Addressing the Sustainable Development Goals in Schools with Chemistry Education

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Deakin STEM Ed Conference 2021

Elements of Sustainable Chemistry (ESC) eschemistry.org

School of Education, Deakin University, Victoria @delaneysw

Acknowledgement of Country

I join you in this conference today from the lands of the Wurundjeri people, First Nations people and Traditional Custodians of the Country on which I live and work and recognise their continuing connection to land, waters and culture. I pay respect to their Elders past, present and emerging.

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Today's workshop

What we are <u>not</u> doing today

- Hands-on practical activities (so no personal protective equipment required ☺)

What we will cover

- Introduction to systems thinking / integrated learning of chemistry
- Examples of SDGs in Chemistry education
- Mapping SDGs to secondary chemical science topics
- Resources to implement SDG-focused practical activities in schools

Elements of Sustainable Chemistry (ESChemistry.org)

Elements of Sustainable Chemistry

Who we are

- Interdisciplinary, practice-oriented research hub of chemists and chemistry educators

What do we do

- Recognise the **material basis of society** as a core element of sustainability challenges
- Educate about the molecular basis of sustainability using **systems thinking**
- Support teachers with **professional learning**
- **Co-design** T&L activities for classrooms
- Provide systems thinking oriented, **practical activities** that directly address sustainability

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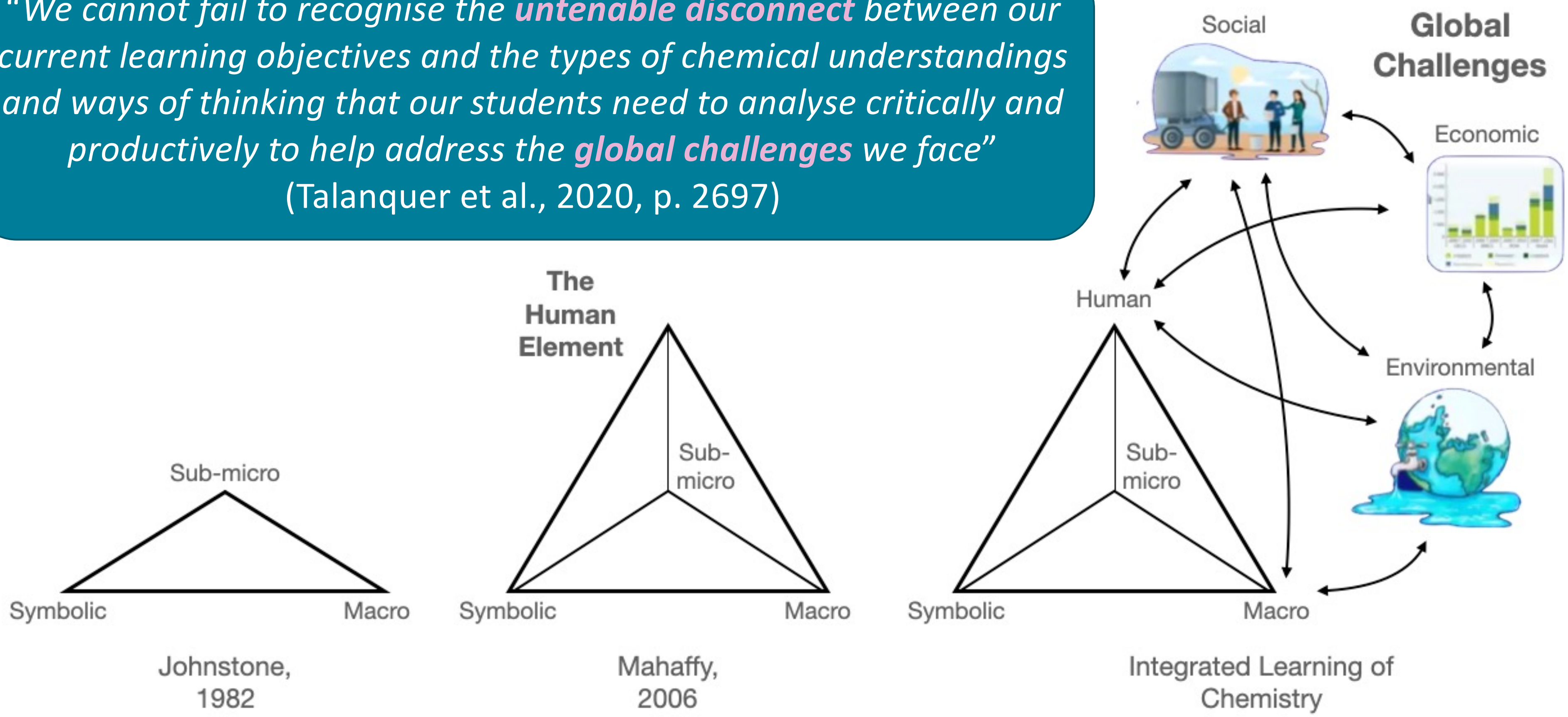
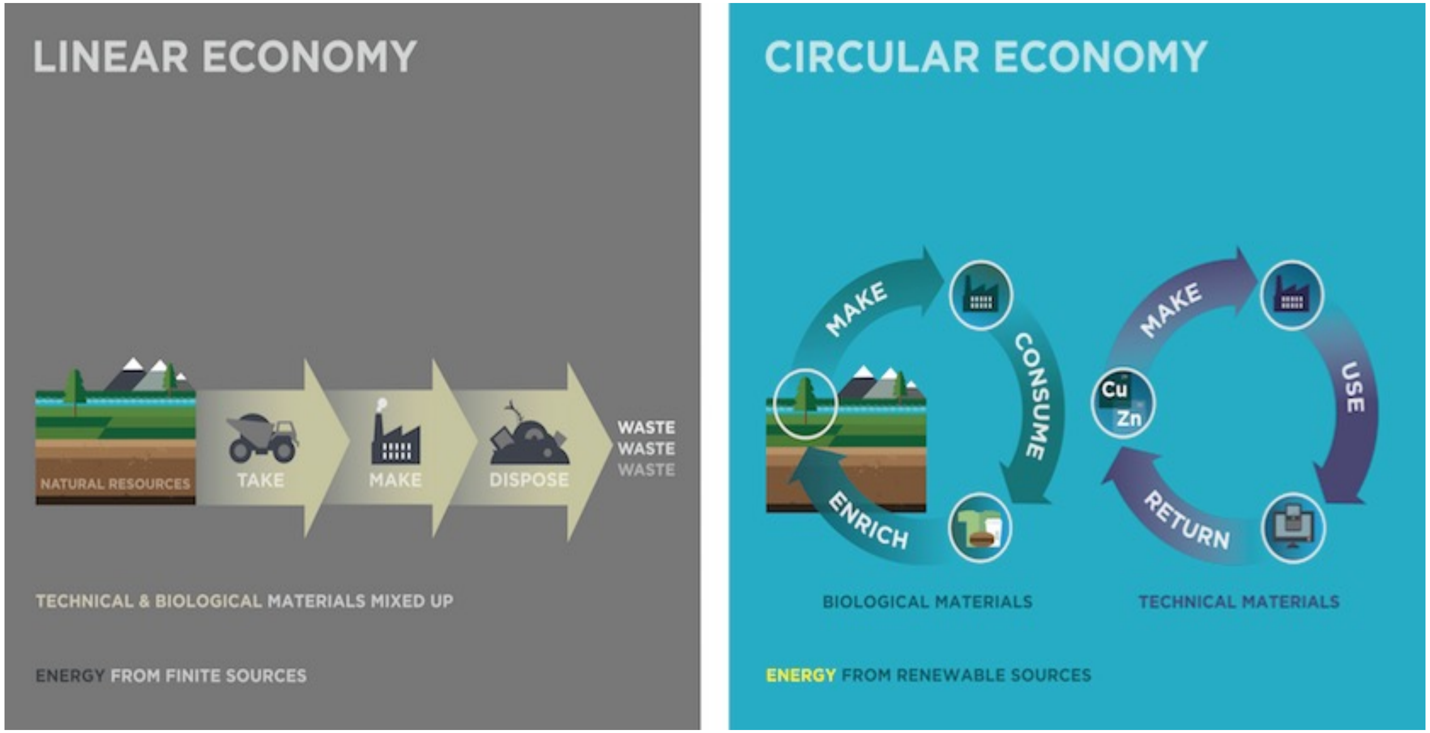
Integrated Learning of Chemistry

"We cannot fail to recognise the ***untenable disconnect*** *between our current learning objectives and the types of chemical understandings and ways of thinking that our students need to analyse critically and productively to help address the* ***global challenges*** *we face"*
(Talanquer et al., 2020, p. 2697)



The Linear and Circular Economy



https://www.ellenmacarthurfoundation.org/our-work/activities/new-plastics-economy

Systems Thinking in Chemistry Education

Recognise the **material basis of society** as a core element in sustainability challenges

Shape the **practice of chemistry** by sustainability science

Re-orient chemistry education to address the sustainability of earth and societal systems

Educate about the **molecular basis of sustainability** using **systems thinking**

Mahaffy, P. G., Matlin, S. A., Whalen, J.M. & Holme, T. A. (2019). Integrating the Molecular Basis of Sustainability into General Chemistry trough Systems Thinking. *Journal of Chemical Education.* 96(12), 2730-2741. Doi: 10.1021/acs.jchemed.9b00390

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Systems Thinking in Chemistry Education

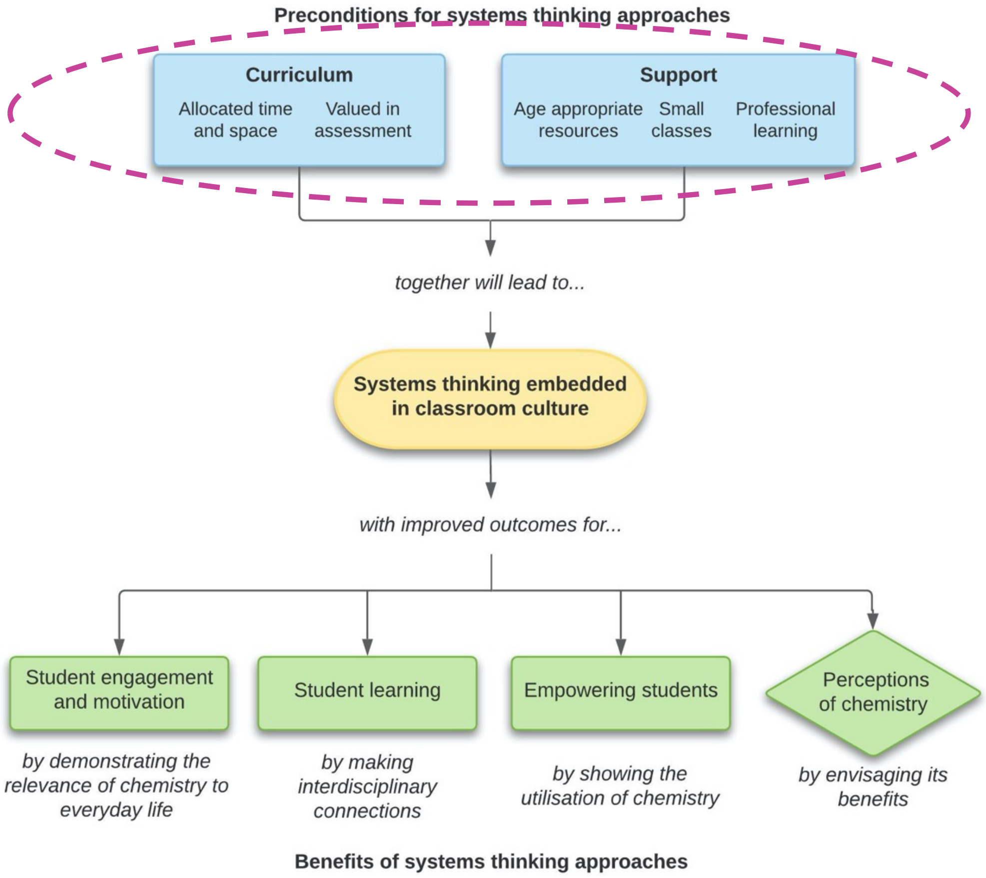
Reductionist / Analytical / Elaborative cognitive processes

- Focussed on the parts
- Bottom-up
- Categorising objects/items
- Field-independent: Focussed on how the properties of an object cause a behaviour/change
- Learning facts in isolation, stepwise approach
- "Active" behaviour in the learner – questioning/dialogue about individual parts of a problem

Systems / Holistic cognitive processes

- Focussed on the whole
- Context-driven
- Interrelationships between objects/items
- Field-dependent: Focussed on how the interaction of object and context results in a change in an object's behaviour
- Learners construct an 'overall picture' before trying to solve a problem
- "Passive" behaviour in the learner – need to put pieces together before approaching the teacher

Embedding systems thinking in the classroom



Embedding systems thinking in classroom culture

- Pre-conditions identified in semi-structured interviews with secondary and tertiary chemistry educators

Delaney, S., Ferguson, J.P. and Schultz, M. (2021). Exploring opportunities to incorporate systems thinking into secondary and tertiary chemistry education through practitioner perspectives, *International Journal of Science Education*, DOI: 10.1080/09500693.2021.1980631

United Nations Global Goals for Sustainable Development (SDGs)

And… as a framework to evaluate the scientific, ethical, social and environmental issues in chemistry contexts

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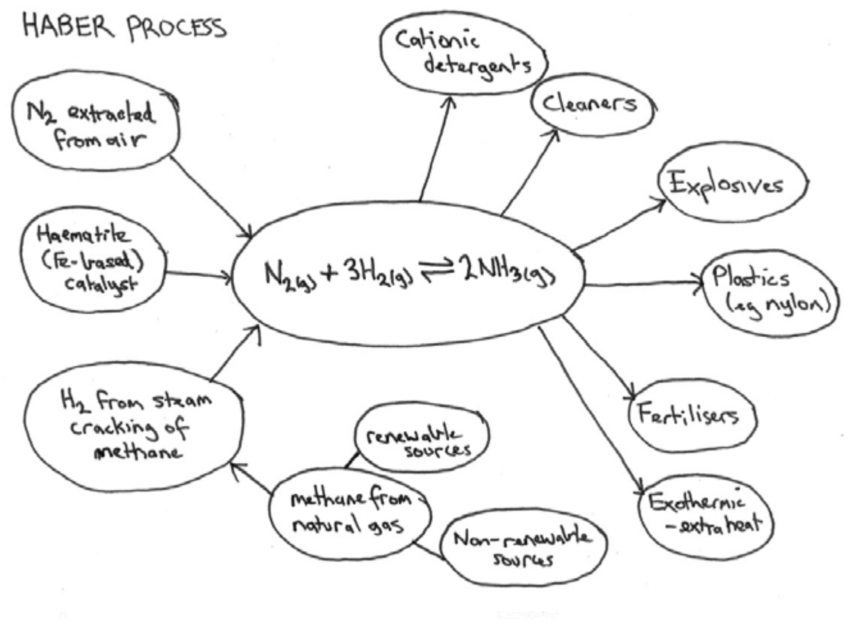
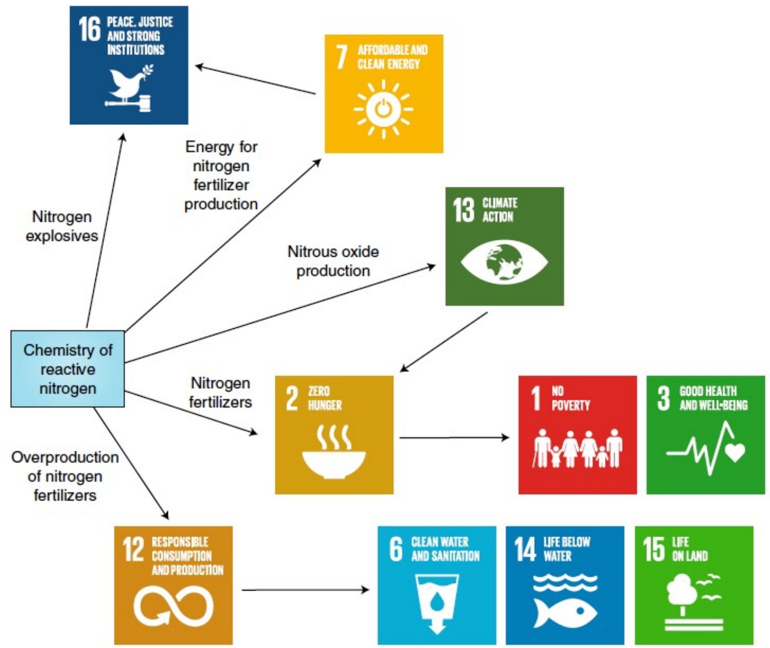
Evaluating systems thinking - Systems Maps





Eaton, A. C., Delaney, S., & Schultz, M. (2019). Situating Sustainable Development within Secondary Chemistry Education via Systems Thinking: A Depth Study Approach. *Journal of Chemical Education*. doi: 10.1021/acs.jchemed.9b00266

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Evaluating systems thinking - Systems Maps

The ”central learning outcome” of chemistry…

“Chemicals have benefits and hazards, and ***these must considered together***” (p. 499)

”… pedagogically essential to consider that the practice of chemistry has both negative and positive impacts” (p. 499)

(Holme and Hutchison, 2018)

Eaton, A. C., Delaney, S., & Schultz, M. (2019). Situating Sustainable Development within Secondary Chemistry Education via Systems Thinking: A Depth Study Approach. *Journal of Chemical Education*. doi: 10.1021/acs.jchemed.9b00266

Holme, T.A, & Hutchison, J. E. (2018). A Central Learning Outcome for the Central Science. *Journal of Chemical Education, 95*, 499-501.

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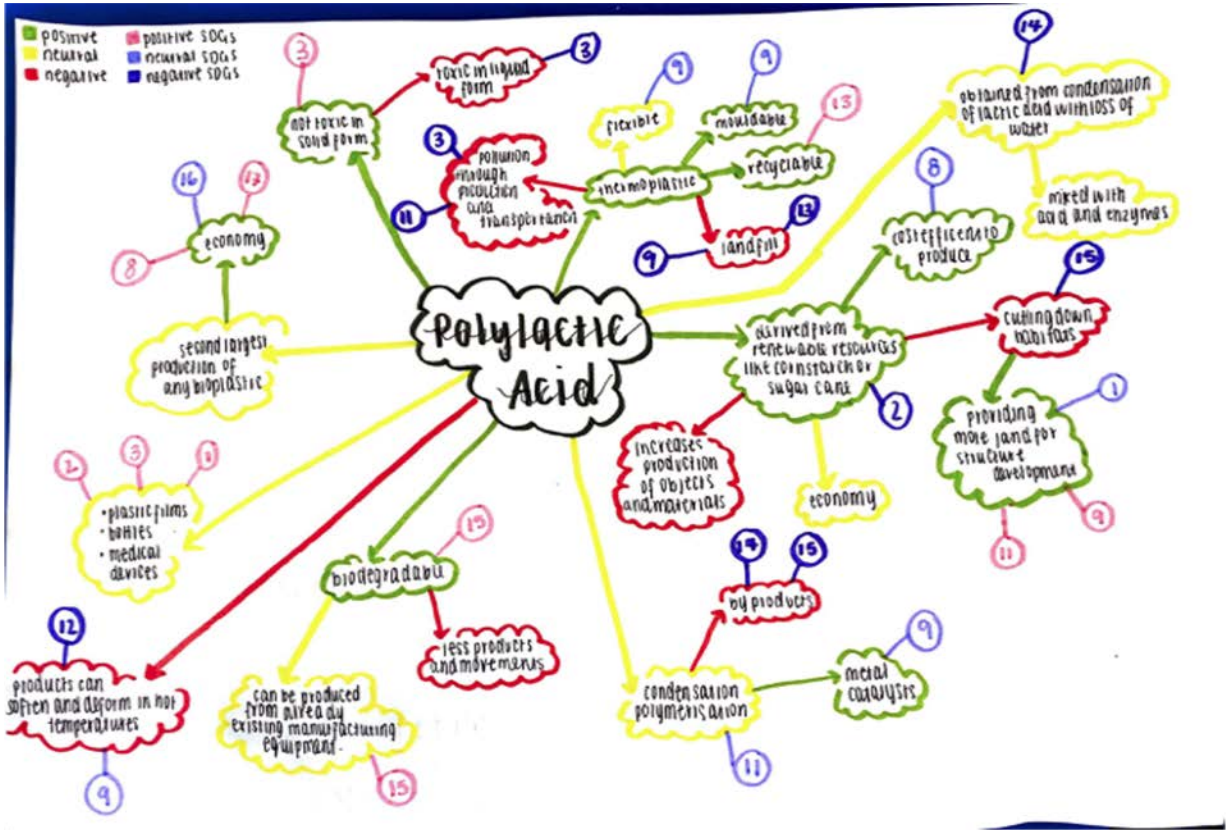

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- Real-world contexts of chemical processes
- Connections to UN Global Goals for Sustainable Development (SDGs)

United Nations Global Goals for Sustainable Development (SDGs)

1. Medicines, local solar energy
2. Improved, adapted agrochemicals
3. Drug design, healthcare products, pollution control
4. Courses in green chemistry and environmental sciences
5. Equal gender chances among chemists
6. Water regeneration and purification
7. Photoelectrochemistry, new batteries
8. Recycling, circular economy, long-living products
9. Research on pure and applied chemistry
10. IUPAC networks to underdeveloped regions

Tundo, P. and Griguol, E. (2018). Green Chemistry for Sustainable Development, *Chemistry International,* 40 (1), 18-24.

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United Nations Global Goals for Sustainable Development (SDGs)

11. Novel materials for buildings, bridges, streets, cultural heritage conservation
12. Sustainable manufactures and waste minimization
13. Innovative solar energy systems
14. Marine chemistry
15. Sustainable use of fossils and forests, renewable resource exploitation
16. Support to the Organization for the Prohibition of Chemical Weapons (OPCW)-goals
17. Cooperation with UN, OECD, OPCW, UNESCO and other scientific organizations

Tundo, P. and Griguol, E. (2018). Green Chemistry for Sustainable Development, *Chemistry International,* 40 (1), 18-24.

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United Nations Global Goals for Sustainable Development (SDGs)

- *How can chemistry help society achieve this sustainable development goal?*
- *How could teachers and students learn and contribute to achieving this goal in the chemistry classroom, VCE or lower secondary*

Shared google doc link with suggestions made by participants from previous conferences

- https://bit.ly/2YQhuXC

- We'll keep it live afterwards – feel free to come back to it

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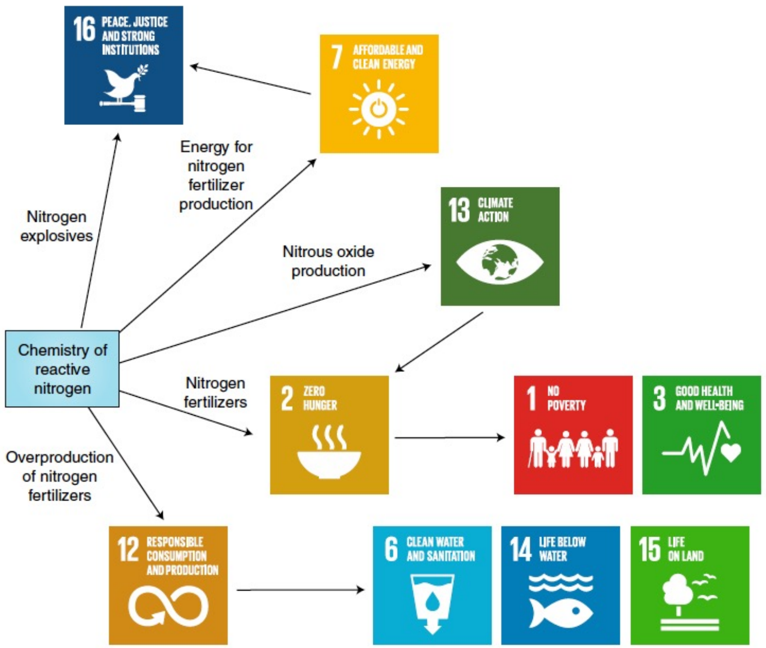
Let’s have a go ourselves



Plastics

https://bit.ly/3AJRqej

Fertilisers

https://bit.ly/3LL5sJ5

Concrete

https://bit.ly/3FLA3OF

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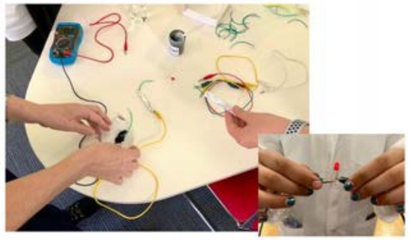
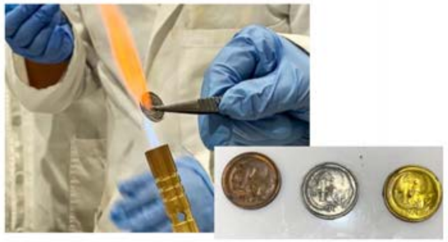
Systems thinking-oriented practical activities



Making an aluminium-air battery



Turning copper coins 'silver' and 'gold'

Copper crystals growing on aluminium sheet

Carbon rod electrolytic writing

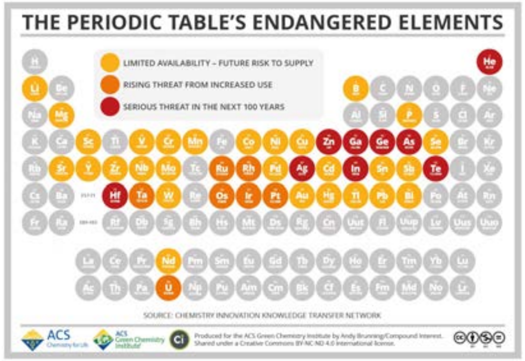
Periodic Table element sort and gallium

Iodine writing and fingerprints

Practical activities highlighting endangered elements

All resources available on website – eschemistry.org

- Zinc, copper, aluminium, gallium, iodine and others



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United Nations Educational, Scientific and Cultural Organization

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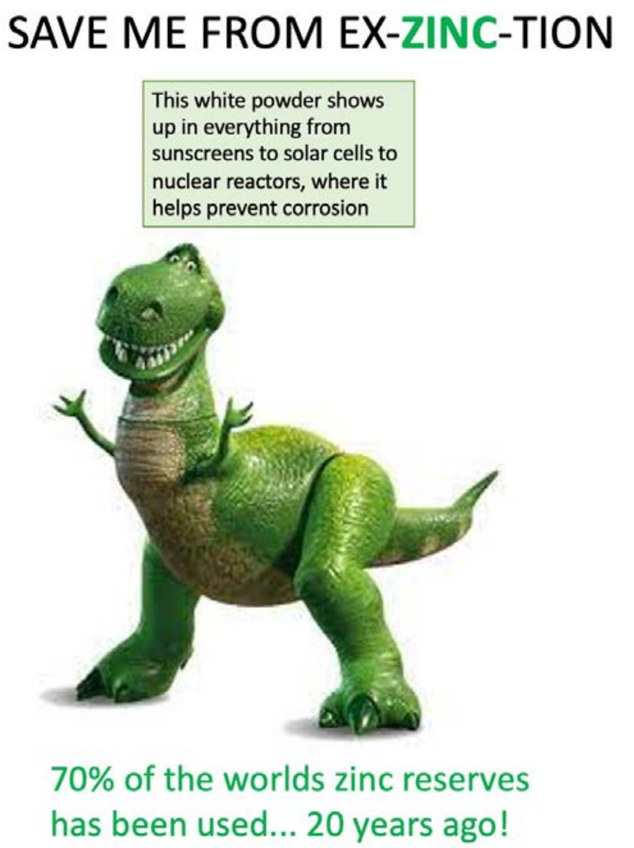
Endangered Elements poster



Endangered Elements Poster

- **Why** are they considered 'endangered'?
- **Where** and **What** are they sourced from?
- **What** are they used for?
- **So what** can we do about it?

- Link three **Sustainable Development Goals (SDGs)** to how these elements to meeting 21st century challenges

Systems thinking-oriented practical activities

Practical activities highlighting elements

All resources available on website – eschemistry.org

- Mini-thermite reaction - Energy in/out from aluminium processing
  - 3% of global electrical supply used to extract aluminium
  - **Recycling** aluminium uses only 5% of the energy requirements to make new aluminium

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Australian National Commission for UNESCO

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Systems thinking-oriented practical activities

Sustainable Concrete

- Co-designed with researchers from Institute for Frontier Materials, Deakin
- Guided inquiry control of variables (COV) investigation for secondary schools

- Cementous material alternatives
- Fine aggregate alternatives to river sand
- Coarse aggregate alternatives (incl. recycled materials)
- Options for water source

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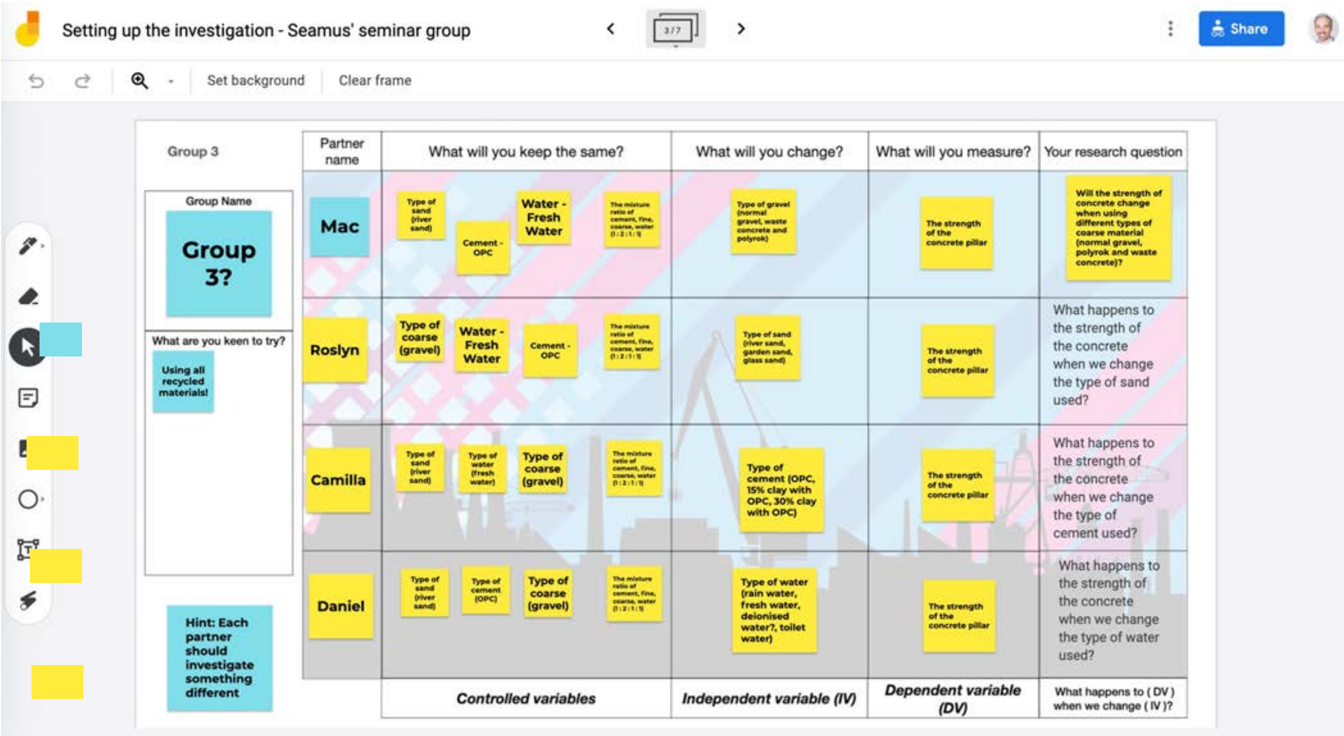
Systems thinking-oriented practical activities

Sustainable Concrete



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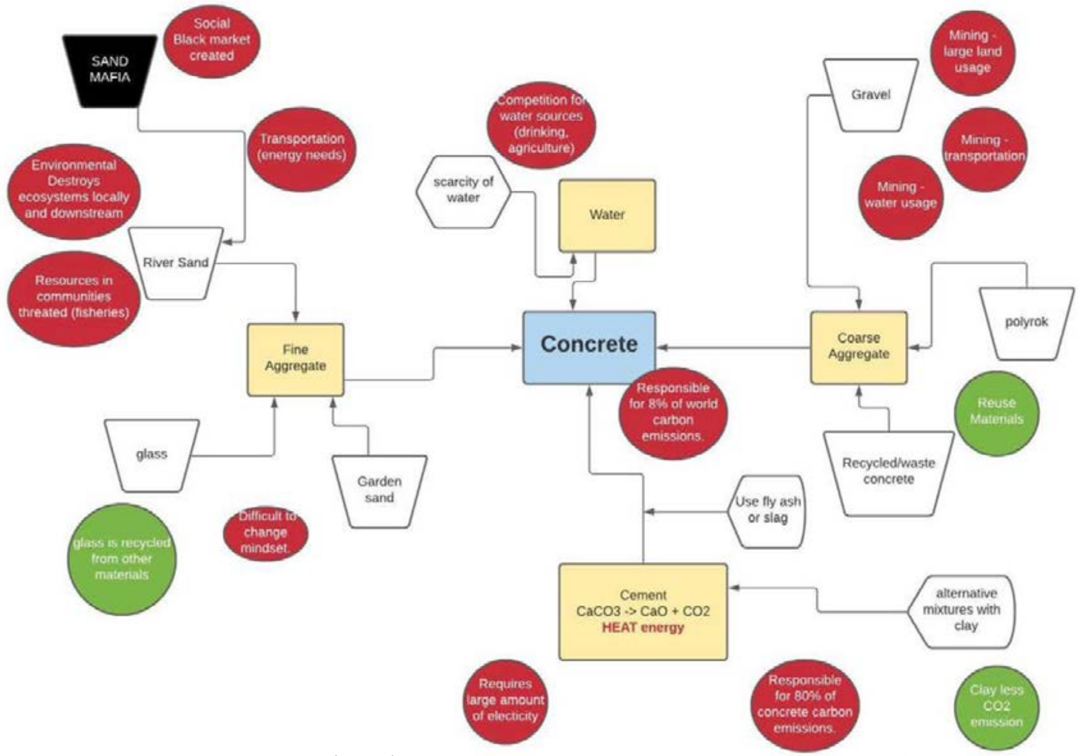
Systems thinking-oriented practical activities

Sustainable Concrete



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Systems thinking-oriented practical activities

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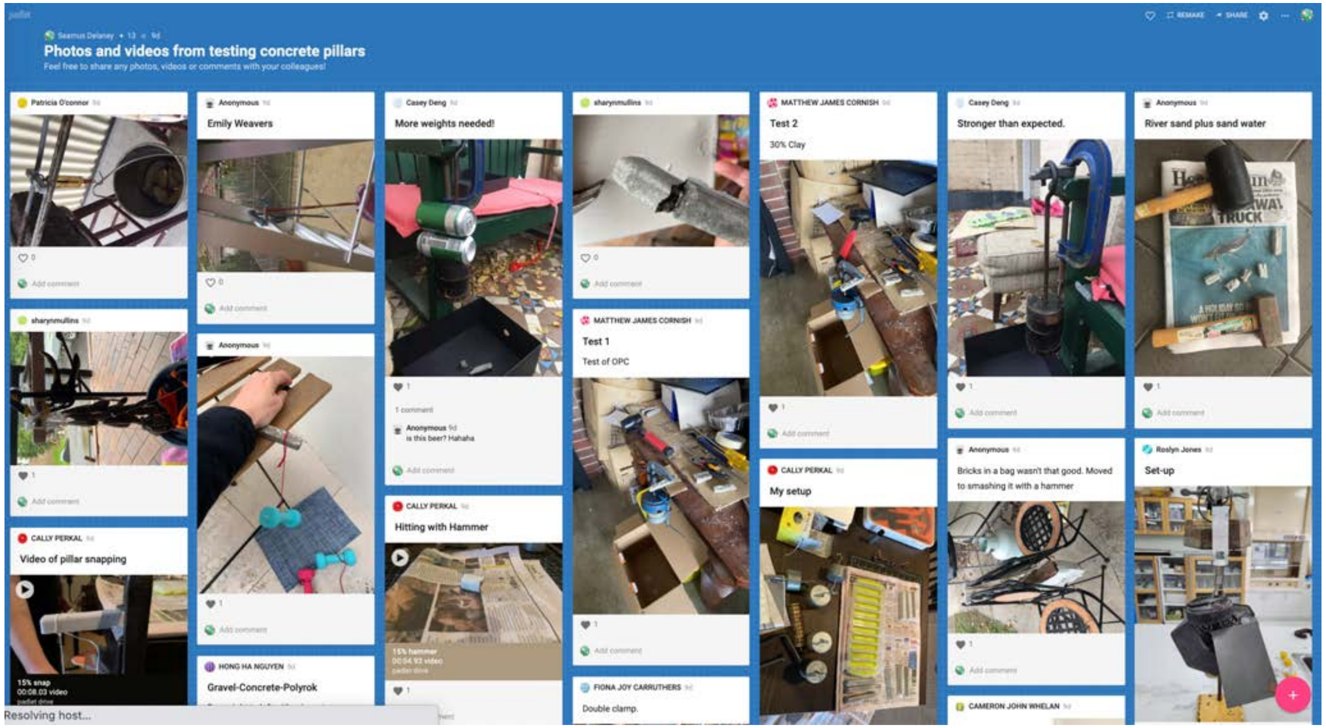

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Systems thinking-oriented practical activities

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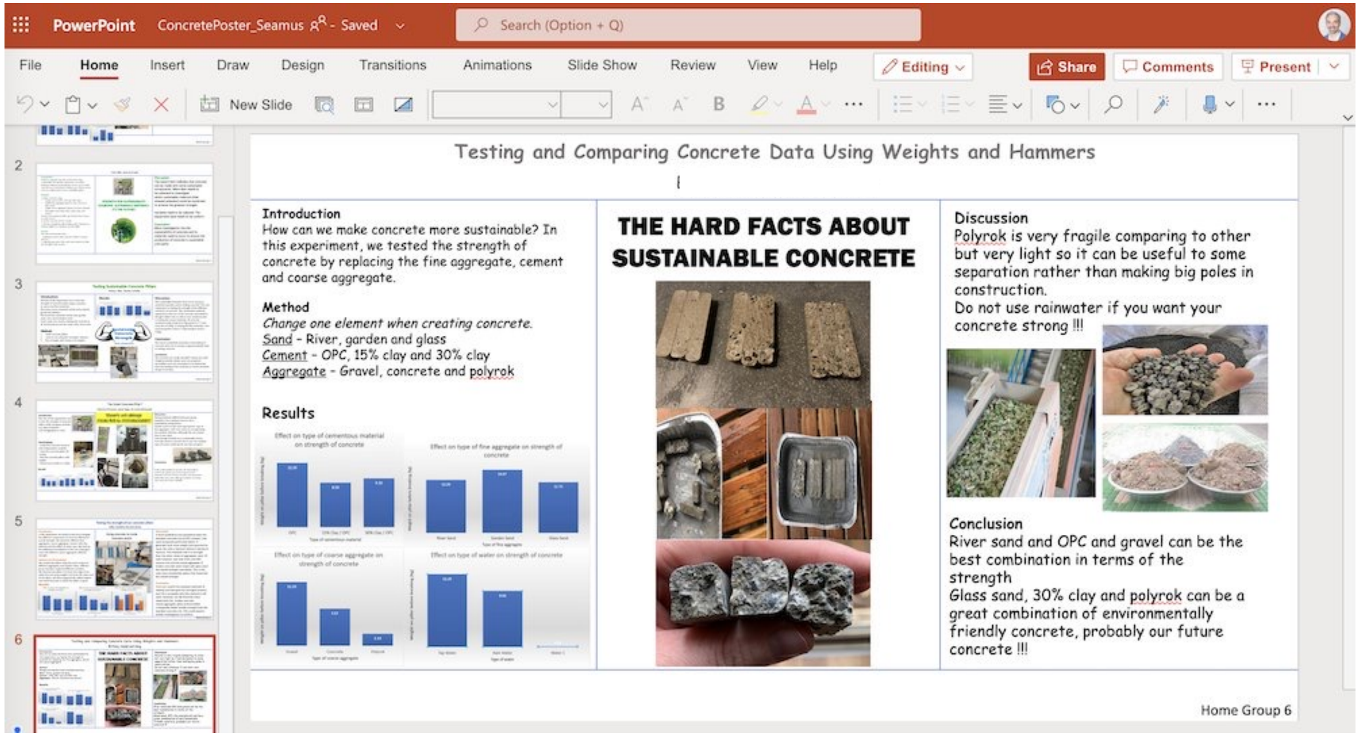

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Systems thinking-oriented practical activities

Practical activities highlighting future energy/living challenges

Future STEM Gen project

- Local energy for global futures (dye-sensitised solar cells, bio-algae)
- Smart gardens
- Water filtration (primary science)

https://www.futurestemgen.education/

Systems thinking-oriented practical activities

Authentic real-world contexts with practical activities

- Longer, group- or class-based ‘design’ projects
- Teachers might ask the ‘question’ but potential for students develop the problem

Resources for design-based practical activities

- Beyond Benign
  - https://www.beyondbenign.org/
- National Science Foundation Centre for Sustainable polymers
  - https://csp.umn.edu/labs/

beyondbenign
green chemistry education

NSF Center for
Sustainable Polymers

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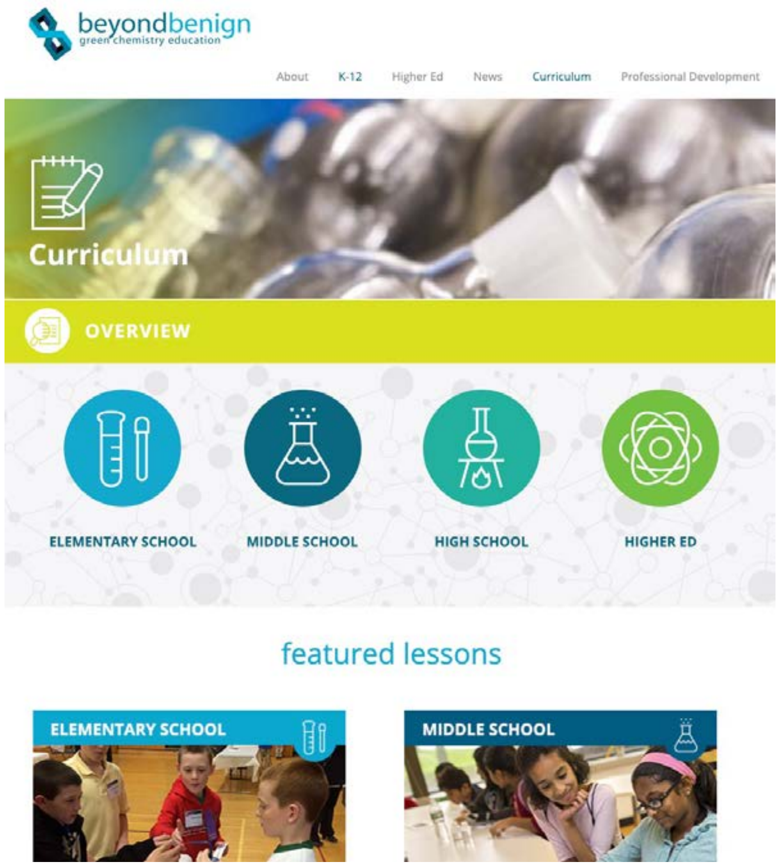
Systems thinking-oriented practical activities

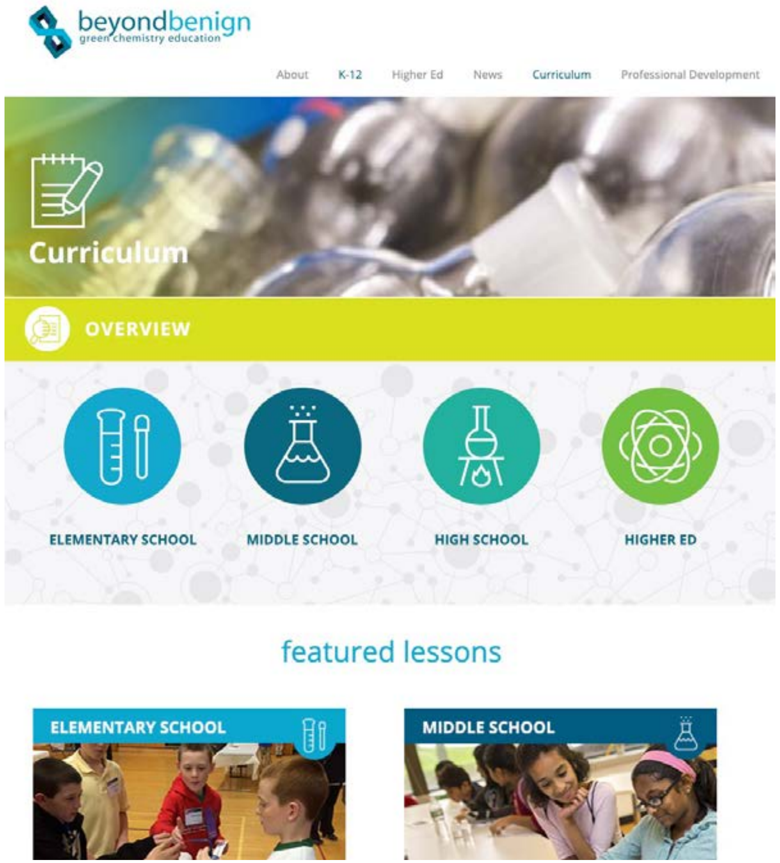


beyondbenign
green chemistry education

Lots of great teacher/student resources for different year levels (K-12) and topics

- US-based, so curriculum links are USA
- Open-source, Creative Commons
- MS Word documents

Systems thinking-oriented practical activities



beyondbenign
green chemistry education

Some of my design/system thinking favourites

- Life cycle analysis of polystyrene and mushroom-based (mycelium) packaging materials
- Recycling polylactic acid
- ‘Sharklet’ anti-microbial surfaces

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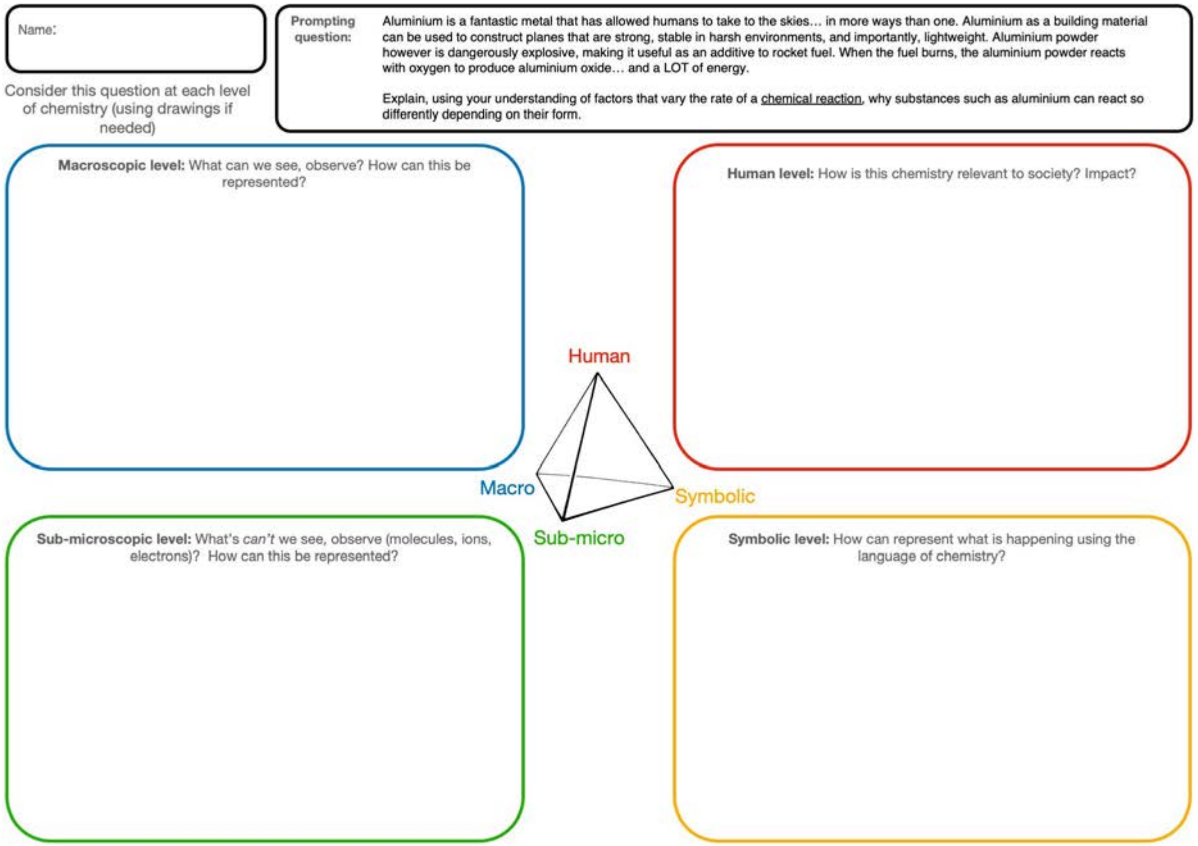
Humanising Chemistry Education



- Drawing **conceptual connections** across the four levels of chemistry
  - Macro
  - Sub-micro
  - Symbolic
  - **Human**

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Acknowledgements

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Mary-Kay Orgill (University of Nevada, Las Vegas)

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