Fostering Standards Literacy in General Education at an R1 Institution
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Final Summary Paper
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Project Description

Standardization processes guide businesses and organizations in implementing practices that are sustainable for the environment, the economy and society. They affect global challenges such as managing water and food resources equitably, while maintaining safety and efficiency. The overarching goal for this project was to incorporate standards literacy into general science courses at Michigan State University (MSU), allowing for increased awareness and understanding of standards and standardization processes and their significance in the social context. This work placed an emphasis on helping non-stem majors develop an enhanced degree of general "standards literacy". An emphasis was placed on the way that STEM disciplines (science, technology, engineering and mathematics) are implicated in the development of standards that range from manufacturing and process control to regulation and program evaluation, while also stressing the way that standards development, implementation and compliance are shaped by contingent factors of the social context. We refer to our approach as "liberal arts standards education," to emphasize its relevance to all college graduates, irrespective of their academic major or their projected career and future work life. To achieve this objective, we developed standards literacy modules in two laboratory courses in the Center for Integrative Studies in General Science (CISGS). The target courses offered an attractive opportunity, as more than one half of MSU undergraduates move through this course structure.

A. Goals and Objectives

The goals for the project team were to develop and implement standards education instructional modules and hands on investigations in two laboratory courses in CISGS. These included an Integrative Studies in Biology (ISB) and an Integrative Studies in Physical Science (ISP) lab program. These lab programs are components of the University undergraduate requirements. The collective goal of these lab programs is to help enhance the scientific literacy of non-STEM undergraduates. The development and implementation of technical standards was an ideal mechanism to help students better understand the role of science in society.

Specific objectives:

1) Curricular Development: We developed instructional modules for each of the two target laboratories, aligned to the course objectives. Specifically, we want our students to understand:
   - What a technical standard is.
   - The process by which standards are created, implemented and regulated.
   - The implications (economic, social, political, etc.) of standardization.
   - The role of science and the scientific process in the development of standards

2) Curricular Implementation: We delivered the standard instructional modules in the targeted laboratory courses during Summer and Fall 2016. There were a total of 50 sections of these courses delivered during the implementation semester, ultimately impacting a total of over 1200 students. Critical aspects of the implementation included:
   - Collection of standards instructional materials related to water and food safety.
   - Training and supporting teams of graduate students from a wide range of disciplines who directly deliver these lab courses to students.

B. Project Evaluation

The Center for Integrative Studies in General Science assessment team conducts the assessment and evaluation of the project. The evaluation objective was to determine the impact of the program on the participating students. Specifically, to assess students' learning gains aligned to the curricular objectives described in section A.1 of this report. Data sources include surveys (pre- and post-) and student artifacts including homework, pre-and post-lab assignments and other standard-related assignments.

The objective of the survey was to better understand students' perceptions, ideas and knowledge about standards and standardization processes and the role that they play in the social context and their everyday lives. The survey was administered in written format, at the start of the courses (pre-survey), before the students had had any instructional engagement with standards; and at the end of the courses (post-survey), after the students have been engaged in activities designed to increase their exposure and awareness to issues related to standards literacy.
We collected samples of student artifacts including homework, pre-and post-lab reports and recorded debates that were a part role playing activities that took place in the context of classes. The objective for this data stream was to compare between students' self-reported survey data and actual students work. Triangulation between these different data sources allowed us to have a better understanding about the learning gains related to standards literacy.

Project Implementation

C. Curricular Development

New lab activities were developed and implemented in the context of an Integrative Studies in Biology (ISB) lab program and also in an Integrative Studies in Physical (ISP) Sciences lab program, each with the purpose of introducing students to the concept of technical standards and the role of science in the development and implementation of those standards. These case study labs additionally exposed students to the concept of technical standards from start to finish; including how and why they are proposed, developed, and implemented.

1. In the context of the ISB lab program, the lab activity was related to standardization in food production. Students conducted a hands-on investigation of the number of aphids allowable in whole hops, which is a key ingredient in the making of beer. The industry standard, according to the U.S. Food and Drug Administration's Food Defect Action Level Handbook (Insects; AOAC 967.23), is that 'there cannot be on average more than 2,500 aphids per 10 grams of whole hops'. Students were given packages of whole hops and microscopic equipment, and were required to identify and record the total number of aphids per gram of hops. This allowed student groups to determine whether or not the industry standard had been met. Additional objectives for this lab were to compare brands of hops grown in the United States versus Great Britain, and to compare differences between certified organic versus non-organic hops. This lab included a follow-up discussion and student led debate on whether the current industry standard for whole hops is acceptable.

2. In the context of the ISP lab program, students investigated the use of road salt (NaCl) and its potential ecological impacts. This is a real-life situation that is of local importance, especially in many states of the Midwest. Given the evidence in the literature that chloride concentrations often exceed the EPAs chronic 7-day standard, by significant amounts and durations, there is value in experimenting to determine appropriate standards for road salt application. Students used a bioassay of various chloride concentrations on the germination and radicle growth of a test organism (Butter crunch lettuce) to inform their proposed standard. Through stakeholder role-playing and balancing their own concerns about water quality, students were asked to determine and propose a standard to be put forward, this based on their own scientific evidence. This was a valuable exercise that helped to highlight the challenges associated with the determination of technical standards of any kind.

D. Data Collection and Analyses

Survey: Students enrolled in ISB 208L in Summer 2016 (N=18) and Fall 2016 (N=681); and students enrolled in ISP 203L in Summer 2016 (N=23) and Fall 2016 (N=508) were asked to complete a written survey during class time. The instrument included open and close ended items (Appendix 1). The table below presents a summary of the survey data collection.

Table 1. Survey Data Collection Summary

	Summer 2016		Fall 2016	
	ISB 208L	ISP 203L	ISB 208L	ISP 203L
Students Enrolled	18	23	681	508
Pre-survey responses (response rate %)	NA	23 (100%)	588 (86%)	473 (93%)
Post-survey responses (response rate %)	NA	21 (91%)	486 (71%)	464 (91%)

Given that the surveys were administered using written responses we decided to analyze a random sample (n=60) of the responses for both of the target courses in Fall 2016. These responses included only students that completed both the pre- and the post-surveys:

- Pre- scheme: Picked a set of 30 respondents starting in the pool (all sections) of pre-survey responses and for those respondents we found the corresponding post survey responses.
- Post- scheme: Picked a second set of 30 respondents starting in the pool (all sections) of post-survey responses and for those respondents we found the corresponding pre-survey responses.

This scheme gave us a total sample of 60 responses for students that completed both the pre- and the post- survey questionnaires.

Student artifacts: The objective for this data stream was to compare between students' self-reported survey data and actual student work. We collected student artifacts related to the standards modules including homework and pre-and post-lab reports; students were also engaged on in-class debates related to determining an appropriate standard for salt application (appendix 2). We recorded the group debates, transcribed them verbatim and analyzed the transcriptions.

Project Results

E. Survey Results:

Students were asked to report their level of confidence related to several aspects of standard literacy. We used a Likert 5-point agree/disagree scale (1- Strongly disagree; 2- Somewhat disagree; 3- Undecided; 4- Somewhat agree; 5- Strongly agree). Our data indicate a slight change in the mean values for the responses from undecided (3) in the pre-survey to somewhat agree (4) in the post survey. This trend holds for both courses in both semesters. Figure 1 shows the mean values for the responses for the ISP203L FS16 course, and Figure 2 shows the mean values for the responses for the ISB208L FS16 course.

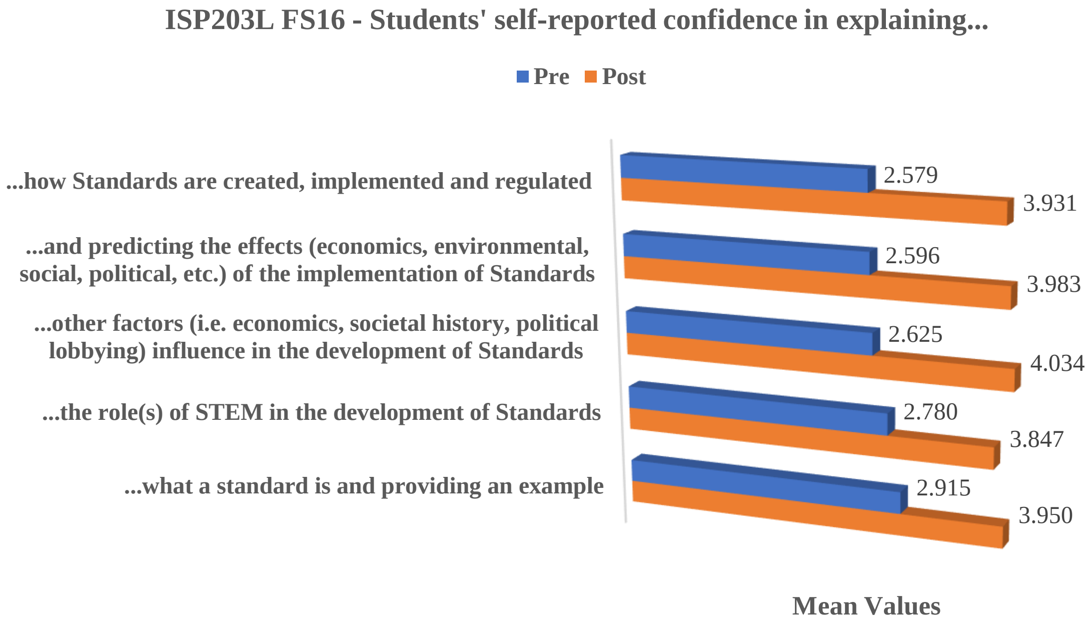


Figure 1. Participants' self-reported confidence about different aspects of standard literacy N=60

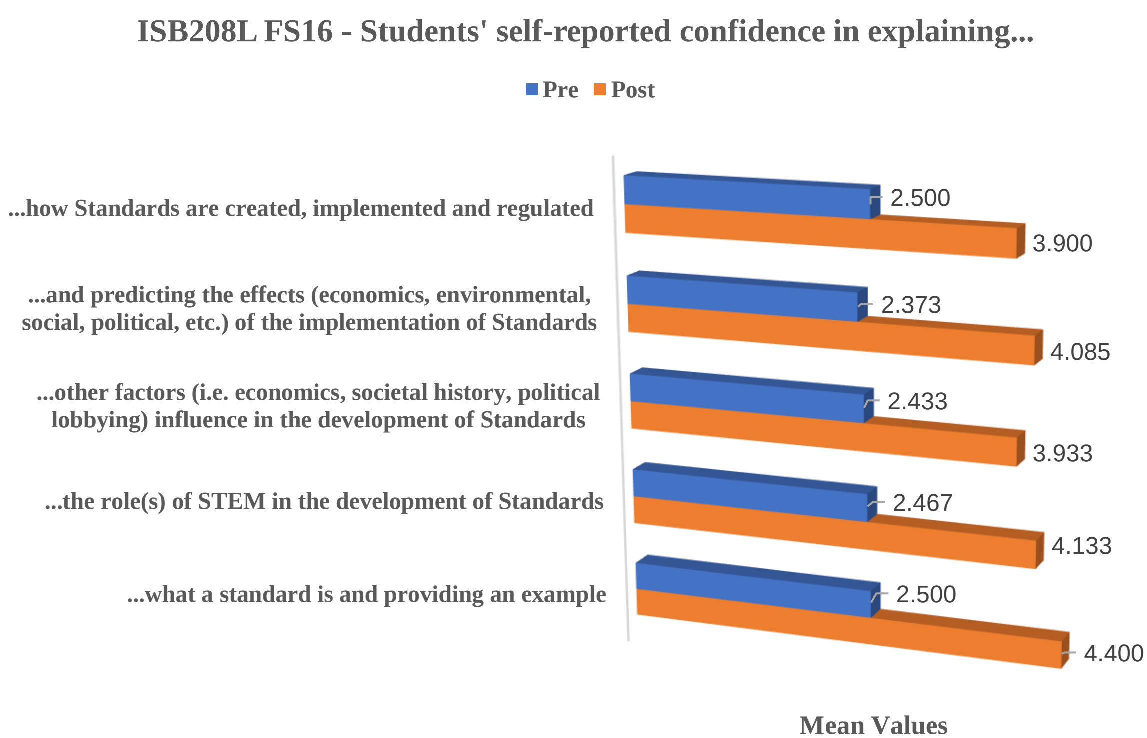


Figure 2. Participants' self-reported confidence about different aspects of standard literacy N=60

The primary coding structure for the open-ended items was based on the project objectives. In particular we focused on aspects related to student's awareness and knowledge about the development of standards, and their significance in the social context. Using iterative coding we characterized important aspects of the instructional experience (standards modules) and the impact it had on standards literacy in General Education courses. Table 2 shows the categories and the criteria used to include a response in a given category (rules of inclusion). Table 3 summarizes the results from the analyses by providing exemplar responses for each of the coding categories.

Table 2. Coding Categories and Inclusion Criteria

Coding Categories	Rules of Inclusion
Manufacturing (M)	Responses related to manufacturing.
Process (P)	Responses related to the standards creation process
Regulation (R)	Responses related to methods for monitoring or enforcing standards
Evaluation (E)	Responses related to checking and assessing the success of the standard
General Knowledge (G)	Responses that indicate a general understanding of standards
Lobbying (L)	Responses related to political lobbying
Stakeholders (S)	Responses related to stakeholders (influence, opinions, stakes, interests) on standards
Economics (EC)	Responses related to money or economic implications
STEM Connection (SC)	Responses related to connections between science and standards
Other (O)	Responses unrelated to the question

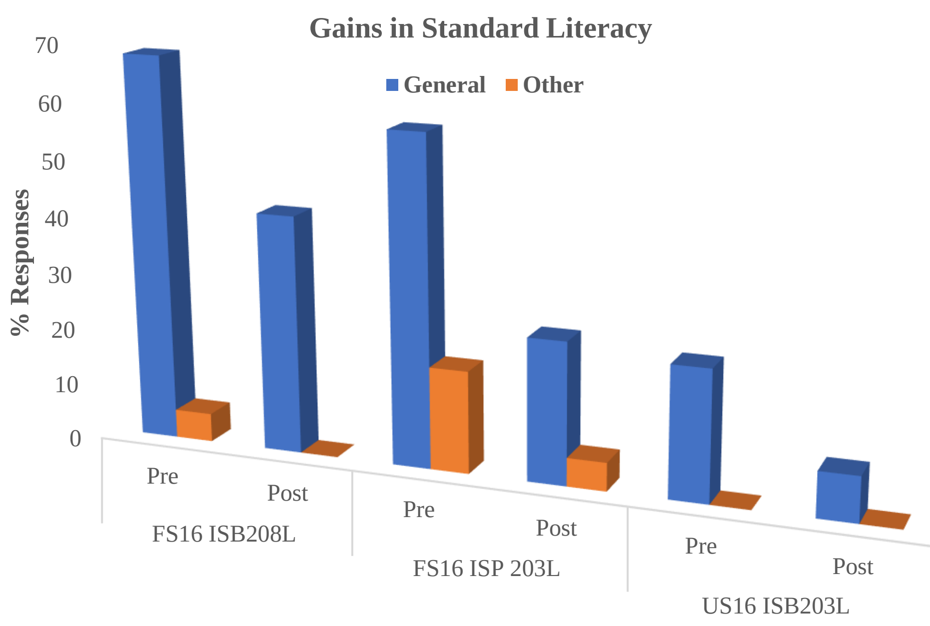
Table 3. Coding Exemplars

Response Quote	Coding Category*
"[…] **standards are proposed, thoroughly debated, and then have to be approved before they can be implemented by specific fields**. **They are maintained by consequences being enforced for not following them**."	**Process**, **Regulation**
"**The idea behind standards is that they make the world a better, safer place**. […] **some standards are set to profit companies** with no **regard to environmental health**. […] **For instance, a new standard limiting the amount of plastic bags that can be produced per year would lose plastic manufacturers a lot of money** but **would hopefully help the environment**."	**General**, **Economic**, **Stakeholders**
"Standards are **created through research and testing**, they are **implemented by the government passing legislation enacting their use,** and they are **regulated by government agencies**"	**Process**, **Scientific connection**, **Regulation**

*Please note that a given response can be assigned more than one code. The data is color-coded to indicate the alignment between the codes and the response.

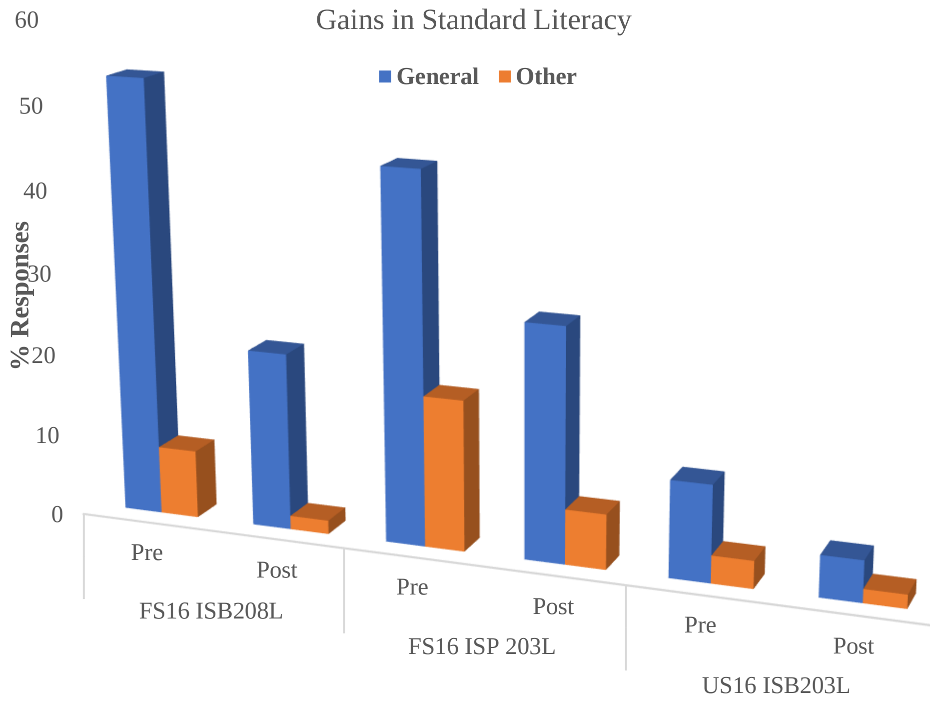
Gains in Standard Literacy: Our analyses comparing the pre- and post- survey responses to the open-ended questions indicate that after participating in the standard modules students in both courses provided more elaborated and complete responses. For example, students were asked:

"What role(s) do STEM disciplines play in the development of Standards? Use a specific example to illustrate." For the pre-survey, 73% of the responses fell in the general or other categories indicating that the responses did not provide specific standard-related information and only conveyed general information (G) or that the response was unrelated to the question (O). For these same students, only 42% of the post-survey responses were assigned to the general category (Figure 3). The charts in Figures 3 and 4 summarize the gains in standard literacy. Table 4 further illustrates the gains in standard literacy by providing exemplar responses from pre- and post-surveys.



	FS16 ISB208L		FS16 ISP 203L		US16 ISB203L	
	Pre	Post	Pre	Post	Pre	Post
General	68	42	58	25	23	8
Other	5	0	18	5	0	0

Figure 3. Comparison between students' pre- and post-survey responses to the question: What role(s) do STEM disciplines play in the development of Standards? Use a specific example to illustrate."



	FS16 ISB208L		FS16 ISP 203L		US16 ISB203L	
	Pre	Post	Pre	Post	Pre	Post
General	53.12	21.58	44.82	28.22	11.62	4.98
Other	8.3	1.66	18.26	6.64	3.32	1.66

Figure 4. Comparison between students' pre- and post-survey responses to the question: "Explain how Standards are created, implemented and regulated."

Table 4. A representation of exemplar responses from pre- and post-surveys.

What role(s) do STEM disciplines play in the development of Standards? Use a specific example to illustrate.	
Pre-survey responses (codes)	**Post-survey responses (codes)**
"[STEM] all play very specific roles in the development of standards, unfortunately, I do not know these key roles but hope to learn them in the near future" (O)	"[STEM] all play a vital role in the development of standards. With technology and science, that is how a standard is developed. Engineering comes into play within the firm who [sic] develops the standard. The firms use their research, data, and technology to develop these standards." (P, SC)
"[STEM] enhance standards by proving things in experiments." (G)	"[STEM] play a huge role in the development of standards. With science we can see the negative effects of too much road salt so in the future there will most likely be a standard of how much can be used." (SC)
"Scientists play a role in standards because they are the ones sticking to the standards and technology helps them log all data." (G)	"The role that science plays in placing standards is that scientists help research and provide ways that will help our environment out in keeping safe and efficient and this research helps create standards that will in turn save our envrionment [sic] and people. An example [sic] would be that scientists did research to see how much pollution we are putting into the air and provided us with evidence and how there are standards in place to stop us and manufactuers [sic] from creating so much pollution." (SC, R)

Explain how Standards are created, implemented and regulated	
"They are created by higher officials to set rules and are implemented through the people that set them." (G)	"Standards are created by officials and implemented through guidelines. For example, the USDA regulates food labeling of organic foods." (R)
"Through each individual field. Historical references. Government, laws, media." (G)	"Through this class I have learned that standards are proposed, thoroughly [sic] debated, and then have to be approved before they can be implemented by specific fields. They are maintained by consequences being enforced for not following them." (P, S, R)
"Standards are created through policy." (G)	"They are heavily debated between all sides to ensure a compromise and agreed to all affected industries then have to implement them." (S, P)

F. Student Artifacts Analyses

In this section we present the results from analyzing student artifacts and the triangulation between survey results and artifact analyses.

Our results suggest that students' participation in the standard instructional modules contributed to increased standard literacy. We analyzed laboratory reports (artifacts) where students were asked to choose a standard, explain why they chose it, and how it would affect different stakeholders. The analyses indicated that students were able to integrate the scientific data that they generated during their laboratory work and applied it to their responses both in the post-survey and their class assignments (laboratory reports, debates).

Table 5 shows an example of triangulation between two data sources, surveys (pre- and post) and student artifacts (laboratory report). Both examples exhibit increased awareness related to the role of STEM disciplines on standard development. This is evidenced by the complexity of the responses in the post survey compared to the pre-survey responses; students specifically referred to the salt concentration experiment that they did as part of their laboratory work, (underlined text on the table).

Table 5. Exemplar for triangulation between data streams: Survey responses and lab reports

Survey responses (Q: STEM disciplines influence on standard development)		Student Artifacts
Pre-	Post-	Lab. report entries**
"They [STEM] are the means to understanding the needs of standards and what they should be." (G)*	"All of the above [STEM] are required to conduct research and experiments necessary to understand what needs to go into creating a standard. <u>Ex: The amount of salt used in winter needs to be measured in order to know what levels</u>	"[…] Overall I believe that if enough evidence was produced, we would end up [with a standard] between 230 ppm and 500 ppm because while it is low, it seems to be the peak before the environment is more drastically harmed, where

	effect the environment." P, SC)	companies will still make a profit and be able to abide by the laws that would protect the planet that they need in order to own their companies."
"Science , technology, and engineering help provide the facts which determine a standard." (G)	Science is very important when setting standards. Most of the time, we need to use logic and tests when deciding what is "normal". For instance, to return for a moment to our road salt discussion on Monday, science must be used in order to find out a.) how harmful road salt is to the environment, and b.) how necessary it is to drivers safety, in order to find a reasonable balance and set a safe standard." (P, S, SC)	"Ultimately, we determined that the standard for sodium chloride should be 1000ppm. The decision came form each group agreeing to compromise for the "greater good" […] This will be a good standard because while road salt will still be used in extreme weather situations, it will not be permitted to be used excessively."

* The letter in parenthesis indicates the code assigned to the response. Refer to table 2 for coding categories and inclusion criteria.
** The objective for this lab report was to define a standard for the application of road salt on the MSU campus considering various stakeholders perspectives.

Summary of the project's suitability and potential for adoption in other educational organizations

Standards do in fact provide an ideal mechanism to help students engage in integrative learning. Standards as an embedded component of an undergraduate curriculum can help to foster scientific literacy, while at the same time engaging students in issues of real-world social consequence. Engaging students in the full process of standard development and implementation, and consideration of the diverse stakeholder perspectives, results in students developing enhanced analytical thinking, evidence based argumentation, and effective communication skills.

As is the case with any laboratory investigation, activities and case studies must be carefully selected and field tested. They must be engaging for students, but also consistently replicable.

For example, the ISB exercise in which students investigated *Food Defect Action Levels, Aphids, Hops and Standards* was an extremely engaging topic for students. Students were keen to discuss and manufacturing process of beer, and intrigued by the notion that insects were an allowable element of common foods consumed by the public. The topic and the activity itself were highly engaging. The success of this activity however, was dependent on whether the hops purchased actually contained aphids. During the pilot of this activity, we did find aphids (by looking at raw hops under a dissecting microscope) in packaged raw hops and were able to draw conclusions on whether a specific industry standard had been met (and calculate how many aphids, on average, would have been in a single can of beer). However, on two subsequent attempts, the same source of packaged raw hops produced zero aphids. On the upside, this hands-on activity was engaging and students were eager to find and calculate the number of aphids per beer. On the down-side, in order to produce consistent results, we were forced to manipulate the packaged hops by adding aphids collected from the teaching greenhouses on campus. While this was not the preferred method by which to carry out this activity, manipulating the results did ensure that every student was able to identify and enumerate aphids from a sample of raw hops to complete the lab. If attempting to use this module, it would be important to be sure to pre-test the sources of packaged hops or (better) acquire prepackaged hops from a local supplier.

The ISP exercise in which students are asked to propose an EPA standard for the use of road salt was comparably engaging for students as a real-world issue of local importance. Students are consistently engaging in hypothesis development and data collection and analysis on a weekly basis in this lab program, but the standards stakeholder roleplaying exercise made the end results come alive with vibrant discussion in attempts to reach a consensus on the chloride standard. Every student was assigned a particular stakeholder role and was tasked to represent the stakeholder's interests while also taking into account other stakeholder interests as well as the scientific evidence from the bioassay. This activity enabled students to see the relevance of science and scientific data to solve real world problems. Additionally, it required students to incorporate multiple viewpoints and values in their decision making as well as communicating those decisions. The use of this technical standard activity in this lab program has enhanced student participation, the perceived relevance of science. This lab has become a permanent element of the ISP lab program and has been implemented every semester since its initial development.

Given that we have contextualized standards literacy as a component of general education at a major university, there is a need to determine whether it is helping our students to achieve our targeted learning outcomes. Assessment and evaluation is an essential component of determining the success of these curricular reform efforts. Assessment techniques and instruments must however be crafted and implemented in such a way as to collect valuable and useable data. It is important to complement open ended survey data with other data collection efforts such as analyses of student work to be able to determine the nature of the learning gains related to standards literacy. Based on this in our current project we have added qualitative data streams such as focus groups and are building upon the artifact analyses from this initial project to include more deliberate assessments of student learning gains. A challenging component to make our assessment more scalable is the data collection platform; it is important to use on-line options such as Qualtrics. We have incorporated this model into our new NIST project.