Type them into questions box!

“Why am I muted?”
Don’t worry. Everyone is muted except the presenter and host.
Thank you and enjoy the show.

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ACS Scholars Endowment Founder Joe Vacca, retired Vice President of Chemistry, Merck & Co, meets with his 2018 ACS Scholar Johanna Masterson, now a grad student at Princeton University.

“Chemistry has been good to me...so I wanted to make a significant gift to provide that opportunity to others.”
ACS & Cargill Article on Sustainability

How does the chemical industry contribute to planetary sustainability?

Check out this article from ACS Industry Matters and discover the way Cargill uses chemistry to tackle the challenge of feeding more people with less land.

Florian Schattenmann,
CTO and VP of R&D at Cargill

www.acs.org/Cargill

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Last Webinar of the Year of 2020

Thursday, December 17, 2020 at 2-3pm ET
Speakers: Victor McElroy, National Science Board and University of the District of Columbia and Barbara Sawrey, ACS Board of Directors and UC San Diego

What You Will Learn

- How America can continue to lead in fundamental research
- How can American discoveries continue to empower U.S. businesses and entrepreneurs to succeed globally
- How can the U.S. increase STEM skills and opportunities for all Americans
- How does ACS and the chemistry enterprise fit into these questions

Co-produced with: ACS External Affairs & Communications and the National Science Board

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Systems Thinking in Chemistry Education: Preparing Global Citizens for a Sustainable Future

Presentation slides are available now! The edited recording will be made available as soon as possible.

www.acs.org/acswlabinars

This ACS Webinar is co-produced with the ACS Green Chemistry Institute.
What a systems thinking approach looks like in chemistry education: its essential characteristics and the benefits of its use

How a systems thinking approach extends and differs from context-based approaches to chemistry teaching and learning

How a systems thinking approach can prepare students to become global citizens capable of taking informed action to support planetary sustainability
CONTEXT-BASED TEACHING AND LEARNING

Motivates students to learn science
Promotes ability to see connections between chemistry and their everyday world
Promotes long-term retention of knowledge

Illustration by Dan Bright, in https://edu.rsc.org/feature/putting-chemistry-in-context/2000106.article
Fritz Haber was a German chemist who received the Nobel Prize in Chemistry in 1918 for his invention of the Haber-Bosch process, the method used in industry to synthesize ammonia from nitrogen and hydrogen gases.

\[
\text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g)
\]

Scientists discover greener method to produce ammonia

Agriculture's hunger for nitrogen oversteps planetary boundaries


https://visibleearth.nasa.gov/images/52827/red-tide-long-florida-panhandle/52838
Systems Thinking

“an approach for examining and addressing complex behaviors and phenomena from a more holistic perspective” (Orgill et al., 2019, p. 2720)

An IUPAC Project
2017 - 2020

Systems Thinking in Chemistry Education (STICE)

How might systems thinking apply to Chem Ed, and how can that help the next generation address emerging global challenges?


Benefits of Systems Thinking

Promotes learning of chemistry content
- More meaningful learning
- Increased retention of content
- Increased motivation to learn science

Develops the knowledge and skills needed for reasoning about chemical phenomena
- Improved question asking abilities
- Improved critical thinking and problem-solving skills

Prepares students to understand and address complex, real-world problems in order to promote planetary sustainability
- Increased abilities to see connections between chemistry and other disciplines
- Increased abilities to transfer knowledge and skills from one problem situation to another
- Increased sense of ability to effect change in the world around a student
York, S.; Orgill, M. ChEMIST Table: A tool for designing or modifying instruction for a systems thinking approach in chemistry education. *J. Chem. Educ.* 2020, 97 (8), 2114-2129; DOI: 10.1021/acs.jchemed.0c00382.

Icons from C&E News Cover Story, Volume 98, Issue 5
Which benefit of systems thinking do you think is MOST important for helping students become global citizens who promote a sustainable future?

- Increased retention of chemistry content
- Increased motivation to learn science
- Improved critical thinking and problem solving skills
- Increased abilities to see connections between chemistry and other disciplines
- Increased ability to transfer knowledge and skills to new situations
SYSTEMS THINKING

Recognizes a system as a whole not just a collection of parts

Examines relationships among the parts of a system

Examines how system behaviors change over time

Identifies interactions between a system and its environment, including with humans.

Identifies variables that cause system behaviors

Icons from C&E News Cover Story, Volume 98, Issue 5

\[ \text{H}_2(g) + \text{N}_2(g) \rightarrow \text{NH}_3, \text{Ammonia} \]

Core reaction

Fossil fuels

Energy subsystem

Chemical inputs subsystem

Intermediates & products subsystem

Materials subsystem

Atmospheric impacts subsystem

Biodiversity impacts subsystem

Soil and agricultural impacts subsystem

NH\textsubscript{3} uses subsystem

Reaction conditions subsystem

Fertilizer commercial refrigerant, molecular energy carrier

Interactions between a system and its environment, including with humans.

Variables that cause system behaviors

System behaviors change over time

Relationships among the parts of a system

Interactions between a system and its environment, including with humans.

Variables that cause system behaviors

System behaviors change over time

Relationships among the parts of a system

Near fertilizers, explosives, organic nitrogen compounds (plastics, resins, glues pesticides, pharmaceuticals)

Terrestrial, fresh and marine ecosystems

Agricultural productivity, food security, soil fertility, microbial life

Fertilizer commercial refrigerant, molecular energy carrier

NH\textsubscript{3} uses subsystem

Reaction conditions subsystem

High T, High P

Equilibrium considerations

Catalysis

Energy subsystem

Chemical inputs subsystem

Intermediates & products subsystem

Materials subsystem

Atmospheric impacts subsystem

Troposphere – GHG warming Stratospheric O\textsubscript{3} depletion

Nitrous oxide

Aquatic impacts subsystem

Eutrophication, anoxia, dead zones

Fossil fuels

Air

H\textsubscript{2}, N\textsubscript{2}
Systems Thinking is identified as one of 5 key competencies as essential for a sustainable future*

UN Sustainable Development Goals

169 targets require strategies based on consideration of systems rooted in the flow of materials and energy: Fundamental chemistry at the heart


Planetary Boundaries Framework

The Molecular/Material Basis of Sustainability

- The flow of material and energy is integral to all aspects of society and the environment.
- Chemistry understands and controls matter through analyzing, synthesizing, and transforming substances.
- Chemistry education has a special responsibility to address the sustainability of earth and societal systems.
- Molecular basis of sustainability: “The ways in which the material basis of society and economy underlie considerations of how present and future generations can live within the limits of the natural world.”
- MBOS: Important, but largely invisible aspect of both sustainability agendas and our chemistry courses!

Anastas, P. T., Zimmerman, J. B. The molecular basis of sustainability. Chem 2016, 1, 10–12


Anna Pattison
King’s University
Where do you think ammonia and reactive N best fits into the 1st year post-secondary chemistry curriculum?

- Equilibrium and kinetics
- Thermochemistry
- Structure and bonding
- Main group chemistry
- All of the above
H₂ for NH₃ presently mostly produced from CH₄ (steam reforming/water-gas shift)

80% of the cost of NH₃ is the cost of natural gas

Price spikes have implications for food security and political unrest
Global prices of fossil fuels, fertilizers, and food are linked
80% of the cost of NH$_3$ is the cost of natural gas


I thought $H_2$ was a colorless gas....

And those variables that color $H_2$ influence the sustainability of the ammonia we use to feed the world, keep food cold, and develop a promising low carbon molecular energy carrier!

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I thought $H_2$ was a colorless gas....

And those variables that color $H_2$ influence the sustainability of the ammonia we use to feed the world, keep food cold, and develop a promising low carbon molecular energy carrier!

**TAKE HOME MESSAGES**

- What a systems thinking approach looks like in chemistry education: its essential characteristics and the benefits of its use
- How a systems thinking approach extends and differs from context-based approaches to chemistry teaching and learning
- How a systems thinking approach can prepare students to become global citizens capable of taking informed action to support planetary sustainability
## Additional Resources

### Want to know more about systems thinking?


- York, S.; Orgill, M. *ChEMIST Table: A tool for designing or modifying instruction for a systems thinking approach in chemistry education*. *J. Chem. Educ.* **2020**, *97* (8), 2114-2129; DOI: 10.1021/acs.jchemed.0c00382.


- References and outcomes from IUPAC Global Systems Thinking in Chemistry Education (STICE) Project [https://iupac.org/projects/project-details/?project_nr=2017-010-1-050](https://iupac.org/projects/project-details/?project_nr=2017-010-1-050)

### Want to know more about systems thinking and sustainability?


- King’s Centre for Visualization in Science (KCVS). Planetary Boundaries interactive digital learning resource: [planetaryboundaries.kcvs.ca](http://planetaryboundaries.kcvs.ca)

### Want to get involved?

- ACS GCI – Green & Sustainable Chemistry Education Module Development Project: [https://www.acs.org/content/acs/en/greenchemistry/students-educators/module-development.html](https://www.acs.org/content/acs/en/greenchemistry/students-educators/module-development.html)

- New IUPAC Global Project: Systems Thinking in Chemistry for Sustainability: Toward 2030 and Beyond (STCS 2030+) - [https://iupac.org/project/2020-014-3-050](https://iupac.org/project/2020-014-3-050)
  - Strengthen contributions of Chemistry as a Sustainability Science, including engaging with IYBSSD 2022
  - Guiding further development of ST in Chemistry Education
  - Engaging further with chemical industry
IUPAC STICE Project
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Stephen Matlin

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Suzanne Boniface
Robert B. Bucat
Yehudit Judy Dori
Temechegn Engida
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Professor of Chemistry and Director,
King's Centre for Visualization in Science

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Science Director, Green Chemistry Institute, American Chemical Society

ACs Green Chemistry Institute

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