Imagining the Future of Undergraduate STEM Education

NATIONAL ACADEMIES *Sciences Engineering Medicine*

NSF

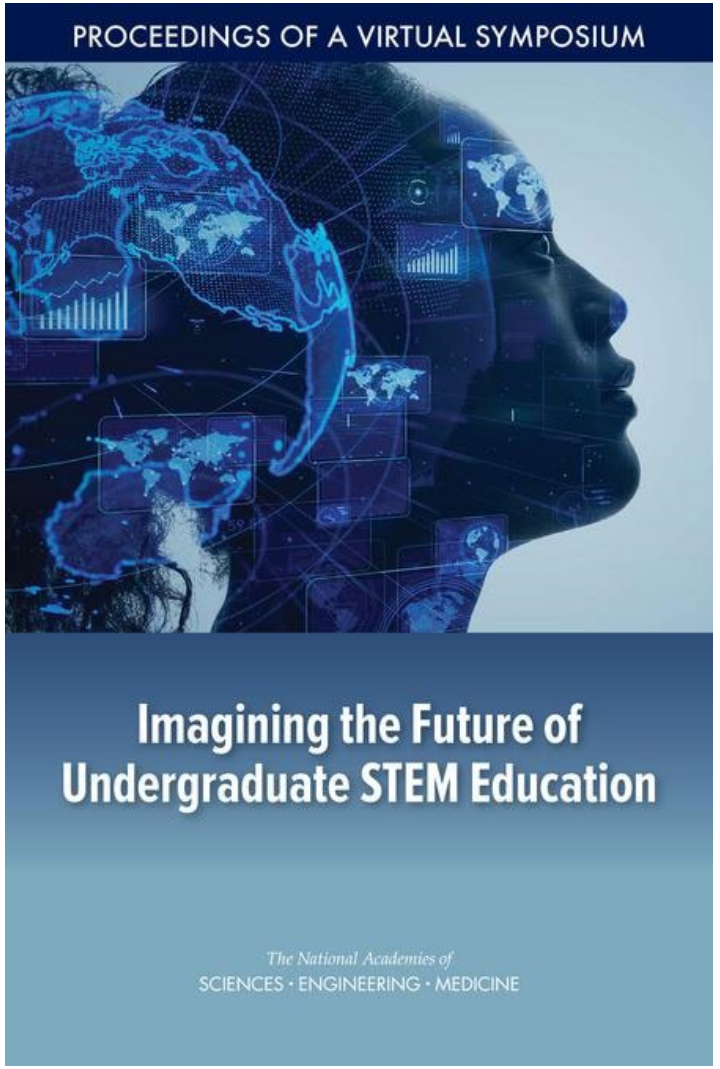
#STEMFuturesHigherEd

Virtual Event held November 2020

Focus on big picture issues for undergraduate STEM education in 2040 in the context of

- the convergence of STEM disciplines
- changes in the population, goals, and pathways of undergraduate STEM students.

Engage a wide range of participants/include new voices from institutions not as frequently part of the national dialogue.



Read or download for free at
https://www.nap.edu/catalog/26314

Virtual seminars this spring will focus on how you can bring ideas back to your own campus

Designing Future Undergraduate STEM Learning Opportunities with Students at the Center
Wednesday, March 9 from 1-4pm ET

Technology for Educating the Undergraduate STEM Students of the Future
Wednesday, March 16 from 1-4pm ET

Learning in the World: Opportunities for the Students of 2040
Tuesday, April 19 from 1-4pm ET

Wrap Up Seminar: Envisioning Undergraduate STEM Education in 2040
Wednesday, May 4 from 1-3pm ET

Wrap Up Seminar:
Envisioning Undergraduate STEM Education in 2040

Symposium Sessions on

- How to make change happen at different scales and what needs to work in concert if things are to change

Moderator

- **Cathy Manduca**, Founding Director, Science Education Resource Center, Carleton College

Plan for Today

Introductions and Significance of the Topic

Presentation of Ideas from Seminars #1, 2, and 3

Undergraduate Perspectives

Perspective from NSF

Panel Discussion on Systems Approach to Change

Powerful Ideas on Creating Change (Break out)

Wrap up Synthesis

Ideas from Seminars #1, 2, and 3

Seminar 1: Designing Future Undergraduate STEM Learning Opportunities with Students at the Center

- **Lynn Andrea Stein**, Professor of Computer and Cognitive Science, Olin College

Seminar 2: Technology for Educating the Undergraduate STEM Students of the Future

- **Nicholas Horton**, Professor of Technology and Society, Amherst College

Seminar 3: Learning in the World: Opportunities for the Students of 2040

- **Leanne Chukoskie**, Associate Professor, Bouvé College of Health Sciences, Northeastern University

Seminar 1: Students at the Center

- Authentic, *in situ*, interdisciplinary active open-ended **projects**
- **Autonomy** – students make choices and self-directed decisions
- **Meta-cognitive** – students learn to see/judge their progress
- **Meaningful** – connected to team, community service, purpose
- **Mentoring** – meet students where they are and support/scaffold
- Build **self-efficacy**

passive → active

knowledge → skills

sage → coach

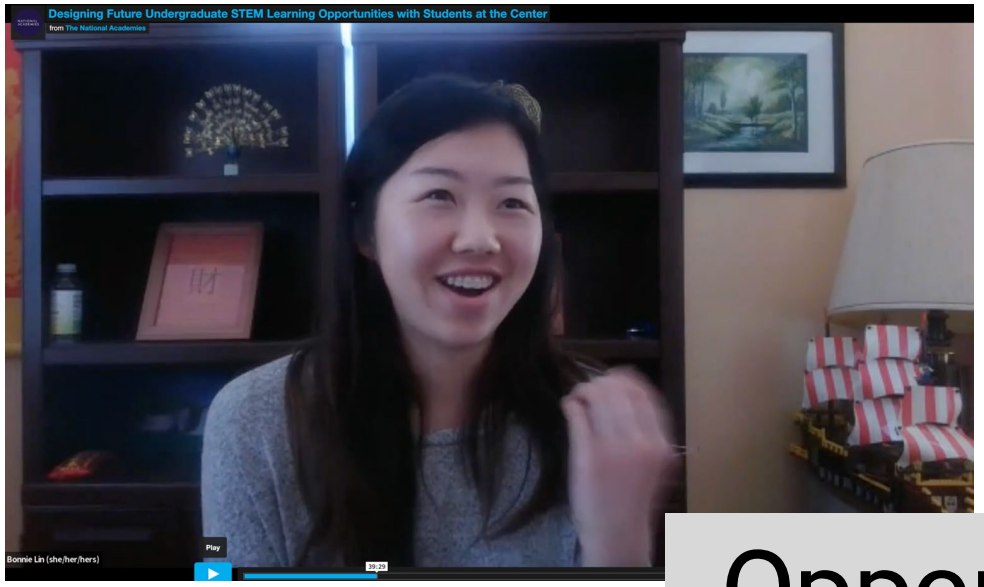
siloed → interdisciplinary

sterile → messy

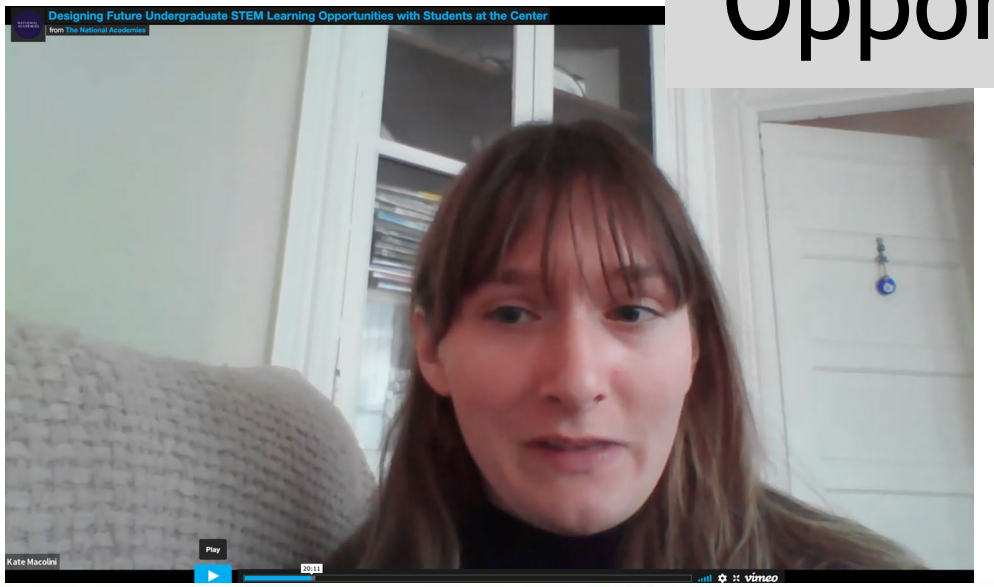
one answer → process

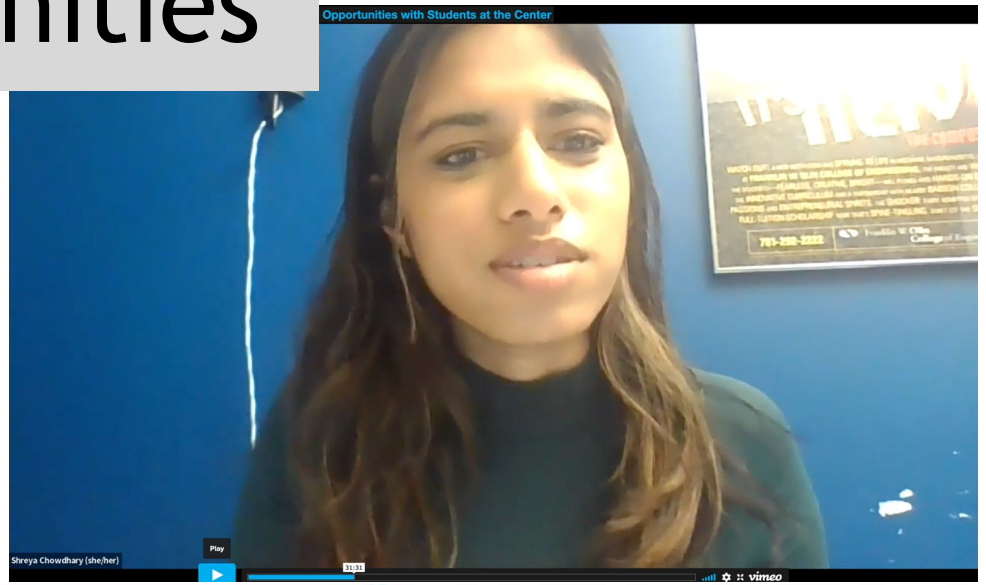
Challenges

- STEM Faculty culture — overemphasis on content
  and fund of knowledge/how to: experiential pedagogies,
  community engagement,
  invisible curriculum
- Institutional structures — policies, facilities, staffing models, calendar
- Systems & metrics of higher education including accreditation
- Secondary education — drums autonomy out

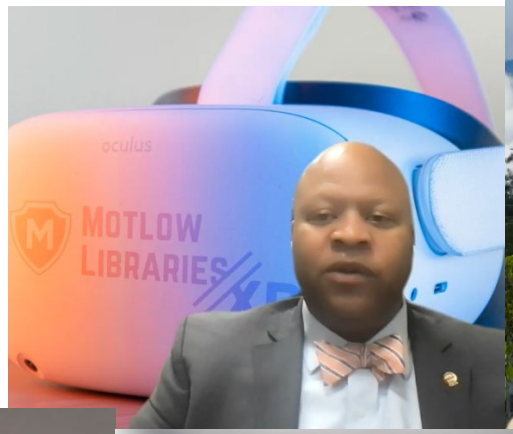


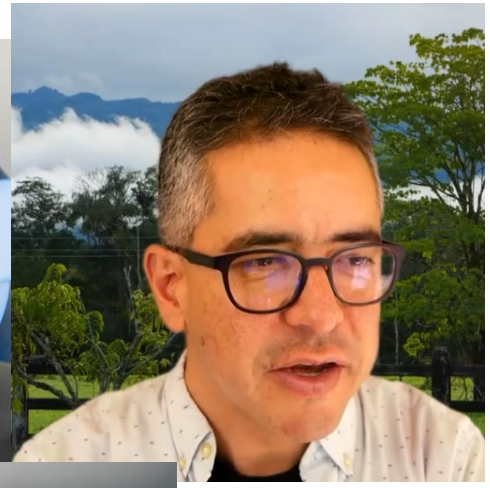
Opportunities

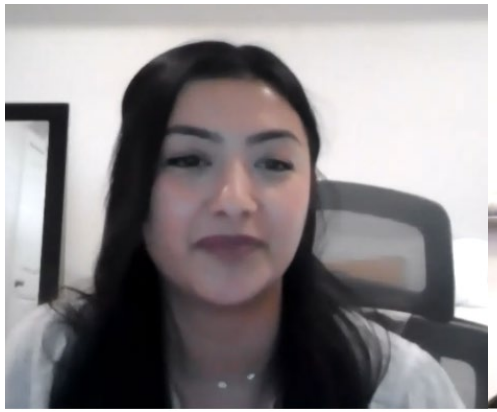


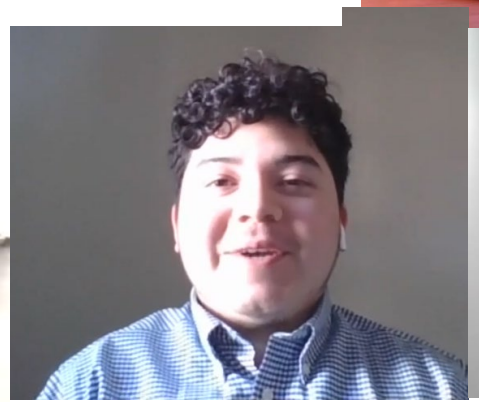


Seminar 2: Technology and the Future of Undergrad STEM









Higher education institutions will have to change

"Improvement in post secondary education will require converting teaching from a solo sport to a community-based research activity." -- Herbert Simon

Risks and Challenges

- Risk: we will perpetuate unequal access to technologies in undergraduate STEM education
- Risk: Technology complexity has increased, making it hard to navigate and manage
- Challenge: Difficult to effectively center technology on undergrade STEM student needs
- Challenge: Need incentives for faculty to develop, refine, and integrate technology
- Challenge: Need incentives across institutions (and partnerships)
- Challenge: Major impediments due to short-term financial issues and viewpoint
- Challenge: two year (community) colleges are critical yet have additional constraints

Opportunities

- Cloud computing has been transformative (helps to level the playing field for students)
- Costs for technology have plummeted (people costs now dominate)
- Great potential for technology designed to allow students to exercise their agency
- Considerable wisdom available from the learning sciences
- Can build on results from what worked (and what didn't) during the pandemic
- Opportunities for creative models to scale sustainable change
- Huge unmet need: technology with equity and social justice mindset

Seminar 3: Authentic Learning Experiences

- **Meaningful work** that is valued by and situated in communities.
- Meets students where they are and involve topics that are **motivating**
- Emphasize the value of each student's **lived experience**
- Involves **interdisciplinary** problem solving

Excited about…

- How students **build skill** in the "4Cs" through this work:
  Communication, Collaboration, Critical Thinking and Creativity

- Catching students **early** with <u>repeated opportunities</u> for problem-based learning
- Creating opportunities for **community college** students

Challenges that keep us in status quo

- Scale, Partnerships, Inclusion, and Assessments: all are necessary for these programs to develop, but all are hard to institute and maintain
- Teaching this way is **intensive** and *not currently valued* appropriately for T&P
- Need more professionals to **support students** in this type of learning effort both at the institution and in partner organizations
- How can we **scaffold** experiential learning into our curricula?
- How do we create opportunities that are **inclusive**, especially for students with different abilities?

Undergraduate Perspectives

- **Amy Phung**, Robotics Engineering, Olin College of Engineering ’21
- **George Francis**, Communication, University of the Virgin Islands ’22
- **Divya Kirani**, Biology, University of California San Diego ’23
- **George Seaton**, Mechanical Engineering, New York Institute of Technology ’23

Perspective from NSF

- **Alexandra Medina-Borja**, Program Director & Executive Secretary
  Division of Undergraduate Education, National Science Foundation

STEM Education for the Future

A Visioning Report

*National Science Foundation

Alexandra Medina-Borja, Ph.D.

Program Director & Executive Secretary

(amedinab@nsf.gov)

Vision for STEM Education of the Future

https://www.nsf.gov/news/mmg/media/images/PF7224_flate_h.jpga

Link to the report: https://www.nsf.gov/news/news_summ.jsp?cntn_id=301784&org=EHR

EHR Advisory Committee: Subcommittee on STEM Education of the Future

Dr. Margaret Honey (Chair)
President & CEO
New York Hall of Science

Dr. Bruce Alberts
Chancellor's Leadership Chair in Biochemistry and Biophysics for Science and Education
University of California, San Francisco

Dr. Hyman Bass
Samuel Eilenberg Distinguished University Professor, Mathematics; Professor, School of Education
University of Michigan

Dr. Carlos Castillo-Chavez
Emeritus and Founding Director of the Simon A. Levin Mathematical and Computational Modeling Sciences Center
Arizona State University

Dr. Okhee Lee
Professor of Childhood Education, Department of Teaching and Learning
New York University-Steinhardt

Dr. Francisco Rodriguez (Ex-Officio Member)
Chancellor
Los Angeles Community College District

Dr. Marilyn M. Strutchens
Emily R. & Gerald S. Leischuck Endowed Professor; Mildred Cheshire Fraley Distinguished Professor, Department of Curriculum and Teaching
Auburn University

Dr. Laurel Vermillion
President
Sitting Bull College

EHR Liaisons: Alexandra Medina-Borja (Executive Secretary & DUE PO); Robin Wright (former DUE DD)

Contributors and Thought Partners

Dr. Jim Spohrer
Director of Cognitive OpenTech at IBM (now retired)
The future of technology and impact on Education (April 25, 2018)

EHR/NSF Program Officers
INCLUDES, CYBERLEARNING, ATE, IGE, FW-HTF, IUSE, CS-FOR-ALL (May 31, 2018)

Dr. Christine Ortiz
Graduate Dean at MIT; Founder of Station 1
The Future of the Research University: Promise and Peril (May 31, 2018)

STEM Education Innovators (September 10-11, 2019)

- Dr. Larry Rosenstock – Emeritus & Founding CEO, High-Tech High
- Dr. Mark Somerville – Dean of Faculty, Olin College
- Dr. Josh Fost - Vice Provost of Academic Innovation, Minerva Schools
- Dr. Arthur Heinrichler – Dean of Undergraduate Studies, Worcester Polytechnic Institute
- Dr. Ann Mckenna - Vice Dean of Strategic Advancement, Arizona State University

Panel: Designing Higher Education Systems Founded on Access and Equity (October 16, 2019)

- Dr. Maria Klawe – President, Harvey Mudd College
- Dr. Claude M. Steele – Professor, Stanford University
- Mr. Antonio Perez, Engineering Student, Olin College (see https://www.youtube.com/watch?v=ywAliVKkhbs)

Guiding questions for the subcommittee:

- How can we **incentivize** higher education institutions to implement necessary change toward these goals, including adopting practices we know work?
- How can **technology** be used as a pedagogical tool and be a democratizing force?
- What **non-traditional pathways** are students taking to acquire skills, competencies, and credentials? How do these new pathways challenge higher education as we know it?
- How do people best learn STEM concepts at **different life stages**? How do different contexts, including where people live, affect learning? And how do we optimize content delivery to improve outcomes?

Structure of the Visioning Report

Priorities

Challenges

Actions

Implementation left for NSF, institutions and society to act

"In the future, there will be a demand for ***humans to do work that machines cannot do or cannot do as well as humans can****.*

Being able ***to think critically, reason probabilistically, and exercise logical, discerning judgement*** *will be some of the most important human competencies. We must cultivate these qualities in young people and "retool" adult learners to master them as well.*

How we harness cognitive and emotional mechanisms to infuse an attitude of ***self-motivation and self-actualization****, in young people and adults, will be the key to our ability to adapt to the new jobs of the future."*

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Workforce: the STEM education system must

Prepare our workforce to **innovate and work with modern technologies,** and also to consider their societal effects.

Define what **foundational knowledge** all students need.

Shift its emphasis from memorization to **understanding concepts in context** and be ready to use available computational power to accomplish tasks.

Lessons from STEM Education Innovators

3 Lessons for the Future

(From STEM Education Innovators):

1. Learning environments are **student-centered, project-based, and personalized**.

2. Equity and inclusion are **foundational** principles.

3. Technology holds promise for creating equitable learning environments, but it also alters the skills we need in the future, and **changes what and how we teach**.

A Vision for STEM Education of the Future

Equitable and Inclusive

Powered by evidence-based instruction and technology

Across all life stages and key transitions

Personalized, project-based, and learner-centered

21st century skills oriented

"…we must consider the entire education ecosystem so that children of all backgrounds, race, ethnicity, gender, religion and income levels can learn the wonders and possibilities of STEM and maintain that interest and passion throughout their lives."

Our challenge now is to make it happen

What research is still needed?

What are the focus and scale of the investments required to achieve adoption?

Are we ready to revise content?

What other questions are we not asking?

How are we training new faculty? Are there new opportunities with a new generation of professors?

Q&A

HTTPS://WWW.NSF.GOV/EHR/MATERIALS/STEM%20EDUCATION%20FOR%20THE%20FUTURE%20-%202020%20VISIONING%20REPORT.PDF

https://www.nsf.gov/news/mmg/media/images/A-Consensus_h.jpg

A VISION STATEMENT

"All citizens can contribute to our nation's progress and vibrancy. To be prepared for the STEM careers of the future, ***all learners must have an equitable opportunity to acquire foundational STEM knowledge****.*

The STEM Education of the Future brings together our ***advanced understanding of how people learn with modern technology*** *to create more personalized learning experiences, to inspire learning, and to foster creativity from an early age.*

It will unleash and harness the curiosity of young people and adult learners across the United States, ***cultivating a culture of innovation and inquiry****, and ensuring our nation remains the global leader in science and technology discovery and competitiveness."*

The STEM Education of the Future will harness technology in ways that provide ***equitable access to all learners and ensure that all learners thrive****. Skillful instruction aided by technological advances can overcome structural barriers such as cost, distance, opportunity, socioeconomic background, or prior STEM preparation, and allow all STEM learners to overcome stereotypes and biases with the support of their learning communities.*

Well-prepared educators and mentors will use evidence-based methods, pedagogies and technologies that are ***informed by research on how people learn in different contexts and across their lifespans****. Wherever appropriate, all new technologies, including those powered by artificial intelligence, will be used in formal and informal settings in tailored ways to ensure learners acquire competencies and STEM knowledge.*

SELECTED ACTIONS RELEVANT TO GRADUATE EDUCATION

Enable students to acquire core 21st century research competencies, including the ability to

be creative,

to solve meaningful research problems,

to work across disciplinary boundaries, and

to collaborate with diverse teams.

Lesson I: Learning environments are student-centered, project-based, and personalized.

LEARNER-CENTERED

the learner is at the center of all planning and actions.

intentionally build communities of practice between students and faculty, recognizing that learning is a social act that includes guidance and mentoring.

learning environments are culturally and linguistically relevant to students, engaging and welcoming.

PROJECT-BASED

Learning focuses on **real-world problems** that require STEM concepts.

Assessment and grading practices align with project-based learning:

- From performance-based assessments with rubrics that help students develop competencies over time, to evaluations based on portfolios of student work.
- There are many opportunities for students to complete complex, technology-based projects with a variety of approaches to evaluations and grades.

PERSONALIZED

Self-directed learning.

Sometimes students start with a project of personal interest and decide how to acquire the knowledge needed to solve the problem, whether enrolling in classes, seeking mentoring, or accessing information through other means.

Differences in foundational knowledge are instead mitigated individually through faculty mentoring or other strategies

Allows students to engage in self-directed learning based on individual preferences and pacing in a personalized way.

Lesson II: Equity and Inclusion are Foundational Design Principles

"…creating greater diversity and participation should be designed into the educational ecosystem.

Every learning environment, tool, classroom, syllabus, instructor, and intervention must consider, from the beginning, how to serve all students.

Only then will learners of all ages and backgrounds have equitable opportunities to participate in the STEM enterprise. "

Lesson III: Technology holds promise for creating equitable learning environments, but it also alters the skills we need in the future, and changes what and how we teach.

1. Preparing learners of all ages to **work actively with technology** and other contemporary tools of science and mathematics, as technology will continuously change the nature of work and STEM.

2. Technology's promise to **provide tools to improve research, teaching, and learning**.

Making Change Happen: Examples to Inspire

- **Sean Tvelia,** Professor of Geology and Chair of Department of Physical Sciences
  Suffolk County Community College

- **Leslie A. Gregg-Jolly,** Professor of Biology
  Grinnell College

- **Micki Meyer,** Assistant Vice President for Student Affairs and Community
  Rollins College

- **Emily Miller,** Deputy Vice President for Institutional Policy
  Association of American Universities

Commentator:

- **Yves Salomon-Fernández**, Senior Vice President for Operations Planning
  Southern New Hampshire University

Break out Session

2:25-2:45pm ET
Break Out Groups

- Introductions (5 minutes)
- Reflect on the ideas you heard today
  What is the most powerful thing that you can do next? (15 minutes)

2:50-3:00pm ET
Reconvene in the main room.

- Everyone is invited to share (in the chat) the most powerful idea you heard from somebody else and/or what you will be doing next to create change.

Upcoming Event

Roundtable on Systemic Change in Undergraduate STEM Education, Spring 2022

Monday, May 23 from 10am–3:45pm ET

Join us as we explore the changing landscape of the workplace and workforce!