals demonstrate information sharing, using and synthesis
- Have proposals include the use of institutional data
- Have proposals include the use of SoTL and DBER literature

### ▼ Ensure proposals have institutional buy-in

- Require proposals to demonstrate connections with other individuals, leaders or units within the institution
- Ensure institutional engagement and that proposals are a team effort
- Ensure involvement of institutional leaders
- Provide institutional incentives for project success
- Have institutional-level calls

### ▼ Include expectations for project evaluation and reporting

- Require proposals to include a map of measures related to goals and to include a formative assessment plan and reflective continuous improvement plan
- Provide guidance on expectations for internal and external evaluation
- Require annual reports that are formative and reflective
- Require the evaluator to be part of the project team
- Require plan for evaluating impact in terms of student inclusion

## Recommendation 2 Increase the number of successful proposal submissions from more varied institutions and institutional types

**Structure calls to be more adaptable for submissions from a wide range of institutions and institutional types; for example, meet campuses where they are - have distinct expectations for projects at campuses that are experienced in this work, and for projects at campuses that are new to this work; recruit and support proposals from a wide range of institutions and institutional types**

### ▼ Provide resources, opportunities and connections to support successful proposal submissions from more institutions

- Provide support, connections, mentoring, guidance, and/or a community for success for first-time proposers or those at institutions new to this work
- Offer assessment of readiness grant opportunities and/or planning grant opportunities; scaffold institutional readiness
- Include a list of resources and past awardees to contact in the solicitation
- Support the development of cross-institutional capacity-building partnerships
- Fund opportunities to apply what is known to be effective in new contexts
- Support opportunities for cross-institutional learning
- Identify lessons learned from projects in the portfolio, publish the lessons in open access spaces and include these references in the solicitation
- Offer two distinct funding tracks: (1) Readiness Track and (2) Traditional Track

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# Reflections

## Ann E. Austin, University Distinguished Professor of Higher, Adult, and Lifelong Education; Associate Dean for Research, College of Education; Assistant Provost for Faculty Development—Academic Career Paths, Michigan State University

Over the past decade and a half, many efforts have focused on transforming STEM undergraduate education. Recently, some observers have used the term "tipping point" to suggest that the collective efforts are indeed making a difference—that how faculty teach, how institutions support evidence-based teaching, and how students learn are changing in noteworthy ways. The recent workshop on "Assessing Institutional Transformation of Undergraduate STEM Education," hosted by the Association of American Universities, provides evidence of transformation while, simultaneously, revealing the challenges and opportunities still to be addressed.

The overall approach of the workshop planners to designing the meeting and articulating the guiding questions is testimony to the significant progress already achieved in collective understanding of how systemic change occurs. First, the invitation to the workshop and the framing of its agenda took a decidedly systems approach, recognizing that any discussion of measures of impact or elements of change processes must take into account the multiple levels of the system in which STEM reform is occurring; that is, change occurs in departments, in institutions, within cross-institutional networks, and at the national level. Recognizing and organizing change efforts within a systems perspective shows an important recognition of the nature of higher education institutions, an awareness of complexity which is an essential element in successful change efforts. Second, the workshop emphasized that "assessing transformation" requires attention both to the impact of implementation efforts and to the change processes themselves. Again, this framing advances the conversation in highlighting the relevant elements of understanding change. Third, a recognition of the importance of context in understanding and advancing change permeated the framing, facilitation, and conversations of the workshop. These features of the workshop show that efforts to transform undergraduate STEM education have reached a degree of maturity and sophistication, such that a workshop bringing together national change leaders can be based on collective recognition that change is complex and challenging and requires a systemic approach.

I also noticed that the workshop participants were eager to delve into the questions posed in the workshop, ready with examples, observations, and experiences to inform their discussions. By the conclusion of the workshop I had reached a compelling conclusion: Many efforts have been conceptualized, implemented, and, in some cases, funded. Progress in the project of transforming STEM education is note-worthy and encouraging, but the path ahead remains long and challenging. Even if a tipping point has been reached in which change efforts are enjoying demonstrable impacts (which I think has and is occurring), the time is right for the community of change leaders to step back, assess where we collectively have been and what has been achieved, articulate what has been learned about change in higher education, and clarify priorities for further attention.

Continuing efforts to systematically reflect, analyze, prioritize, and frame the path forward, based on what has already been achieved, should address several key questions. What has worked and why in advancing transformation in undergraduate STEM education? What strategies and interventions have not worked, and why not? What has been learned about effective strategies as they pertain to various target levels of transformation (department, institution, multi-institutional network, national)? How does context matter in efforts to foster transformation (a topic that was woven through the discussions in the workshop)? Around what issues has there been saturation in terms of projects and attention, and what issues, populations, or locations of transformation have been overlooked? Who has been involved in transformation efforts, and who is not fully participating in this agenda? What are the reasons some are not participants and are there ways to be more inclusive? What should be the next priorities for funding agencies, national associations, and institutional change leaders, and how might the efforts of these various stakeholders be more fully and productively connected (and when would such connections be valuable)? This workshop was a highly productive starting point in gathering stakeholders to wrestle with these questions. I hope opportunities for advancing consideration of these issues will continue.

I can envision several practical and impactful steps forward to continue the synthesis, comparison, and deep discussion required to address these cross-cutting questions. One useful step already emerging in several conversations (for example, in the plans emerging in the National Academies' Roundtable on Systemic Change in Undergraduate STEM Education) is to "map the landscape" of change efforts to reform STEM undergraduate education. This effort would involve inventorying initiatives (over the past decade, for example) designed to advance STEM reform efforts, noting the level of the system each initiative targets (i. e., course, department, institution, cross-institution, national, including funders' priorities), and specific outcomes from each. Such a mapping process, building on project reports, could help identify parts of the system where efforts and progress have been extensive, and conversely, areas where more work is needed. Researchers, reform leaders, and funding agencies could benefit from this mapping.

Closely related to a mapping process might be several facilitated national convenings, hosted by a funding agency or national association. These meetings could bring together stakeholders, PIs, and institutional leaders involved in the STEM reform movement to grapple with the compelling questions mentioned above and, through facilitated conversation, to identify and discuss lessons learned about advancing change goals. The National Science Foundation's ADVANCE Institutional Transformation program, focused on increasing the recruitment, retention, and success of women in STEM fields in higher education, provides an example of how PI meetings can be the base for developing active networks of institutional leaders and researchers. Over more than a decade, the ADVANCE PI meetings have cultivated active interactions among institutional change leaders who eagerly share lessons learned and innovative strategies for promoting change.

A third idea, mentioned in the workshop, is to establish repositories for materials, instruments, and tools that have been produced in various funded projects to advance Undergraduate STEM Education. A curated repository (with each tool accompanied by information about its purpose, how it can be used, who has been using it, who has ownership, and the impact of the tool) would require dedicated curating. Such a repository could help jump-start the work of institutions new to systemic reform in STEM education and their leaders. A fourth strategy might be to provide leadership development opportunities focused on approaches and strategies for conceptualizing, designing, and implementing systemic undergraduate STEM reform at each level of the system—department, college, university, and storm. Department chairs, deans, provosts, and other senior leaders, as well as leaders of scholarly and professional associations, need to have the tools to work with colleagues to implement STEM reform. Fifth, much is known about what teaching strategies are most effective in fostering student engagement and learning. A project already under discussion, and offering much promise, is discussion across relevant stakeholders around professional standards in teaching. Each of these ideas seems promising at this moment within the movement to transform undergraduate STEM education, and, in fact, several are in nascent or more developed stages of consideration within various groups, such as the National Academies of Sciences, Engineering, and Medicine, the AAU, and smaller research and leadership groups.

In addition to these ideas for expanding a national network of change leaders and other stakeholders committed to assessing progress, highlighting lessons, and aiding higher education institutions in addressing challenges in institutional transformation, I want to emphasize two other issues discussed at the AAU workshop. First, participants offered specific and practical suggestions for revisions in the grant solicitation for the NSF IUSE Program. Ideas included requiring applicants for grants to provide an analysis of their institutional context, including barriers as well as existing programs with which they would coordinate; to discuss the several theories that inform their understanding of the problem they propose to address and their strategies to do so; to identify how project leaders are and will engage institutional leaders and other key stakeholders; and to discuss how evaluation plans would be integrated into the change agenda and would explicitly inform project development and implementation. As a researcher with grant experience, former NSF Program Officer, and institutional leader, I find these ideas very useful and hope they will be considered. Second, workshop participants observed that some institutions are less poised than others to compete successfully in the competition for funding to promote institutional change. I agree, and support the ideas raised in the workshop for scaffolding institutions less experienced in the funding arena. Some of these ideas included providing workshops and "ideas labs" in which institutional leaders could incubate ideas and get feedback, encouraging proposals that adapt ideas developed in one institutional context for another institutional type, and compiling and disseminating resources for those new to developing proposals for institutional transformation.

I appreciate the workshop that AAU hosted, as well as the energetic participation of each attendee. I sense that we are indeed at a "tipping point" where the efforts to transform undergraduate STEM education are gaining traction and taking hold with faculty, in classrooms, and across institutions. By providing opportunities for those working to effect systemic change in higher education to reflect and compare experiences, convenings like the AAU workshop help leverage research findings and practical experiences and encourage continued progress and innovation.

## Karl A. Smith, Professor Emeritus of Civil, Environmental, and Geo- Engineering, University of Minnesota and Cooperative Learning Professor of Engineering Education, Purdue University

The current AAU Undergraduate STEM Education Initiative to influence the culture of STEM departments so faculty members are encouraged and supported to use evidence-based teaching practices as well as assess the transformation of undergraduate STEM education is important and timely. As part of this initiative AAU engaged scholars and institutional leaders in a discussion about the National Science Foundation Improving Undergraduate STEM Education solicitation and more broadly the state of institutional transformation in undergraduate teaching and learning. I was pleased to engage in this workshop and encourage the community to invest in continual assessment of the transformation, since periodic assessments are not sufficient to facilitate change.

I've been at the University of Minnesota since 1972 when I started a position in an engineering research laboratory. I was encouraged to complete a PhD and explored a traditional engineering PhD. However, in the mid-70s I switched from a traditional engineering PhD program to an educational psychology PhD program. The was due in large part to an experience I had in a teaching assignment where the approach that had been used on me (lecture-homework-exams) failed and I thought there had to be a better way to do it. I searched for other ways to help students learn and discovered the Johnson & Johnson cooperative learning model. I implemented it in my classes, systematically researched it, and in 1981 introduced it to the engineering education community.[1,2] In the subsequent years I've been involved in numerous initiatives to encourage faculty to embrace evidence-based instructional practices, especially cooperative learning, and I highlight three experiences at the University of Minnesota, Michigan State University, and Purdue University.

The University of Minnesota has been involved in many, mostly externally grant-funded, projects to improve student learning. For example, in the early-80s the University engaged in the Northwest Area Program on Active Learning. Steve Schomberg, project director, noted that "Over a three-year period (1982-1985), they tried out 20 methods of involving students in instructional activities, and trained more than 200 faculty to use one or more active learning strategies."[3] Subsequent projects have emphasized engaging students in large classes, internationalizing the curriculum, preparing future faculty, and so forth. Although there has been a sustained effort at the University of Minnesota to embrace evidence-based instructional practices, especially interactive learning, there is little evidence of widespread transformation in STEM disciplines. Biology is the exception with the implementation of the SCALE-UP model and a dedicated building with active learning classrooms. Also, A Guide to Teaching in the Active Learning Classroom: History, Research and Practice was published.[4]

1 Karl A. Smith, David W. Johnson, and Roger T. Johnson, "The Use of Cooperative Learning Groups in Engineering Education," in *Proceedings Eleventh Annual Frontiers in Education Conference, Rapid City, SD,* eds. L.P. Grayson and J.M. Biedenbach (Washington: IEEE/ASEE, 1981), 26-32.

2 Karl A. Smith, David W. Johnson, and Roger T. Johnson, "Structuring Learning Goals to Meet the Goals of Engineering Education," *Engineering Education* 72, no. 3 (1981): 221-226.

3 Steven F. Schomberg, *Strategies for Active Teaching and Learning in University Classrooms: A Handbook of Teaching Strategies Developed by University of Minnesota Faculty with Support from the Northwest Area Foundation* (Minneapolis: University of Minnesota, 1986).

4 Paul Baepler, J.D. Walker, D. Christopher Brooks, Kem Saichaie and Christina I. Petersen, *A Guide to Teaching in the Active Learning Classroom History, Research, and Practice* (Sterling: Stylus, 2016).

Michigan State University was selected to participate in the Lilly Endowment Teaching Fellows program in 1991 and I was invited to serve as a consultant to the program. The impact of the Lilly Endowment Teaching Fellows program was documented by Ann Austin.[5] In 1993 President Peter McPherson introduced the Six Guiding Principles as part of an initiative to consider what it means to be a Land Grant University in the 21st Century. Guiding principle number two is *Achieve More ACTIVE LEARNING*. I was invited to serve as a Senior Consultant to the Provost and my role was to help implement cooperative learning at Michigan State. Today, there are many pockets at Michigan State where evidence-based practices, such as cooperative learning, are implemented.

Purdue University launched one of the first engineering education departments and PhD programs in 2005. I was on sabbatical at Purdue during the 2004-2005 academic year and participated in conversations about the creation of a department. In 2006 I began phased-retirement from the University of Minnesota and joined the Purdue Engineering Education department part-time to help create the PhD program. The PhD program didn't follow the traditional Johns Hopkins model but instead embraced the findings of studies of the doctorate (Carnegie Initiative on the Doctorate, Woodrow Wilson Responsive PhD, and Re-envisioning the PhD). The PhD program is competency-based with ten competencies, portfolio-guided assessment, and embraces approaches such as a readiness assessment instead of the traditional qualifying exam. Recently Purdue Engineering Education graduated the 100th PhD and I am hopeful that these and many other Engineering Education and STEM DBER graduates can help lead the transformation of STEM undergraduate education.

These experiences not only inform but also shape my reflection on the workshop hosted by AAU. The National Science Foundation has had an enormous influence on the advance of evidence-based practices in STEM undergraduate education, for example through the Engineering Education Coalitions, and funding CCLI and IUSE projects. The 1996 report to the National Science Foundation – *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology*[6]–articulated ambitious goals for SME&T education and highlighted the importance of inquiry (p. ii):

> All students have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students learn these subjects by direct experience with the methods and processes of inquiry.

The authors recommend that inquiry be placed at the core of learning goals consistent with ABET and they have an emphatic recommendation that SME&T faculty (p. iv):

> Believe and affirm that every student can learn, and model good practices that increase learning; starting with the student's experience, but have high expectations within a supportive climate; and build inquiry, a sense of wonder and the excitement of discovery, plus communication and teamwork, critical thinking, and life-long learning skills into learning experiences.

The emphasis on institutional and community transformation is critical to sustaining and scaling change. The predominant emphasis on individual faculty and classes has had some impact; however, has not led to the extent or quality of implementation of evidence-based instructional practices that would benefit many students. The three examples I cited from my experience at the University of Minnesota, Michigan State University and Purdue University, support the idea of the importance of institutional leadership.

5 Ann E. Austin, "Supporting Junior Faculty Through a Teaching Fellows Program," in *Developing New and Junior Faculty: New Directions for Teaching and Learning No. 50,* eds. M.D. Sorcinelli and A.E. Austin (San Francisco: Jossey-Bass, 1992), 73-86.

6 *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (Washington: National Science Foundation NSF 96-139, 1996).

Individual change is occurring and has been occurring for some time. In 2000 Jean MacGregor, Jim Cooper, Pat Robinson and I reported a synthesis of interviews with forty-eight individuals from across the United States who were infusing their large classes with small-group activities or were working explicitly to create student communities within large classes.[7] One of the surprises from our interviews was the large proportion who noted that they thought they were the only one who were engaging their students in large classes. The sense of isolation persists to this day.

The implementation of evidence-based instructional practices by necessity takes place at the individual faculty and classroom level and hence this is a critical area for further investigation. Faculty hiring, training and rewards has an effect and merits further study. The effect of the long socialization in conventional practice (lecture-homework-exams) likely makes it difficult for some faculty to imagine other ways of helping students learn. One indication of this is that evidence-based instructional practices such as cooperative learning have been gaining presence in STEM education; however, they are far from being the dominant practice, which continues to be lecture.[8] Mediating the socialization effect merits further investigation. Faculty beliefs about teaching and learning have been the subject of limited study, and deeper understanding of faculty beliefs would likely reveal challenges and barriers that need to be addressed.

The question of how much structure and direction to provide in solicitations for proposals is tricky as too much stifles creativity and too little results in widely disparate proposal submissions. My response is one of my favorites, "it depends."[9] Perhaps a range is called for. For some clearly identified wicked problems, such as achieving more high fidelity implementation of evidence-based instructional practices, a highly structured format may be appropriate. For emerging opportunity areas, such as embracing the findings from neurological research, a less structured approach may yield more exciting results.

My experience over the past six years with the NSF-funded I-Corps™ for Learning (I-Corps™ L) project, which was focused on adapting the Lean Startup model (search for a sustainable and scalable model – customer discovery – agile engineering (iterate and increment)) to sustaining and scaling education innovations, convinces me that it is essential to incorporate emphasis in proposals on sustaining and scaling innovations after the project funding ends.

Continuing to build and expand the research community and especially broaden the landscape of those submitting competitive proposals is another thorny problem. Our experience helping build the engineering education research community indicates that it is possible; however, takes time and a concerted effort.[10,11,12,13]

7 Jean MacGregor, James L. Cooper, Karl A. Smith, and Pamela Robinson, eds. *Strategies for Energizing Large Classes: From Small Groups to Learning Communities: New Directions for Teaching and Learning No. 81* (San Francisco: Jossey-Bass, 2000).

8 Marilyne Stains, Jordan Harshman, Megan K. Barker, Stephanie V. Chasteen, Renee Cole, Sue Ellen DeChenne-Peters, M. Kevin Eagan Jr., et al., "Anatomy of STEM Teaching in North American Universities," *Science* 359, no. 6383 (2018): 1468-1470.

9 Anthony M. Starfield, Karl A. Smith, and Andrew L. Bleloch, *How to Model It: Problem Solving for the Computer Age* (New York: McGraw-Hill, 1990).

10 Nicole Pitterson, Cheryl Allendoerfer, Ruth A. Streveler, Juan D. Ortega-Alvarez, and Karl A. Smith, "The Importance of Community in Fostering Change: A Qualitative Case Study of the Rigorous Research in Engineering Education (RREE) Program" (submitted for publication, 2019).

11 Karl A. Smith, "Continuing to Build Engineering Education Research Capabilities," *IEEE Transactions on Education* 49, no. 1 (2006): 1-3.

12 Karl A. Smith, "Cooperative Learning: Lessons and Insights from Thirty Years of Championing a Research-Based Innovative Practice," *Frontiers in Education Conference (FIE), Rapid City, SD,* (2011): T3E-1-T3E-7, doi: 10.1109/FIE.2011.6142840.

13 Ruth Streveler, Alejandra J. Magana, Karl Smith, and Tameka Clarke Douglas, "Cleerhub.Org: Creating a Digital Habitat for Engineering Education Researchers," *American Society for Engineering Education Annual Conference & Exposition, Louisville, KY,* (2010), https://peer.asee.org/16754.

## Jacqueline R. Roberts, Professor and Chair of Chemistry and Biochemistry, DePauw University

The recommendations made in this report are valuable and an accurate summary of the "Essential Questions and Measures: Assessing Institutional Transformation of Undergraduate STEM Education Workshop" hosted by the Association of American Universities (AAU) this past February in Washington, DC. From the context of one small liberal arts college, this document provides a reflection on the following report recommendations:

- Examining the key findings from the impact/outcomes of the reform effort
- Examining the key findings from the change process of the reform effort
- Examining the IUSE solicitation recommendations

Overall, much of the report resonates within the context of liberal arts schools. However, there are some aspects that may present challenges to smaller schools, while other aspects will benefit and potentially provide liberal arts schools with a clearer path to funding from the NSF Improving Undergraduate STEM Education (IUSE) program.

**Key Findings**

At the beginning of the workshop we were asked to identify essential indicators and factors when looking at implementation projects. The data collected from this activity were analyzed by AAU and reported as Key Findings for Institutional and Multi-Institutional Projects to Transform Undergraduate STEM Education (examining both the impact/outcomes of the reform effort and the change process of the reform effort). In writing this reflection, some of top categories were reviewed (and in some cases grouped together) to provide a context from one small liberal arts school's perspective.

***Common data:***
***Student and alumni learning outcomes data:***

Having a common data source, shared metrics, and assessment strategies would be a tremendous help to liberal arts schools, as many are less likely to have a dedicated assessment specialist, normally do not have science/math education departments, and may only have one person in the office of institutional research to help with data analysis. In addition, having assessment tools available to collect student and alumni outcomes data would be beneficial to liberal arts colleges given their more limited resources.

***Alignment of evidence-based practices with rewards, hiring and training:***
***Faculty approaches to teaching and teaching improvement:***
***Conditions for sustained change:***

Alignment of evidence-based practices with rewards, hiring and training is key to institutional transformation. It is also important that faculty are constantly monitoring and updating their teaching to be more inclusive and focused on evidence-based practices. There are often barriers to this ideal process at liberal arts colleges compared to large research institutions. At the former there are much smaller science and math departments (in some cases, the entire department may have 3 faculty) which means that one recalcitrant faculty member can derail any reform efforts, so getting broader faculty "buy-in" is important at smaller schools. There is also a great deal of faculty autonomy at smaller schools, often with each faculty member being allowed to determine his or her own approach to a course, select a textbook, activities, and assessments. The upshot is there may be a lack of clear, shared departmental learning goals for individual courses or majors. In addition, once a faculty member is fully promoted with tenure, in many cases there are no further personnel reviews, making it a challenge to convince or compel senior faculty to alter their course content or pedagogy. Although there are benefits of having greater faculty independence and this stronger "bottom up" structure at small liberal arts schools, this can present an impediment to motivating and organizing departmental change compared to at larger schools where there may be clearer hierarchical structure with "top-down" organization, which makes it easier to mandate shared learning goals, common labs, assessments, and pedagogies. On the positive side, when an entire department at a small liberal arts school does unite toward a common goal, a powerful transformation can be seen.

***Departmental commitment:***
The report emphasizes the importance of departmental commitment; however, as science and math departments tend to be small at liberal arts colleges, it might instead be more productive to have science/math divisions as a whole commit to shared student successes.

***Examining cross-institutional collaborations and peer networks:***
In addition to suggestions in the report, cross-institutional collaborations and peer networks would also be beneficial to faculty at liberal arts colleges, especially those in smaller departments. For example, a school's consortium (e.g., Great Lakes Colleges Association (GLCA) or Associated Colleges of the Midwest (ACM)) could help coordinate partner schools in learning about evidence-based teaching and successful institutional change so that faculty in similar situations at other institutions could work together, thus reducing feelings of isolation and the unproductive "reinvention of the wheel."

**IUSE Solicitation Recommendations**
Based on conversations during the workshop, two different recommendations for refining the solicitation for the IUSE application were developed. The first recommendation was to provide more structure, explicit wording and guidance for proposal calls. In addition to specific information and language to be used, it was suggested that NSF offer two distinct funding tracks: 1) Implementing, Scaling, or Transferring Change, and 2) Studying, or Exploring Change. More explicit wording and guidance would help faculty at small liberal arts schools, as they may lack the infrastructure to support grant applications. For example, with regard to the recommendation that dissemination beyond publication be required: Could previous awardees host webinars on the successes and failures of their project so these "lessons learned" could be transferred to other campuses? Could consortia for small schools (e.g., the GLCA or the ACM) apply to the IUSE program to host centralized workshops? These could be themed workshops around one topic (e.g., Computer Science or Physics) or more general for all science/math departments with different focuses based on the readiness of the school participating. Having a consortium of departments working together may help smaller departments or those with reluctant or disinterested faculty members.

The second recommendation to NSF was to increase the number of successful proposal submissions from more varied institutions and institutional types, and to also offer two different funding tracks: 1) Readiness, and 2) Traditional tracks. The addition of this "Readiness" track could help liberal arts schools apply for funds so the institution could develop the assessment strategy needed to collect baseline data, or to partner with other institutions who have received funding, or even help train faculty change agents for institutional reform. This recommendation would allow for smaller schools to start down the path for NSF funding via a readiness grant and potentially provide the mechanism by which they could apply for a more traditional grant. This would open up opportunities for new institutions to receive funding, so the same larger institutions do not continue to receive multiple grants while many smaller schools struggle with just trying to submit a proposal.

## Michael J. Pullin, Associate Dean of Academic Affairs, Queensborough Community College, City University of New York

As someone who has been a PI for NSF STEM education grants at both 2-year and 4-year institutions, I am pleased with the recommendations detailed in this report. In particular, I think that the call for efforts to encourage proposals from a wider range of institutions is much needed.

In 2014, after serving as a faculty member at a research university for 10 years, I moved to a 2-year college as an administrator. One motivation for the move was my work in preparing STEM community college students for transfer to 4-year institutions and the pursuit of careers in the sciences and engineering. That work included REU and EPSCoR-funded summer research programs aimed at community college students, a STEP grant to prepare students for transfer, and a sabbatical semester spent teaching at a tribal 2-year college. Those experiences taught me that community colleges are home to many bright students with the talent and drive to successfully pursue STEM graduate degrees and research careers, but sometimes without the guidance and support to do so.

Many have correctly pointed out that increasing the recruitment, retention, and graduation of community college students in STEM degrees would help increase the number of underrepresented minority and first-generation college students who pursue STEM bachelor's and graduate degrees. That would help correct the persistent and troubling underrepresentation problem in many STEM fields and support the nation's STEM workforce needs.

Given the open admissions policies and high proportion of students needing developmental mathematics courses at community colleges, it is perhaps fair to ask if community college students can successfully pursue bachelor's and graduate degrees in STEM fields. A National Center for Science and Engineering Statistics study of the academic background of science, engineering and health graduates found that about half of bachelor's and graduate degree graduates started in community college.[14] Additionally, students who earn an associate's degree before transfer typically match (and sometimes outperform) students at the transfer institution who started there as first-time freshmen. Clearly, some STEM community college students are succeeding to earn higher-level degrees.

However, many 2-year college students face difficult challenges. Community colleges are home to many low-income students who need to work to support themselves and may only be able to attend part time. They are also home to many first-generation students who may not have guidance from family and friends on how to navigate college and academic degree programs. They may also not understand the career and degree options in STEM. Additionally, many community college students arrive underprepared. A significant fraction are required to take developmental (non-credit, preparatory) mathematics, a significant barrier for students pursuing STEM degrees. Only a small fraction of 2-year college students arrive ready for calculus.

More community college STEM students will succeed only when they are provided with monetary and academic support, advising and mentoring, and professional development (including research opportunities). Most importantly, they must have outstanding professors who utilize evidence-based teaching practices that increase student learning and performance. The IUSE program is designed

14 Geraldine M. Mooney and Daniel J. Foley, "Community Colleges: Playing and Important Role in the Education of Science, Engineering, and Health Graduates," *National Center for Science and Engineering Statistics Info Brief*, NSF 11-317 (2011): 1-5.

to support the development, implementation, and adoption of such teaching practices. Other NSF programs also fund a wide range of support programs for STEM students.

Community college faculty hoping to submit proposals to the NSF face many challenges. Two-year college faculty are typically not expected to maintain an externally-funded research program. Accordingly, they have relatively high teaching loads, typically 12-15 credits per semester. That leaves little time for grant writing or conducing funded research. Additionally, they may not have much knowledge of educational theory or findings and trends in STEM education research and little time to become knowledgeable. Many of the PIs for IUSE proposals today are STEM education specialists or content area faculty that have many years of progressive experience in building and running STEM education and outreach programs. For these reasons, it is difficult for a typical community college faculty member to write an IUSE proposal that competes successfully for funding.

How do we help community college STEM faculty develop proposals that will compete successfully for funding and conduct educational research that adds significantly to the field while also increasing the number and success rates of their students? How can we help them catalyze change across their departments or institutions? The recommendations that resulted from this workshop are an excellent place to start. Personally, I think that providing community college faculty interested in STEM education research with workshops and meetings, professional mentoring, and networks would be especially helpful. The greater inclusion of community colleges in IUSE funded studies, along with faculty collaborators at those colleges, could also have a positive impact.

Increasing the participation of 2-year colleges and their faculty in the IUSE program will not be easy. However, doing so will bring a broader range of perspectives to the program. It will also mean that many bright and promising students will find their place in the STEM endeavor. Their work will lead to scientific research that better represents their communities, improves their standing in the world, and benefits everyone. I hope we can make that happen in the coming years.

# Appendix

Workshop participants worked together to identify important questions, forms of evidence and indicators of progress that should be considered when examining the impact of an implementation project, as well as when examining the change process that occurred in an implementation effort across the multiple levels at which project work can occur. In total, 20 consideration areas emerged from the data. They are listed alphabetically and described below. This list is followed by eight tables showing the results of the analysis of frequencies of consideration areas by examination focus (impact or change process) for each of the four project levels.

***Alignment of evidence-based practices with rewards, hiring and training:*** Alignment of the use of evidence-based practices with policies, practices and discussion of faculty promotion and tenure; evaluation, recognition and rewards for teaching; hiring and developing new faculty and instructors; and graduate program training.

***Alignment of student success with prestige:*** Alignment of student success with prestige and elevation of the teaching profession; creating professional standards of teaching; considering the negative impact of research culture.

***Broader Impacts:*** Improved teaching-focused questions and projects coming from Broader Impacts sections of proposals; better monitoring of Broader Impacts outcomes.

***Collective vision:*** Existence of a collective vision, shared responsibility and culture that values student success and excellence in teaching.

***Common data:*** Having common data sources, shared measures, metrics, data approaches and analyses.

***Conditions for sustained change:*** Examining conditions such as the leadership, clout, structures, strategies, supports, readiness, motivation and data necessary to create systemic change.

***Department commitment:*** Department commitment to and shared ownership of student success and excellence in teaching, evident though practices, culture, discussions, curricula reform, section alignment, metrics and use of student data.

***Examining cross-institutional collaborations and peer networks:*** Looking at the formation, nature, benefits, outcomes, support, longevity, and spread of lessons and practices of cross-institutional collaboration and peer networks.

***Existence of within-institution cross-boundary partnerships:*** Within-institution cross-boundary partnerships across disciplines, departments and units; spread of lessons and practices across disciplines, departments and units.

***Faculty approaches to teaching and teaching improvement:*** Examining classroom practices; faculty attitudes and beliefs about teaching; faculty desire to improve or change teaching; faculty knowledge, comfort and buy-in to evidence-based practices; perceived sense of teaching support; faculty engagement in professional development and research on teaching.

***Federal support, resources and policy:*** Existence of more supportive federal resources, structures, and policy discussions to advance work.

***Importance of context:*** Importance of considering context in implementation, evaluation and findings.

***Indicators of progress:*** Indicators of progress, continual improvement, and saturation; new baseline standards.

***Institutional commitment:*** Institutional commitment to student success and excellence in teaching; providing institutional support, resources and incentives; demonstrating institutional buy-in and prioritization.

***Professional certifications and endorsements:*** Involvement and endorsement by discipline-based professional societies and accrediting bodies; developing prestigious certifications.

***Public understanding and attitudes toward science and higher education:*** Public views and values of science and higher education; measures of scientific literacy; examining best ways of communicating science to the public.

***Repositories to share materials and information:*** Creation of infrastructure to widely share materials, resources and information.

***Strive toward equity and inclusivity:*** Support diversity and equal opportunity for students, aspiring faculty and administrators, and institution types.

***Students and alumni learning outcomes data:*** Student learning, enrollment, experience, achievement and outcomes data; alumni learning and outcomes data.

***Take stock of what is known:*** Synthesize knowledge from project evaluations and research studies; conduct cluster analyses and landscape maps; identify strategies to address common challenges.

## Table 1

***Examining the Impact of Institution-wide Efforts***

| Consideration | Count | Percent |
|---|---|---|
| Student and alumni learning outcomes data | 25 | 19.2 |
| Conditions for sustained change | 19 | 14.6 |
| Department commitment | 19 | 14.6 |
| Faculty approaches to teaching and teaching improvement | 16 | 12.3 |
| Institutional commitment | 11 | 8.5 |
| Alignment of evidence-based practices with rewards, hiring and training | 9 | 6.9 |
| Indicators of progress | 8 | 6.2 |
| Strive toward equity and inclusivity | 8 | 6.2 |
| Collective vision | 6 | 4.6 |
| Existence of within-institution cross-boundary partnerships* | 5 | 3.8 |
| Importance of context | 3 | 2.3 |
| Alignment of student success with prestige | 1 | 0.8 |
| Common data | 0 | 0.0 |
| Examining cross-institutional collaborations and peer networks | 0 | 0.0 |
| Repositories to share materials and information | 0 | 0.0 |
| Take stock of what is known | 0 | 0.0 |
| **Total** | **130** | **100.0** |

*Note.* *Category unique to institutional-level impact data

# Table 2

***Examining the Change Process of Institution-wide Efforts***

| **Consideration** | **Count** | **Percent** |
|---|---|---|
| Faculty approaches to teaching and teaching improvement | 19 | 22.1 |
| Alignment of evidence-based practices with rewards, hiring and training | 18 | 20.9 |
| Conditions for sustained change | 9 | 10.5 |
| Department commitment | 7 | 8.1 |
| Institutional commitment | 7 | 8.1 |
| Collective vision | 6 | 7.0 |
| Student and alumni learning outcomes data | 6 | 7.0 |
| Indicators of progress | 5 | 5.8 |
| Importance of context | 4 | 4.7 |
| Alignment of student success with prestige | 1 | 1.2 |
| Common data | 1 | 1.2 |
| Repositories to share materials and information | 1 | 1.2 |
| Strive toward equity and inclusivity | 1 | 1.2 |
| Take stock of what is known | 1 | 1.2 |
| Examining cross-institutional collaborations and peer networks | 0 | 0.0 |
| Existence of within-institution cross-boundary partnerships | 0 | 0.0 |
| **Total** | **86** | **100.0** |

## Table 3

***Examining the Impact of Multi-Institutional Efforts***

| **Consideration** | **Count** | **Percent** |
|---|---|---|
| Examining cross-institutional collaborations and peer networks | 8 | 21.6 |
| Student and alumni learning outcomes data | 6 | 16.2 |
| Conditions for sustained change | 4 | 10.8 |
| Common data | 3 | 8.1 |
| Faculty approaches to teaching and teaching improvement | 3 | 8.1 |
| Importance of context | 3 | 8.1 |
| Indicators of progress | 3 | 8.1 |
| Repositories to share materials and information | 2 | 5.4 |
| Alignment of student success with prestige | 1 | 2.7 |
| Collective vision | 1 | 2.7 |
| Department commitment | 1 | 2.7 |
| Strive toward equity and inclusivity | 1 | 2.7 |
| Take stock of what is known | 1 | 2.7 |
| Alignment of evidence-based practices with rewards, hiring and training | 0 | 0.0 |
| Institutional commitment | 0 | 0.0 |
| **Total** | **37** | **100.0** |

## Table 4

***Examining the Change Process of Multi-Institutional Efforts***

| Consideration | Count | Percent |
|---|---|---|
| Examining cross-institutional collaborations and peer networks | 19 | 38.0 |
| Faculty approaches to teaching and teaching improvement | 5 | 10.0 |
| Common data | 4 | 8.0 |
| Conditions for sustained change | 4 | 8.0 |
| Institutional commitment | 3 | 6.0 |
| Student and alumni learning outcomes data | 3 | 6.0 |
| Take stock of what is known | 3 | 6.0 |
| Collective vision | 2 | 4.0 |
| Department commitment | 2 | 4.0 |
| Importance of context | 2 | 4.0 |
| Indicators of progress | 2 | 4.0 |
| Alignment of evidence-based practices with rewards, hiring and training | 1 | 2.0 |
| Alignment of student success with prestige | 0 | 0.0 |
| Repositories to share materials and information | 0 | 0.0 |
| Strive toward equity and inclusivity | 0 | 0.0 |
| **Total** | **50** | **100.0** |

## Table 5

***Examining the Impact of Efforts within a Funding Portfolio***

| Consideration | Count | Percent |
|---|---|---|
| Take stock of what is known | 7 | 17.5 |
| Importance of context | 6 | 15.0 |
| Conditions for sustained change | 4 | 10.0 |
| Strive toward equity and inclusivity | 4 | 10.0 |
| Department commitment | 3 | 7.5 |
| Indicators of progress | 3 | 7.5 |
| Broader Impacts* | 2 | 5.0 |
| Examining cross-institutional collaborations and peer networks | 2 | 5.0 |
| Faculty approaches to teaching and teaching improvement | 2 | 5.0 |
| Institutional commitment | 2 | 5.0 |
| Repositories to share materials and information | 2 | 5.0 |
| Student learning and alumni outcomes data | 2 | 5.0 |
| Alignment of student success with prestige | 1 | 2.5 |
| Alignment of evidence-based practices with rewards, hiring and training | 0 | 0.0 |
| Collective vision | 0 | 0.0 |
| Common data | 0 | 0.0 |
| **Total** | **40** | **100.0** |

*Note.* *Category unique to portfolio-level data

## Table 6

***Examining the Change Process of Efforts within a Funding Portfolio***

| Consideration | Count | Percent |
|---|---|---|
| Strive toward equity and inclusivity | 8 | 22.2 |
| Take stock of what is known | 8 | 22.2 |
| Conditions for sustained change | 7 | 19.4 |
| Common data | 2 | 5.6 |
| Department commitment | 2 | 5.6 |
| Importance of context | 2 | 5.6 |
| Indicators of progress | 2 | 5.6 |
| Alignment of student success with prestige | 1 | 2.8 |
| Broader Impacts* | 1 | 2.8 |
| Institutional commitment | 1 | 2.8 |
| Repositories to share materials and information | 1 | 2.8 |
| Student learning and alumni outcomes data | 1 | 2.8 |
| Alignment of evidence-based practices with rewards, hiring and training | 0 | 0.0 |
| Collective vision | 0 | 0.0 |
| Examining cross-institutional collaborations and peer networks | 0 | 0.0 |
| Faculty approaches to teaching and teaching improvement | 0 | 0.0 |
| **Total** | **36** | **100.0** |

*Note.* *Category unique to portfolio-level data

## Table 7

***Examining the Impact of National Efforts***

| **Consideration** | **Count** | **Percent** |
|---|---|---|
| Public understanding and attitudes toward science and higher education* | 12 | 20.7 |
| Student learning and alumni outcomes data | 8 | 13.8 |
| Professional certifications and endorsements* | 5 | 8.6 |
| Collective vision | 5 | 8.6 |
| Alignment of evidence-based practices with rewards, hiring and training | 4 | 6.9 |
| Alignment of student success with prestige | 4 | 6.9 |
| Repositories to share materials and information | 4 | 6.9 |
| Indicators of progress | 3 | 5.2 |
| Conditions for sustained change | 2 | 3.4 |
| Faculty approaches to teaching and teaching improvement | 2 | 3.4 |
| Federal support, resources and policy* | 2 | 3.4 |
| Institutional commitment | 2 | 3.4 |
| Strive toward equity and inclusivity | 2 | 3.4 |
| Department commitment | 1 | 1.7 |
| Importance of context | 1 | 1.7 |
| Take stock of what is known | 1 | 1.7 |
| Common data | 0 | 0.0 |
| Examining cross-institutional collaborations and peer networks | 0 | 0.0 |
| **Total** | **58** | **100.0** |

*Note.* *Category unique to national-level data

## Table 8

***Examining the Change Process of National Efforts***

| **Consideration** | **Count** | **Percent** |
|---|---|---|
| Conditions for sustained change | 5 | 19.2 |
| Take stock of what is known | 4 | 15.4 |
| Indicators of progress | 3 | 11.5 |
| Alignment of evidence-based practices with rewards, hiring and training | 2 | 7.7 |
| Professional certifications and endorsements* | 2 | 7.7 |
| Common data | 2 | 7.7 |
| Importance of context | 2 | 7.7 |
| Public understanding and attitudes toward science and higher education* | 2 | 7.7 |
| Department commitment | 1 | 3.8 |
| Examining cross-institutional collaborations and peer networks | 1 | 3.8 |
| Federal support, resources and policy* | 1 | 3.8 |
| Student learning and alumni outcomes data | 1 | 3.8 |
| Alignment of student success with prestige | 0 | 0.0 |
| Collective vision | 0 | 0.0 |
| Faculty approaches to teaching and teaching improvement | 0 | 0.0 |
| Institutional commitment | 0 | 0.0 |
| Repositories to share materials and information | 0 | 0.0 |
| Strive toward equity and inclusivity | 0 | 0.0 |
| **Total** | **26** | **100.0** |

*Note.* *Category unique to national-level data

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# Promoting Transformation of Undergraduate STEM Education

# Workshop Summary Report

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