Pathways to STEM Degrees and the Barriers and Opportunities

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Texas A&M University

2016 National Academies Special Topics Summer Institute on Quantitative Biology
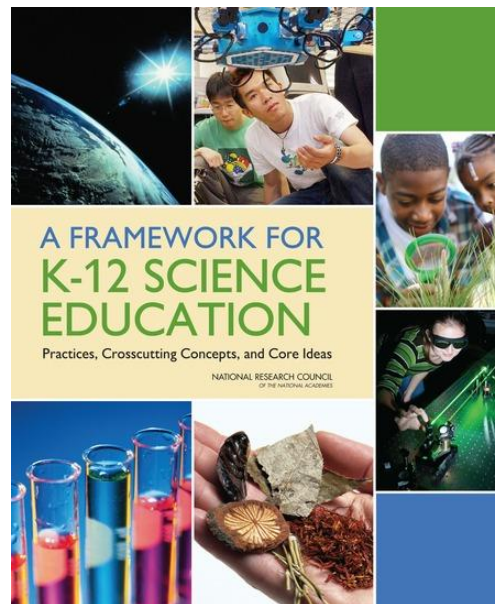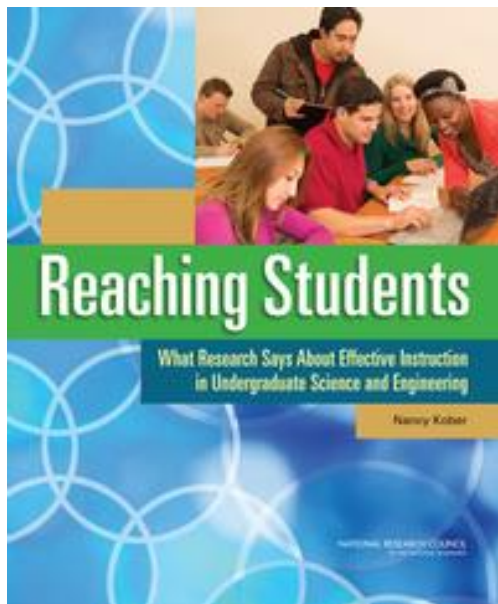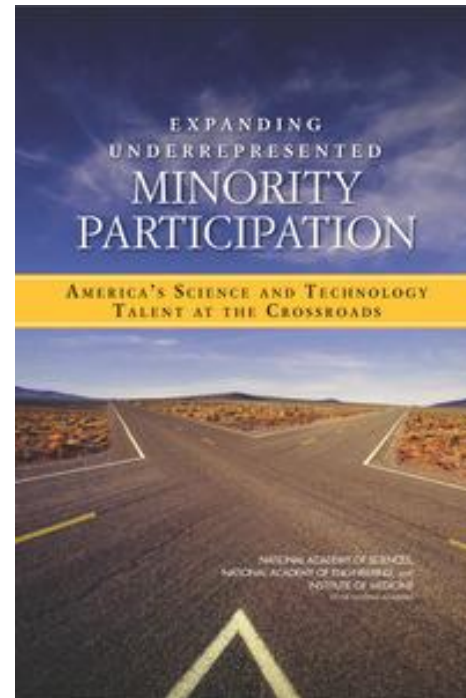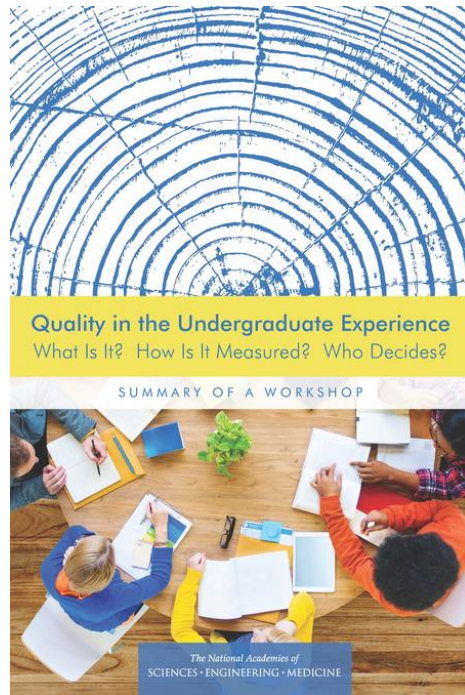
June 19-24, 2016

North Carolina State University, Raleigh

The National Academies of
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Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways

DISCIPLINE-BASED EDUCATION RESEARCH
Understanding and Improving Learning in Undergraduate Science and Engineering

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Quality in the Undergraduate Experience
What Is It?   How Is It Measured?   Who Decides?

SUMMARY OF A WORKSHOP

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EXPANDING UNDERREPRESENTED MINORITY PARTICIPATION

AMERICA'S SCIENCE AND TECHNOLOGY TALENT AT THE CROSSROADS

NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, and
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES

Reaching Students

What Research Says About Effective Instruction in Undergraduate Science and Engineering

Nancy Kober

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

A FRAMEWORK FOR K-12 SCIENCE EDUCATION

Practices, Crosscutting Concepts, and Core Ideas

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Study Charge

- **Review evidence** related to barriers facing 2- and 4-year undergraduates who intend to major in STEM and opportunities for overcoming these barriers.

- **Provide research-based guidance** to inform policies and programs aimed to attract and retain students to complete associate's and bachelor's degrees in STEM disciplines.

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Committee

Shirley Malcom (*Chair*)**,** American Association for the Advancement of Science

Cynthia Atman, Center for Engineering Learning and Teaching, University of Washington

George Boggs, American Association of Community Colleges (emeritus)

Pamela Brown, Office of the Provost, New York City College of Technology, City University of NY

Peter Bruns, Howard Hughes Medical Institute (emeritus)

Tabbye Chavous, Departments of Psychology and Educational Studies, University of Michigan

Charles De Leone, Department of Physics, California State University, San Marcos

Frank Dobbin, Department of Sociology, Harvard University

S. James Gates, Jr., Department of Physics, University of Maryland

Sylvia Hurtado, Graduate School of Education and Information Studies, Univ. of California, Los Angeles

Leah H. Jamieson, College of Engineering, Purdue University

Adrianna Kezar, Pullias Center for Higher Education, University of Southern California

Kenneth Koedinger, Human-Computer Interaction Institute, Carnegie Mellon University
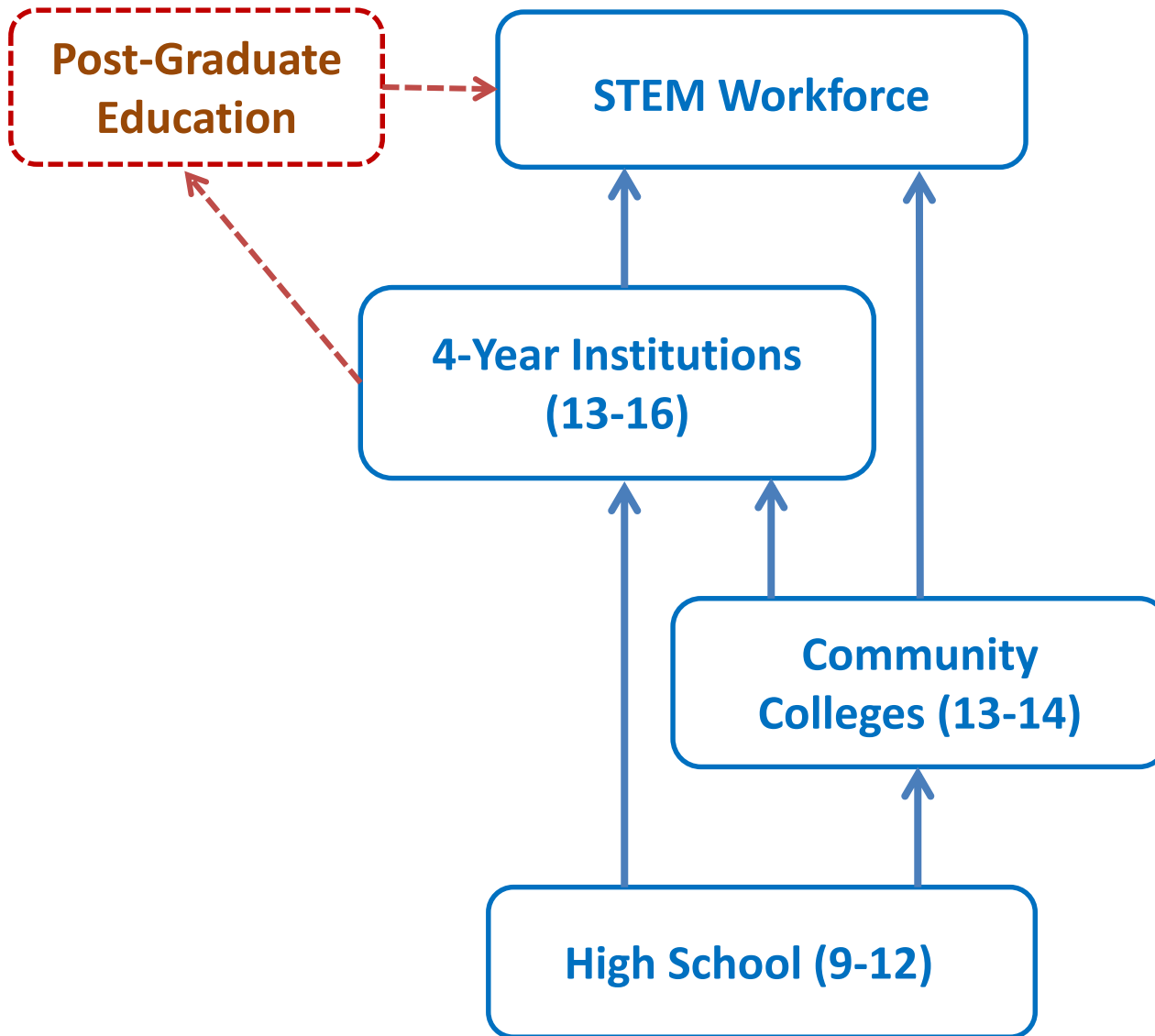
Muriel Poston, Dean of Faulty, Pitzer College

Mark Rosenberg, President, Florida International University

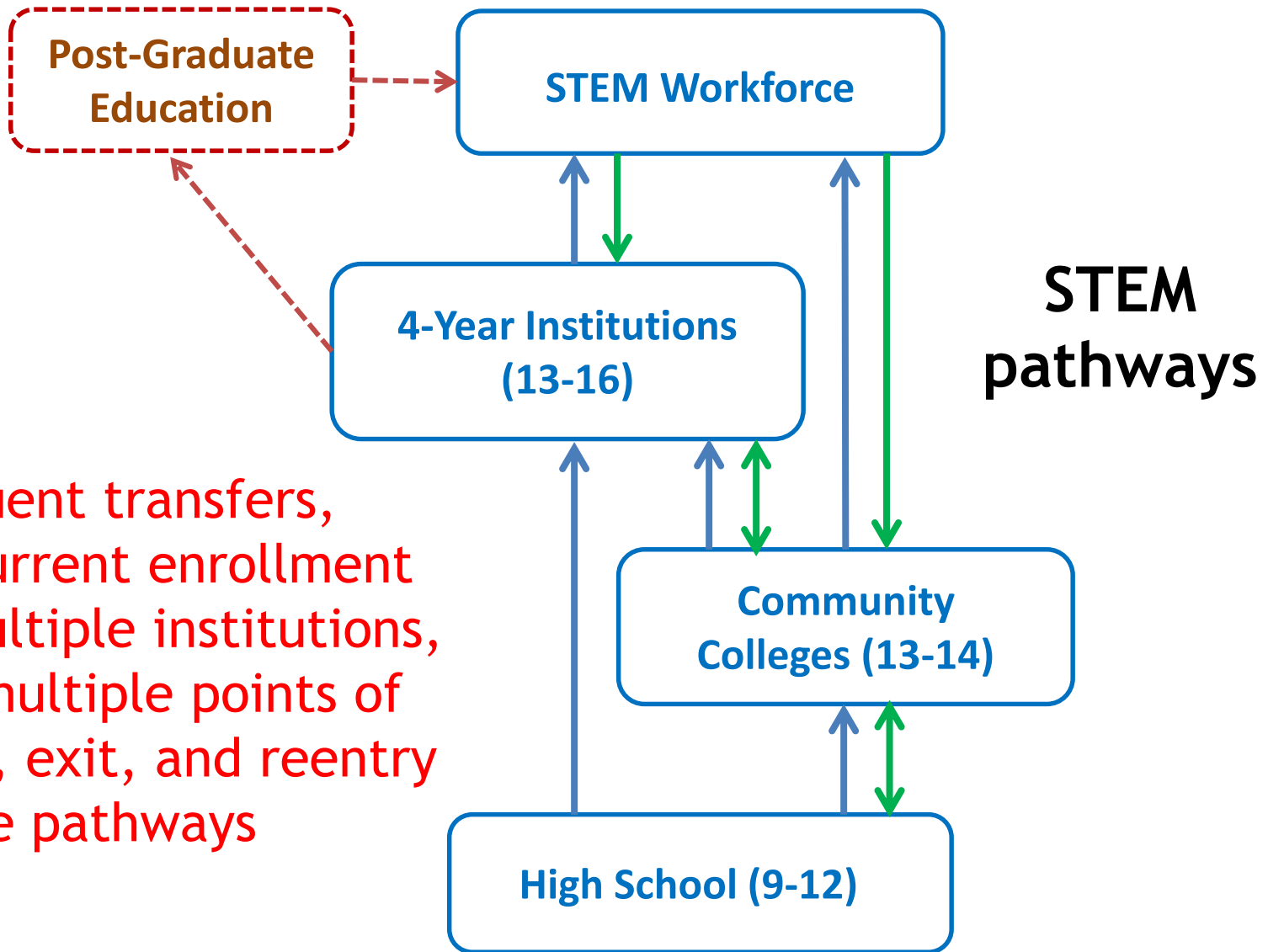**Uri Treisman,** Charles A. Dana Center for Mathematics and Science Education, Univ. of Texas, Austin

Michelle Van Noy, Education and Employment Research Center, Rutgers University

X. Ben Wu, Department of Ecosystem Science and Management, Texas A&M University

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Post-Graduate Education

STEM Workforce

4-Year Institutions (13-16)

Community Colleges (13-14)

High School (9-12)

STEM pathways (pipeline)

Post-Graduate Education

STEM Workforce

STEM pathways

4-Year Institutions (13-16)

Frequent transfers, concurrent enrollment at multiple institutions, and multiple points of entry, exit, and reentry to the pathways

Community Colleges (13-14)

High School (9-12)

REPORT TO THE PRESIDENT

ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS
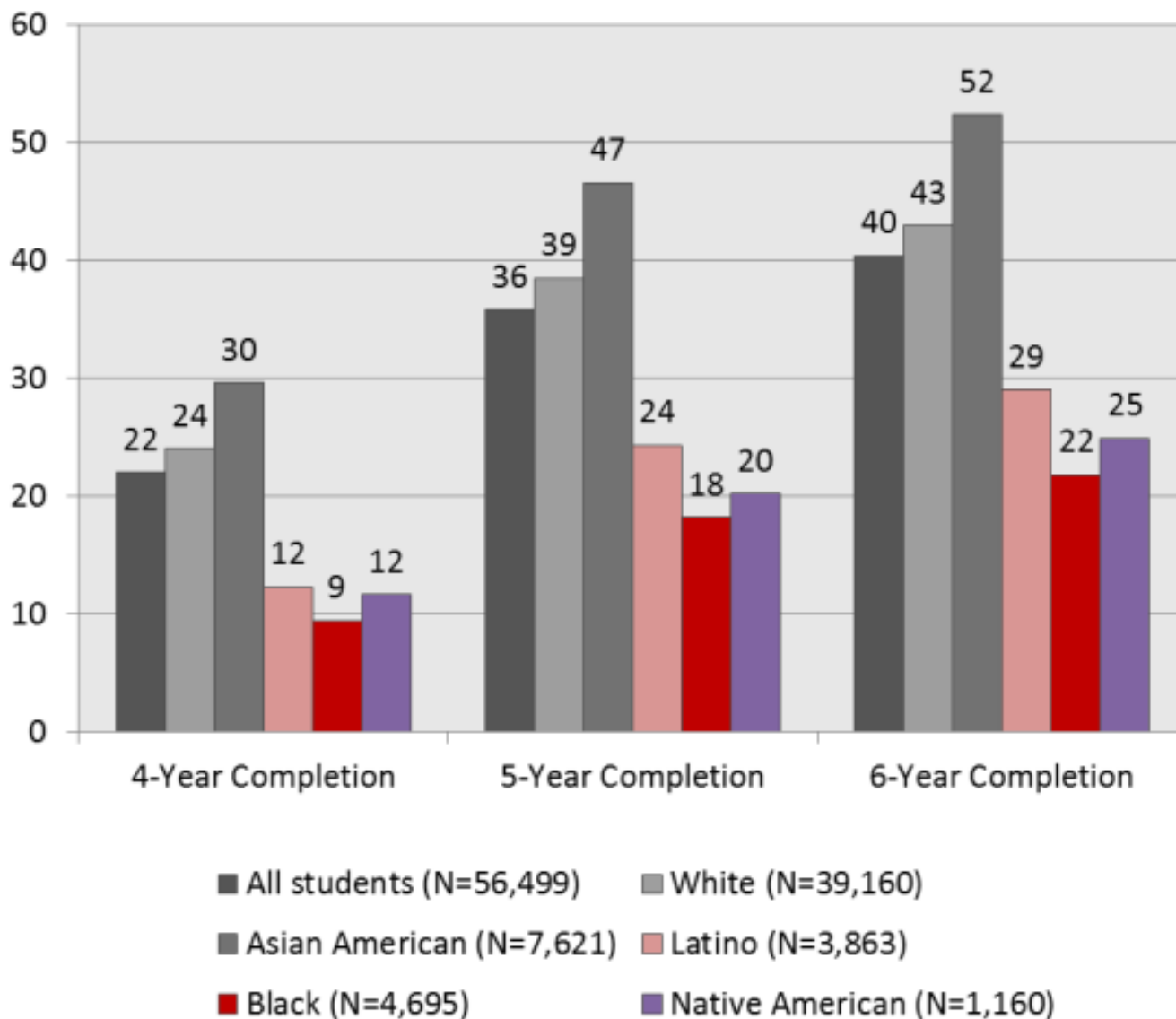
Executive Office of the President

President's Council of Advisors on Science and Technology

FEBRUARY 2012

Produce one million additional STEM professionals in the next decade (increase by 34% annually), to ensure economic strength, national security, global competitiveness, environment, and health of the United States.

Cumulative percentage of STEM aspirants who completed STEM degrees in 4, 5, and 6 years

Source: Eagan et al., 2014 (Fig 7)

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- Why do many of the students who enter higher education with an interest in pursuing study in STEM lose that interest before degree completion?

- How can the quality of the educational experience of undergraduate STEM students be improved?

Major Topics (Chapters)

- Multiple STEM Pathways

- Why students enter, stay, or leave – the culture of undergraduate STEM education

- Instructional practices, departmental leadership, and co-curricular supports

- Why students stay or leave – institutional, state, and national policies

- Leading and sustaining change

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Conclusions and Recommendations

- **Today's STEM Students**

  CONCLUSIONS 1-3; RECOMMENDATIONS 1-2

- **Institutional Support for Students**

  CONCLUSION 4; RECOMMENDATIONS 3-7

- **Systemic and Sustainable Change in STEM Education**

  CONCLUSIONS 5-6; RECOMMENDATIONS 8-9

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Today's STEM Students

CONCLUSION 1 — There is an opportunity to expand and diversify the nation's STEM workforce and STEM-skilled workers in all fields if there is a commitment to appropriately support students through degree completion and provide more opportunities to engage in high-quality STEM learning and experiences.

CONCLUSION 2 — STEM aspirants increasingly navigate the undergraduate education system in new and complex ways. It takes students longer for completion of degrees, there are many patterns of student mobility within and across institutions, and the accommodation and management of student enrollment patterns can affect how quickly and even whether a student earns a STEM degree.

Today's STEM Students

CONCLUSION 3 — National, state, and institutional undergraduate data systems often are not structured to gather information needed to understand how well the undergraduate education system and institutions of higher education are serving students.

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Today's STEM Students

RECOMMENDATION 1 — Data collection systems should be adjusted to collect information to help departments and institutions better understand the nature of the student populations they serve and the pathways these students take to complete STEM degrees.

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Today's STEM Students

RECOMMENDATION 2 — Federal agencies, foundations, and other entities that fund research in undergraduate STEM education should prioritize research to assess whether enrollment mobility in STEM is a response to financial, institutional, individual, or other factors, both individually and collectively, and to improve understanding of how student progress in STEM, in comparison with other disciplines, is affected by enrollment mobility.

Institutional Support for Students

CONCLUSION 4 - Better alignment of STEM programs, instructional practices, and student supports is needed in institutions to meet the needs of the populations they serve. Programming and policies that address the climate of STEM departments and classrooms, the availability of instructional supports and authentic STEM experiences, and the implementation of effective teaching practices together can help students overcome key barriers to earning a STEM degree, including the time to degree and the price of a STEM degree.

Institutional Support for Students

RECOMMENDATION 3 — Federal agencies, foundations, and other entities that support research in undergraduate STEM education should support studies with multiple methodologies and approaches to better understand the effectiveness of various co-curricular programs.

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Institutional Support for Students

RECOMMENDATION 4 — Institutions, states, and federal policy makers should better align educational policies with the range of education goals of students enrolled in 2- and 4-year institutions. Policies should account for the fact that many students take more than 6 years to graduate and should reward 2- and 4-year institutions for their contributions to the educational success of students they serve, which includes not only those who graduate.

Institutional Support for Students

RECOMMENDATION 5 — Institutions of higher education, disciplinary societies, foundations, and federal agencies that fund undergraduate education should focus their efforts in a coordinated manner on critical issues to support STEM strategies, programs, and policies that can improve STEM instruction.

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Institutional Support for Students

RECOMMENDATION 6—Accrediting agencies, states, and institutions should take steps to support increased alignment of policies that can improve the transfer process for students.

RECOMMENDATION 7—State and federal agencies and accrediting bodies together should explore the efficacy and tradeoffs of different articulation agreements and transfer policies.

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Systemic and Sustainable Change in STEM Education

CONCLUSION 5 — There is no single approach that will improve the educational outcomes of all STEM aspirants. The nature of U.S. undergraduate STEM education will require a series of interconnected and evidence-based approaches to create systemic organizational change for student success.

Systemic and Sustainable Change in STEM Education

CONCLUSION 6 — Improving undergraduate STEM education for all students will require a more systemic approach to change that includes use of evidence to support institutional decisions, learning communities and faculty development networks, and partnerships across the education system.

Systemic and Sustainable Change in STEM Education

RECOMMENDATION 8 — Institutions should consider how expanded and improved co-curricular supports for STEM students can be informed by and integrated into work on more systemic reforms in undergraduate STEM education to more equitably serve their student populations.

RECOMMENDATION 9 — Disciplinary departments, institutions, university associations, disciplinary societies, federal agencies, and accrediting bodies should work together to support systemic and long-lasting changes to undergraduate STEM education.

How faculty can engage in evidence-based efforts in creating systemic change for student success
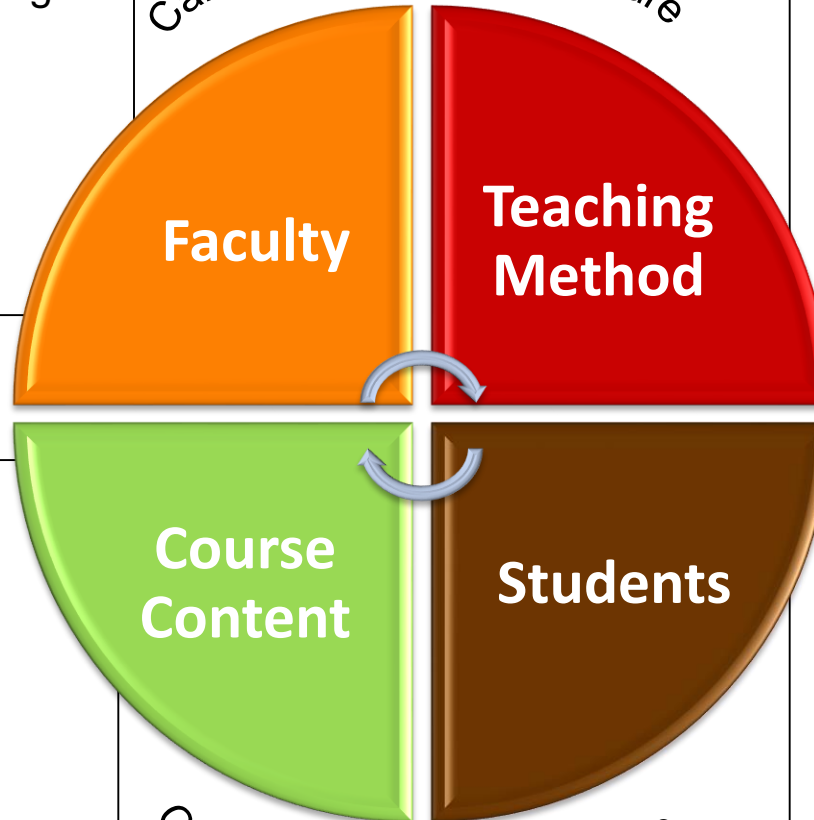
As a teacher and mentor –

- Implement inclusive pedagogy
- Improve the climate of our classrooms
- Provide authentic STEM experiences
- Evidence-based/scholarly approach to teaching

Dynamics of Multicultural Teaching and Learning

Know oneself
- Multiple and interacting social identities and identity status
- Unexamined assumptions
- Stereotyped beliefs

How we teach
- Broaden repertoire of teaching methods; address multiple learning styles
- Classroom norms that emphasize respect, fairness, and equity

What we teach
- Use a curriculum of inclusion
- Represent diverse perspectives
- Draw examples and illustrations from diverse life experiences

Know one's students
- Monocultural - multicultural socialization
- Cognitive development
- Unexamined assumptions and stereotyped beliefs

Campus Climate and Culture

Faculty

Teaching Method

Course Content

Students

Campus Climate and Culture

Adapted from: Adams & Love 2009

A Paradigm for Multicultural Course Change

Component	Exclusive	Inclusive	Transformed
Contents	Give traditional mainstream experiences and perspectives; add authors from different backgrounds who confirm traditional perspectives or support stereotypes.	Add Alternative perspectives through materials, readings, speakers; analyze historical exclusion of alternative perspectives	Re-conceptualize the content through a shift in paradigm or standard; present content through non-dominant perspective.
Instructional Strategies and Activities	Mainly lecture and other didactic methods; question-and-answer discussions; instructor as purveyor of knowledge.	Instructor as purveyor of knowledge but uses a variety of methods to relate new knowledge to previous experience - engage students in constructing knowledge - encourage peer learning.	Change in power structure so that students and instructor learn from each other; methods center on student experience/knowledge such as - analyzing concepts against personal experience - issues-oriented approaches - critical pedagogy
Assessment of Student Knowledge	Primarily examinations and papers.	Multiple methods and alternatives to standard exams and papers; student choice.	Alternatives that focus on student growth: action-oriented projects; self-assessment, reflection on the course.
Classroom Dynamics	Focus exclusively on content; avoidance of social issues in classroom; no attempt to monitor student participation.	Acknowledgement and processing of social issues in classroom; monitoring and ensuring equity in student participation.	Challenging of biased views and sharing of diverse perspectives while respecting rules established for group process; equity in participation.

Morey & Kitano 1997

Authentic STEM Experiences

- Undergraduate research experiences (URE) are especially effective in increasing retention and academic achievements, especially for under-represented minority students

- Scaling up URE with course-based undergraduate research experiences (CURE; e.g., Genomics Education Partnership, FYI at UT Austin)

- Deep reading and investigation of primary literature (e.g., CREATE)

- Course-based authentic scientific inquiries

Authentic Ecological Inquiry using BearCam
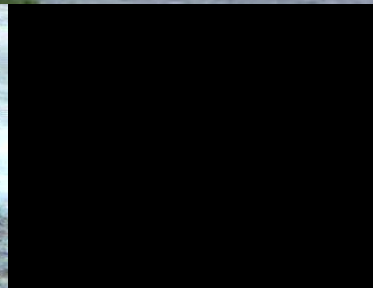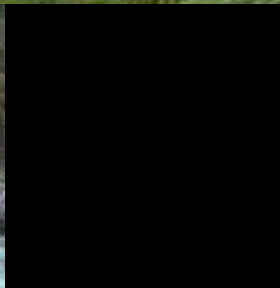
Web-based Authentic Ecological Inquiry using BearCam

| Individual Inquiry Process	Collaboration
1. Background exploration and share	Online group discussion and feedback throughout the process
2. Observing bear distribution and interactions using still pictures	
3. Developing and refining hypothesis	
4. Collecting and analyzing data and interpreting results	
5. Developing ecological report	
6. Calibrated Peer Review (CPR) using a rubric	
7. Revising report based on peer reviews and rubric	

Criteria	3	2	1	0
Objective	The objective (1) is clear, (2) is reasonably specific, and (3) explains the purpose of the study.	Met 2 of 3	Met 1 of 3	Met none
Hypothesis	The hypothesis is (1) logical, (2) testable, and (3) nontrivial.	Met 2 of 3	Met 1 of 3	Met none
Sampling	The number of samples is (1) reported and (2) sufficient, and (3) with sufficient description for sample selection.	Met 2 of 3	Met 1 of 3	Met none
Data Collection	(1) The variables collected are appropriate for testing the hypothesis and (2) there are sufficient description for data collection and (3) and data analysis.	Met 2 of 3	Met 1 of 3	Met none
Data Display	The data display (1) is in an appropriate form, (2) represents appropriate variables, and (3) addresses the hypothesis.	Met 2 of 3	Met 1 of 3	Met none
Results	Results (1) are presented in the text, (2) are specific, and (3) correspond to the variables specified in the methods section.	Met 2 of 3	Met 1 of 3	Met none
Conclusions	Conclusions (1) are based solely on results, (2) are sufficiently developed based on the results, and (3) correspond to the hypothesis.	Met 2 of 3	Met 1 of 3	Met none
Discussions	Discussions include (1) interpretations of the results, (2) limitations of the study, and (3) suggested future studies/new questions.	Met 2 of 3	Met 1 of 3	Met none
Organization	The (1) Introduction, (2) Methods, and (3) Results & Discussion sections, respectively, are free of other contents.	Met 2 of 3	Met 1 of 3	Met none
Report	The report is (1) written in grammatically correct sentences, (2) written in a succinct, technical style, and (3) free of unnecessary repetition.	Met 2 of 3	Met 1 of 3	Met none

Virtual Ecological Inquiry (VEI)
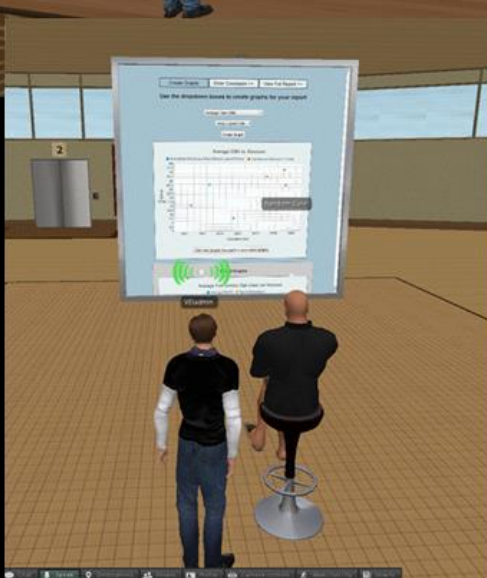
How faculty can engage in evidence-based efforts in creating systemic change for student success

As a member of the institution and profession

- Inform and work with colleagues
- Engage in curricular/co-curricular reform efforts of department and institution
- Engage in disciplinary faculty networks and reform efforts (QUBES, CURE, ScienceCaseNet, PULSE, etc.)