Developing a Learning Progression Framework for Sustainability of Corn and Fuel Production Systems

Elizabeth de los Santos, Sarah Stapleton, and Andy Anderson *Curriculum, Instruction, & Teacher Education, Michigan State University, East Lansing, MI*

Purpose

Our research aims to develop an initial learning progression framework for sustainability of corn and fuel production systems. We conducted semi-structured interviews with 33 middle and high school students and engaged in an iterative process of data analysis to identify the progress variables and levels in the learning progression framework.

Interview Protocol

Example Questions:

- What is similar and different about the production systems?
- Where does the corn/fuel come from? What happens to it as it is used? After it is used?
- Which is most sustainable, and why? What do you think "sustainable" means?

Visual Prompts

Small-scale community garden

Large-scale industrial corn

Native American "Three Sisters" method of growing corn, beans, and squash together

Gasoline

Ethanol

Electricity

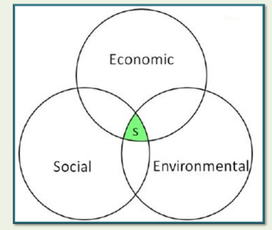
Next Generation Science Standards

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

	Life Cycle Comparisons of Production Systems	**Cost-Benefit Analysis	Scale: Population/ Spatial	Scale: Temporal	Considering Uncertainty: Preparation for Future Learning
***High-Level Responses ~ 10% of sample**	Traces matter and energy through economic and environmental systems • Identifies basic components of the production systems and traces matter and energy through them at atomic-molecular scales	Analysis based on comparing costs or risks and benefits of different systems • Considers more than one cost or benefit and more than one domain • Considers balances between costs and benefits • Connects across domains and systems	Considers scale issues relevant for sustainability • Over wide populations of people • Or requiring large-scale land /infrastructural requirements.	Considers social, environmental, or economic effects over long-term time scales • Considers most important temporal sustainability concerns (e.g. carbon emissions for fuels)	Identifies specific and sustainability-relevant questions • Identifies specific questions that are searchable • Identifies strategic questions that extend their knowledge
Intermediate-Level Responses ~ 50% of sample	Traces sequences of steps leading to a product • Identifies basic components of the production systems and connects them with mechanisms	Analysis based on single attributes of different systems • Define sustainability using one objective • Identifies costs or risks and benefits	Considers sustainability effects • Over smaller populations or regional/local scales • Or over wider scales without relevance to sustainability	Considers the finiteness of resources but not their impacts over time • May only discuss renewable vs. nonrenewable	Identifies specific questions that are not necessarily relevant for sustainability • Expresses uncertainty and identifies specific but not strategic questions
Low-Level Responses ~ 40% of sample	Has limited understanding of the production systems • Identifies basic components • Does not identify mechanisms, or identifies mechanisms with limited details	Broad analysis without mechanisms • Defines sustainability in terms of dichotomies such as good/bad, natural/unnatural, or healthy/unhealthy.	Reasons at the local or individual level • Does not consider issues of population or spatial scale	Reasons for the present • Does not consider long-term issues of supply or effects	Expresses uncertainty without a plan for resolution • Expresses uncertainty about their knowledge but does not identify strategies for resolving it

*Student responses showed better understanding of the production systems for corn than they did for fuel: most students were at the middle level for corn whereas most students were at the low level for fuel.

**We use the GLBRC conception of sustainability as the intersection of economic, social, and environmental concerns.



Examples of Student Responses for Corn and Fuel Production Systems

Life cycle comparisons of production systems

- [Plants need] sun, water, dirt, or specialized soil – that's pretty much all I can think of. *(Low, MS)*

Cost-benefit analysis

- I think that just a community garden would be more sustainable just because there's less I think pesticides and fertilizers that go into it. It just seems like it would just keep the soil healthier and just more natural, I guess. *(Low, HS)*
- For the electric vehicle, it depends on where it's getting its power from. If it's getting it from a sustainable source, I would rank this number one. Electric vehicles also have the issue of making them because I think they come from rare materials… you have to mine for them. *(High, HS)*

Reasoning across scales

- **Temporal**: I guess sustainability is doing actions that can help us still survive and have happy lives without jeopardizing future generations. So, using coal isn't sustainable because we're going to use up those supplies, and we're going to cause more global warming, and that will make it a lot harder for future generations. (*High, HS*)
- **Population/spatial:** I think that we provide enough food—I mean, we don't provide enough food, but we have enough food to feed the entire population, but our distribution methods are not on par with what they need to be to actually get this food to people. (*High, HS*)

Considering uncertainty/preparation for future learning

- I'm not really sure what the benefit of growing beans, corns and squash together is, or if that's any better than anything else. So I'm not really sure about that. (*Low, HS*)
- I'm torn between ethanol and electric because I would have to do more… I'd definitely look more into it, but I'm not really sure how efficient ethanol is. As a bio-fuel it sounds like a good idea but growing it might take like a lot more energy than is worth getting out of it. So I don't know. I'd have to look into the sources for ethanol. (*High, HS*)

Implications

Based on our research, we recommend that sustainability curricula include the following components:

- *Life cycle comparisons of production systems*: Addressing all stages of product life cycles, including environmental effects.
- *Cost-benefit analysis*: Weighing costs and benefits in more than one domain, including consideration of sustainability as the intersection of social, economic, and environmental concerns.
- *Spatial, population, and temporal scales*: Considering issues of spatial scale (could we do this everywhere?), population scale (could everyone do this?), and temporal scale (for how long could we do this?).
- *Considering uncertainty, Preparation for future learning*: Developing strategies for how to seek relevant and specific information about aspects of sustainability that are unknown to students.

Next Steps

1. Develop valid and reliable written assessment items.
2. Revise the interview protocol and refine the learning progression framework, particularly with regard to *scale* and *considering uncertainty*.
3. Develop decision-making teaching modules for the Carbon TIME curriculum.

Contact Information:
Elizabeth de los Santos, delossa9@msu.edu

Support for this research comes from the Great Lakes Bioenergy Research Center, funded by the United States Department of Energy, and from Place-based Opportunities for Sustainable Outcomes and High-hopes, funded by the United States Department of Agriculture. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the United States Department of Energy, or the United States Department of Agriculture.