Undergraduate Students’ Scientifically-Informed Decision-Making about Water-Based Socioscientific Issues

Jaime Sabel[1], Tina Vo[1], Ashley Alred[2], Jenny Dauer[2], Cory Forbes[1,2]

University of Nebraska-Lincoln

[1]Department of Teaching, Learning, and Teacher Education

[2]School of Natural Resources

INTRODUCTION

- Contemporary societies face an array of global challenges: population growth, food production, natural resource use, and environmental degradation.
- These kinds of socioscientific issues (SSIs) provide a strong rationale for the importance of an emphasis on systemic science education efforts aimed at cultivating a scientifically literate populous , including those at the post-secondary level (National Research Council, 2012).
- Water resource use and management is one critical SSI in the twenty-first century, sometimes referred to as the “Water Century”.
- Research has illustrated gaps in students’ knowledge of core hydrologic concepts (Forbes, Zangori, & Schwarz, 2015; Covitt, Gunckel, & Anderson, 2009; Halvorson & Wescoat, 2002) and epistemic dimensions of science (NOS; Lederman, 2007) across the K-16 continuum.
- To make decisions about how and by whom water should be utilized, individuals must confront the social, economic, legal, and political dimensions of water-based SSIs as well as their scientific dimensions.
- More work is needed to understand the structure of decision-making about SSIs, particularly among undergraduate students who will be tomorrow’s global citizens.
- To begin to address this gap in the literature, we investigate undergraduate students’ SSI decision-making, as well as how they leverage resources to make decisions about water-related SSIs.

FRAMEWORK

Science Literacy

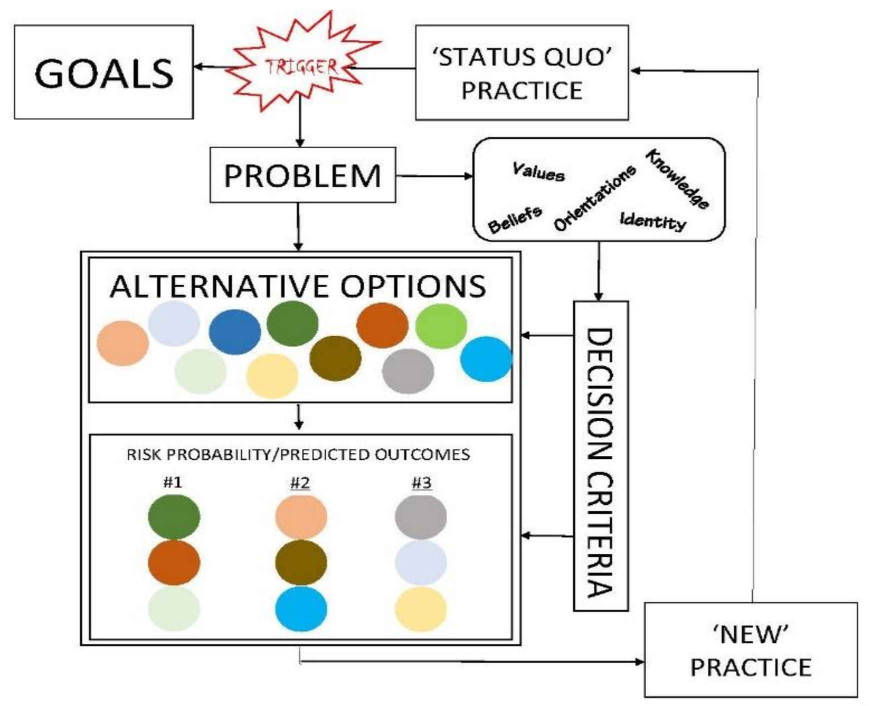
- Leveraging contemporary perspectives in the field (e.g., Bybee, McCrae, Laurie, 2009; Feinstein, 2010; Rudolph, 2014) and work from decision science (Arvai, Campbell, Baird, & Rivers, 2004), we define science literacy as:

  an enhanced capacity, both at the individual and collective levels, to make effective decisions grounded in STEM-informed analyses of complex, real-world challenges.

Multi-criteria Decision Making (MCDM)

- Drawn from work from the decision sciences (Arvai et al., 2004) and the STEM education community (Halverson et al., 2009; Sadler & Zeidler, 2005).
- Involves weighing multiple options based on a complex set of interacting criteria.
- Accounts for how decisions about complex issues with many interrelated dimensions are made over periods of time.

Generalized Model of MCDM



METHODS

- 201 primarily first-year undergraduate students
- Required, introductory course focused on local issues related to agriculture and the environment
- Students completed an assignment focused on a water-based SSI: the use of groundwater from aquifers for agricultural irrigation
  (1) Write a one-sentence statement of what you value that is relevant to this issue. Explain how it is relevant.
  (2) Using both your statement of value and the scientific information in the articles you’ve read or we’ve discussed in class, answer the following: What is your opinion about whether or not we should restrict the amount of water used for agricultural irrigation in [our state]? Why?
  (3) What would someone who disagrees with you say about whether or not we should restrict the amount of water used for agricultural irrigation in Nebraska?
  (4) How would you address these arguments from someone who disagrees with you? Identify the best counter-argument.
- Assignments scored with rubric designed for the project
  - Each dimension scored on a four point scale from 0-3.
  - R1: decision students were asked to make regarding the issue of restricting the amount of water used for agricultural irrigation.
  - R2: objective criteria students included for both correctness and relevance.
  - R3: subjective criteria students included and focused on the degree to which they included reasoning to support their subjective statements.
  - R4: consistency in the decision and support throughout all the assignment answers.
- 15 students participated in semi-structured interviews that focused on their content knowledge about water and their opinions and decision making about water resource management.
  - Interviews coded with a priori codes: Making decisions, Forming opinions, Using/seeking out scientific information, Voting rationale

FINDINGS

Research Question 1: What aspects of the decision-making were students able to engage in most effectively when they considered water-based SSIs?

- Students achieved higher scores, on average, for clearly stating an overall decision than they scored for including objective criteria or supporting their subjective statements (Table 1).
  - More students posed a clearly defined decision with strongly aligned support and no contradictions than students who did not (R1, Table 1)
  - Students infrequently included correct and relevant objective statements throughout the decision (R2, Table 1)
  - Students scored significantly higher on stating an overall decision than they did on any of the rubric items (Table 2)
  - Students scored significantly higher on consistency of the message throughout their answers than they did on including objective criteria or rationale for subjective criteria (Table 2)

Table 1
Rubric Item Descriptive Statistics

Rubric Item	Mean	Mode	Standard Deviation	Obtained Score Range
R1 (overall decision)	2.18	3	0.06	0-3
R2 (objective criteria)	1.74	2	0.06	0-3
R3 (subjective criteria)	1.69	2	0.06	0-3
R4 (consistency)	1.87	2	0.05	0-3

Table 2
Score Differences on Rubric Items

Rubric Item	Rubric Item	df	t	p
R1 (overall decision)	R2 (objective criteria)	197	6.45	0.000*
R1 (overall decision)	R3 (subjective criteria	197	7.44	0.000*
R1 (overall decision)	R4 (consistency)	197	4.41	0.000*
R2 (objective criteria)	R3 (subjective criteria)	197	1.03	0.152
R2 (objective criteria)	R4 (consistency)	197	-2.14	0.017*
R3 (subjective criteria)	R4 (consistency)	197	-2.90	0.002*

*Significant at 0.05

Research Question 2: How do students who were able to engage more effectively in decision-making about water-based SSIs differ from those who engaged less effectively?

- Students with higher scores tended to state clear, explicit decisions and to incorporate support for their positions through their answers
  - “We should limit water usage to an amount that allows farmers to still remain profitable, but also allows the aquifer to be recharged in certain areas. This allows for the economic growth of the region, while providing a feasible way to ensure a water resource for future generations” (218_Water assignment).
- Students with lower scores tended to have much shorter answers and typically did not include as much, or any, support for their statements.
  - “I don’t know if it is possible to restrict farmers from using a certain amount of water because they are ultimately going to take whatever they need to make money but it they were restricted there would have to be strict rules and guidelines in place to enforce the farmers” (306_Water assignment).

Research Question 3: What factors or resources do students use to make and support their decision about water-based SSIs?

- Students used resources from class to state and support their opinion, but did not use those resources when asked to make a decision regarding voting on that issue.
- When discussing their personal opinions, all students claimed that scientific information helped them form their opinions and many referenced readings from class.
  - “I think that we should restrict it a little bit, like cut back on a few areas in the state... There was one article… that had talked about how the restrictions and stuff had even helped the aquifer come back or even raise a couple inches of water...” (Water Student GG_Interview)
- When students were given a realistic voting scenario in which they were asked to make a decision about raising taxes to fund irrigation technology for farmers, they typically supported their decision with broad and vague claims.
  - “I would vote for it. I think that our tax money would be going to a pretty good cause then. That seems like a dream come true with some more effective way of irrigating and it uses less water, so, yes I'll go and vote for that.” (Water_Student II_Interview)

IMPLICATIONS

- The study informs research on students’ understanding of core hydrologic concepts, epistemic dimensions of science , science literacy, and decision science. These scientific concepts, processes, and practices are an important focus for post-secondary students to advance scientific literacy among citizens (NRC, 2012).
- Findings from this study contribute to the field by showing the aspects of decision-making students focus on and the resources they use to inform their decisions about water in real-world contexts.
- These findings have important implications for structuring interdisciplinary STEM learning environments across the PK-16 continuum that will effectively engage students in SSIs and in supporting them to incorporate rationale and evidence into the decisions they make both in the classroom and beyond.
- Findings from this work provide important insight into undergraduate students’ development of scientific literacy and their engagement with decision-making about SSIs.

REFERENCES

- Arvai, J. L., Campbell, V. E. A., Baird, A., & Rivers, L. (2004). Teaching students to make better decisions about the environment: Lessons from the decision sciences. *The Journal of Environmental Education*, *36*(1), 33-44.
- Bybee, R., McCrae, B., Laurie, R. (2009). *PISA 2006: An assessment of scientific literacy*. Journal of Research in Science Teaching, 46(8), 865-883.
- Covitt, B. A., Gunckel, K. L., & Anderson, C. W. (2009). Students’ developing understanding of water in environmental systems. *The Journal of Environmental Education*, 40(3), 37-51.
- Feinstein, N. (2010). *Salvaging science literacy.* Science Education, 95(1), 168-185.
- Forbes, C.T., Zangori, L., Schwarz, C.V. (2015). Empirical validation of integrated learning performances for hydrologic phenomena: 3rd-grade students’ model-driven explanation-construction. Journal of Research in Science Teaching, 52(7), 895-921.
- Halverson, K.L., Siegel, M.A., Freyermuth, S.K. (2009). Lenses for Framing Decisions: Undergraduates’ decision making about stem cell research. *International Journal of Science Education, 31*, 1249–1268. doi:10.1080/09500690802178123
- Halvorson, S. J., & Wescoat J. L., Jr. (2002). Problem-based inquiry on world water problems in large undergraduate classes. *Journal of Geography*, 101(3), 91-102.
- Lederman, N.G. (2007). Nature of science: Past, present, and future. In Abell, S.K. and Lederman, N.G. (Eds.), *Handbook of research on science education* (pp. 831-880). Mahwah, New Jersey: Lawrence Erlbaum Associates.
- National Research Council. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. Washington, DC: The National Academies Press.
- Rudolph, J. L. (2014). Dewey’s “Science as Method” a century later: Revising science education for civic ends. *American Educational Research Journal*, 51(6), 1056-1083.
- Sadler, T. & Zeidler, D. (2005). The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues. *Science Education, 89*, 71-93.