

FRAMEWORK

FOR SYSTEMIC CHANGE
IN UNDERGRADUATE STEM
TEACHING AND LEARNING



AAU Undergraduate STEM Education Initiative

The overall objective of the Association of American Universities' Undergraduate STEM Education Initiative is to influence the culture of STEM departments at AAU universities so that faculty members are encouraged to use teaching practices proven by research to be effective in engaging students in STEM education and in helping students learn.

The goals of AAU's Undergraduate STEM Education Initiative are to:

- ① **Develop an effective analytical framework** for assessing and improving the quality of STEM teaching and learning;
- ② **Support AAU STEM project sites** at a subset of AAU universities to implement the framework, and develop a broader network of AAU universities committed to implementing STEM teaching and learning reforms;
- ③ **Explore means that institutions and departments** can use to train, recognize, and reward faculty members who want to improve the quality of their STEM teaching;
- ④ **Work with federal research agencies** to develop means of recognizing, rewarding, and promoting efforts to improve undergraduate learning; and
- ⑤ **Develop effective means for sharing information** about promising and effective undergraduate STEM education programs, approaches, methods, and pedagogies.



WELCOME

In 2011, AAU launched a five-year initiative in collaboration with our member universities to improve the quality of undergraduate teaching and learning in science, technology, engineering, and mathematics (STEM) fields. This is not another study or research project on STEM education. Instead, it is an effort based on overwhelming existing research to influence the culture of STEM departments at AAU universities so that faculty members are encouraged to use student-centered, evidence-based, active learning pedagogy in their classes, particularly at the first-year and sophomore levels.

In recent years, researchers, many of them at AAU universities, have learned a great deal about the most effective methods of teaching specific STEM subjects. Several AAU universities are already leading the way in implementing the results of this research. But change needs to happen more broadly. There is an urgent need to address the institutional and cultural barriers that keep faculty members from adopting the best teaching practices in their classrooms.

The Framework for Systemic Change to STEM Teaching and Learning, which AAU universities helped to develop, provides a set of key elements that need to be addressed in order to bring about the broad-based and sustained reform we seek.

Hunter R. Rawlings III
PRESIDENT, ASSOCIATION OF AMERICAN UNIVERSITIES

INTRODUCTION

The need for improving teaching of undergraduate STEM fields has received increased attention and taken on new urgency in recent years.

We have begun to see a shift to a much more coordinated vision and effort to improve undergraduate teaching in STEM fields across and within relevant organizations and actors. This shift has been driven in part by new scholarship on teaching and learning which has led to the development of techniques that are more engaging and more effective at helping students learn than the long-established model of the expert lecturer transmitting knowledge. These practices are well documented by the National Research Council report *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*.¹ At the same time, the shift has been further facilitated by recent high-level reports—e.g. The President’s Council of Advisors on Science and Technology “Engaged to Excel” (PCAST) and Vision and Change in Undergraduate Biology Education: A Call to Action reports—that have identified deficiencies and potential solutions in STEM instructional practices and in institutional policies.²

Despite abundant demonstrations of effectiveness, student-centered, evidence-based teaching practices have not become the norm for introductory undergraduate STEM education courses. The reasons for this are complex and multifaceted, including deeply seated customs, faculty rewards structures, time and resources, the competitive pressures to stay productive in research, as well as the need to prepare and get faculty to use these new approaches and for students to accept them. At this time there is no common model that supports institutions, faculty members, and students in shifting to evidence-based practices for teaching and learning.

In 2011, AAU launched an Undergraduate STEM Education Initiative with member universities to improve STEM teaching and learning. The initiative is aimed at influencing the culture of STEM departments so faculty use sustainable, student-centered, evidence-based, active learning pedagogy in their classes, particularly at the first-year and sophomore levels.⁴ **As a key component of the initiative, AAU has developed a framework that can guide institutional commitment to encourage and support teaching practices that are more effective in engaging students in STEM education and in helping students learn.**

1 National Research Council. *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*. Washington, DC: The National Academies Press, 2012. www.nap.edu/catalog.php?record_id=13362

2 2012 President’s Council of Advisors on Science and Technology (PCAST) report “Engage to Excel: Producing One Million Additional College

Graduates With Degrees In Science, Technology, Engineering, And Mathematics.” www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf

American Association for the Advancement of Science, 2011. Vision and Change in Undergraduate Biology Education: A Call to Action. visionandchange.org/files/2011/03/

Revised-Vision-and-Change-Final-Report.pdf
AAU Undergraduate STEM Education Initiative
<http://www.aau.edu/policy/article.aspx?id=12588>

4 AAU Undergraduate STEM Education Initiative
www.aau.edu/policy/article.aspx?id=12588

AAU has developed a framework that can guide institutional commitment to using teaching practices shown by research to be effective in STEM education.

The framework provides a set of key institutional elements that need to be addressed in order to bring about sustainable change. Different strategies will almost certainly be used to achieve improvement in STEM teaching and learning at different institutions, reflecting the engagement and creativity of each campus community. To complement the framework, AAU will establish a parallel resource guide with a rich set of examples, informational resources, and model practices that institutions can use to achieve change within their local context.

The framework and its associated resources are intended to be useful to the various individuals and organizations who work together to improve undergraduate STEM teaching and learning.

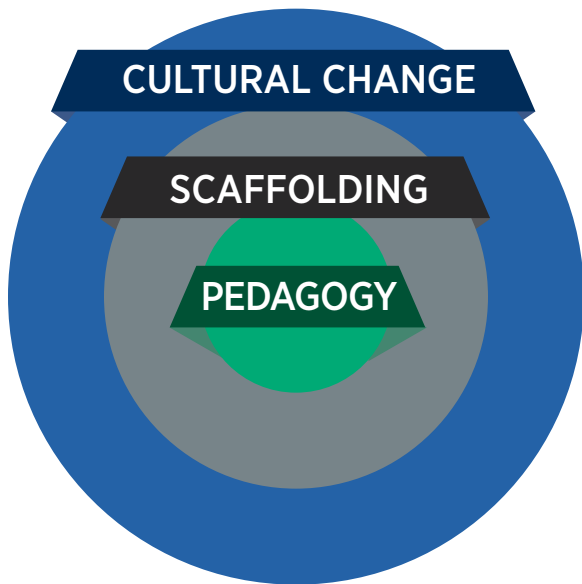
FACULTY MEMBERS can use the framework to assess their level of engagement with evidence-based teaching techniques, and to get ideas for how to improve their teaching.

DEPARTMENT CHAIRS can use the framework to understand how faculty are using evidence-based teaching, to identify strengths and shortcomings, and to help incorporate evidence-based pedagogy in the evaluation of faculty teaching.

COLLEGE AND UNIVERSITY ADMINISTRATORS can use the framework to determine how broadly evidence-based teaching techniques are being used throughout the institution and to establish institutional policy and practices to actively support a culture of evidence-based teaching.

INSTITUTIONS can demonstrate to policymakers and the public that they are using evidence-based techniques, and can engage in institutional research to understand and demonstrate the relationships between these techniques and learning, retention, completion, and other student outcomes.





FRAMEWORK

FOR SYSTEMIC CHANGE IN UNDERGRADUATE
STEM TEACHING AND LEARNING

The Framework for Systemic Change in Undergraduate STEM Teaching and Learning is designed to facilitate change in undergraduate STEM education. This requires identifying the key levels, agents, and mechanism of change, as well as models for sustaining it. The core of AAU's framework is pedagogy, the practices used by faculty members to teach students and guide and support their learning. But to successfully enact and institutionalize the use of evidence-based teaching techniques, two layers around this pedagogical core are necessary; scaffolding, or support, for both faculty and students, and larger cultural change to facilitate changing teaching practices.

Key elements of the AAU framework are described below, organized around these three layers:

- PEDAGOGICAL PRACTICES
- SCAFFOLDING
- CULTURAL CHANGE

Pedagogy refers to the method and practice of teaching. Much, but certainly not all, of pedagogy occurs in the classroom, and the main actors in changing pedagogical practices are faculty and students. “Faculty” here includes all those who teach classes, be they tenure-track faculty members, non-tenure-track instructors and

lecturers, teaching postdocs, graduate students, and undergraduate learning assistants. Students also play an essential role by taking responsibility for their learning. When pedagogy is most successful, faculty and students work in partnership toward the shared goal of learning. Enabling successful pedagogy includes the following elements.

PEDAGOGY

ARTICULATED LEARNING GOALS

- › Develop shared learning goals and outcome measures
- › Consider learning at all levels, from individual courses through programs and degrees
- › Make learning goals explicit to the students and connect assignments to learning goals throughout the course

EDUCATIONAL PRACTICES

- › Engage students as active participants in learning
- › Implement teaching practices proven by research to be effective in STEM education (e.g. evidence-based teaching, scientific teaching)⁵
- › Use data on student learning to refine practice
- › Use scenarios and real-world examples
- › Use technologies effectively

ASSESSMENTS

- › Develop and utilize instructor-independent tools to assess student learning
- › Teach for, and measure, long-term retention
- › Use assessment instruments (and research on assessments) for commonly-cited outcomes that are hard to assess, like “scientific” thinking or problem solving skills

ACCESS

- › Ensure that STEM courses are inclusive of all students
- › Implement practices known to enhance students’ self-efficacy

⁵ Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S.M., and Wood, W.B. (2004). Policy forum: scientific teaching. *Science* 304, 521–522. Available at www.bioquest.org/science_vol304_pg521_522.pdf

The notion of scaffolding refers to the supports, including a sense of community, necessary to first incubate and then sustain evidence-based teaching. Successful implementation of these practices requires more than simply exposing faculty members to such methods and then expecting them to change their behavior inside the classroom. A transition to evidence-based teaching methods is not a single event, after which no further learning or modification of practices is necessary. Department chairs have a critical role to play in ensuring that faculty members are supported in their efforts to first learn and then master different evidence-based teaching techniques.

Scaffolding support of this nature is critical not only for tenure-track faculty but also for contingent faculty and future faculty (i.e. graduate teaching assistants). Students, too, need reinforcement outside the classroom and a variety of different kinds of programs may complement their classroom experiences. However, in order to encourage the use of effective instructional practices inside the classroom the scaffolding elements that focus on faculty are necessary. Between the departmental and the institutional level, structures like those below provide faculty with the necessary resources to engage in evidence-based teaching practices.

SCAFFOLDING

PROVIDE FACULTY PROFESSIONAL DEVELOPMENT

- › Develop faculty awareness of the research bases and underpinnings of proven and effective approaches to teaching so that they can adapt/modify/contextualize them to their local contexts
- › Teach future and junior faculty members how to teach
- › Develop communities of practice

PROVIDE FACULTY WITH EASILY ACCESSIBLE RESOURCES of learning tools and technology

COLLECT & SHARE DATA ON PROGRAM PERFORMANCE

and use it to strengthen programs

- › Assess student retention in the major
- › Measure achievement gaps between various segments of student body and assess the impact of interventions on the gaps
- › Ensure data is disseminated at all levels, institution-wide, department and individual faculty member

ALIGN FUTURE FACILITIES PLANNING

with modern instructional approaches, and consider the reconfiguration and reallocation of current spaces as resources and space permit

Sustainable change requires cultural change, and faculty members live in at least two cultures: an institutional culture and a disciplinary culture.⁶ Leaders at all levels of an institution including departments and other

units, federal and industry funders and partners, and scientific societies must facilitate cultural changes like those below to encourage faculty to adopt new teaching methods and continually hone and improve their techniques.

CULTURAL CHANGE

LEADERSHIP COMMITMENT

- › President and Provost make a public leadership commitment to the importance of evidence-based, student centered teaching
- › Faculty distinguished in their disciplines communicate the importance of this commitment
- › All levels of leadership recognize and address the factors that influence whether faculty members implement evidence-based teaching techniques

ESTABLISH STRONG MEASURES OF TEACHING EXCELLENCE

- › Develop measures of departmental/college commitment to evidence-based teaching, and establish university expectations for this commitment
- › Adopt robustly developed measures of teaching effectiveness, beyond student ratings
- › Assure that during the hiring process there is evidence of substantial promise for teaching effectiveness

ALIGN INCENTIVES WITH THE EXPECTATION OF TEACHING EXCELLENCE

- › Assure that strong measures of teaching excellence are part of tenure and promotion criteria and the decision-making process
- › Assure that local leadership in teaching reform, and refereed publications and grant support related to evidence-based teaching, are counted substantially in merit adjustments to salary, and in promotion and tenure review
- › Reward good teaching, at all levels— institution, college, department and across all populations—senior faculty, junior faculty, contingent faculty, graduate assistants, and teaching assistants
- › Encourage faculty efforts to influence their professional societies to provide leadership in education, and reward such efforts as appropriate service to the discipline

⁶ Manduca, C.A. (2008, October). Working with the discipline: *Developing a supportive environment for education*. Paper presented at the National Research Council's Workshop Linking Evidence to Promising Practices in STEM Undergraduate Education, Washington, DC. Available at www7.nationalacademies.org/bose/Manduca_CommissionedPaper.pdf



WWW.AAU.EDU/STEM

Beyond articulating the key elements listed above, all of which are at some level essential to a changed culture in which routine practices for teaching and learning align with what is known about how students learn, **the framework includes an online interactive tool that showcases innovative institutional efforts** that are already being conducted by universities to implement elements of the framework.

Within each of the three layers of the framework, these expanded set of examples serve as resources to assist institutions in moving from existing practices to those called for within the framework. Mechanisms, or models, for enacting the framework's recommended elements will evolve over the course of the project drawing from established models of practice occurring at AAU member intuitions, the AAU STEM Project Sites, and partner organizations. These models will provide resources for the broader AAU membership and other institutions engaged in STEM educational transformation.

We envision the framework as a living resource that is responsive to the AAU membership needs and contributions and to ongoing changes in understanding of STEM teaching and learning.

Visit **www.aau.edu/STEM** for a set of innovative institutional efforts mapped to elements of the framework. As institutions move to improve their usage of evidence-based teaching practices, AAU hopes these examples will serve as a resource for all colleges and universities working to improve undergraduate teaching and learning in STEM.

STEM ADVISORY COMMITTEE

AAU assembled an advisory committee composed of experts in undergraduate STEM teaching and learning. The advisory committee assists AAU in developing and executing its initiative to achieve its goals. The following individuals serve on the advisory committee:

Cynthia J. Atman, *Director*, Center for the Advancement of Engineering Education and Professor, Human Centered Design and Engineering, University of Washington

Jim Borgford-Parnell, *Assistant Director*, Center for Engineering Teaching and Learning, University of Washington

David M. Bressoud, *DeWitt Wallace Professor of Mathematics*, Macalester College

Peter J. Bruns, *Professor of Genetics Emeritus*, Cornell University and Vice President for Grants and Special Programs (retired), Howard Hughes Medical Institute (HHMI)

Linda Columbus, *Associate Professor of Chemistry*, Department of Chemistry, University of Virginia

Edward J. Coyle, *Arbutus Chair and Director* of the Arbutus Center for the Integration of Research Education, Georgia Institute of Technology

James S. Fairweather, *Professor*, Higher, Adult and Lifelong Education, Michigan State University

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Linda L. Slakey, *Senior Advisor*, AAU Undergraduate STEM Education Initiative, and former Director, Division of Undergraduate Education, National Science Foundation (NSF)

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