Promoting Scientific Literacy and Effective Citizenship through Standards Education

I. Introduction

The Center for Integrative Studies in General Sciences assessment team conducts the assessment and evaluation of the learning gains made by students enrolled in CISGS courses; our data collection includes surveys and student artifacts such as, mid-term and final examinations. Electronic surveys are collected at the start and end of the course, the objective is to understand participants' perceptions and awareness about standards and standardization processes. This report summarizes the data collection for the target courses in Spring 2018. We present a summary of the analyses of student artifacts (mid-term and final exams).

Table 1. Data Summary for Spring 2018

Course	Data Source	Status
ISB 201- section 01	Pre- and post-survey	N=160
	Mid-term and final exams	N=15
ISB 201- sections 02 & 04	Pre- and post-survey	N=320
	Mid-term and final exams	N=30
ISP 203A- sections 01 & 03	Pre- and post-survey	N= 378
	Mid-term and final exams	N=30

Our project goal was to enhance undergraduate students' understanding of standards and standardization processes. To achieve this goal, we developed standards education modules to help students achieve the following standard-related learning goals:

- Understand what standards are and the processes involved in their development.
    - Relative to stakeholders
    - Relative to the role of science
- Explain and predict the implications (ethical, economic, social, etc.) associated with the development, implementation and sustained application of standards.

The modules were implemented in three Integrated Studies Biology (ISB) courses during Fall of 2017 (pilot phase) and Spring 2018. Figure 1 summarizes the instructional implementation.

Standards Modules Implementation

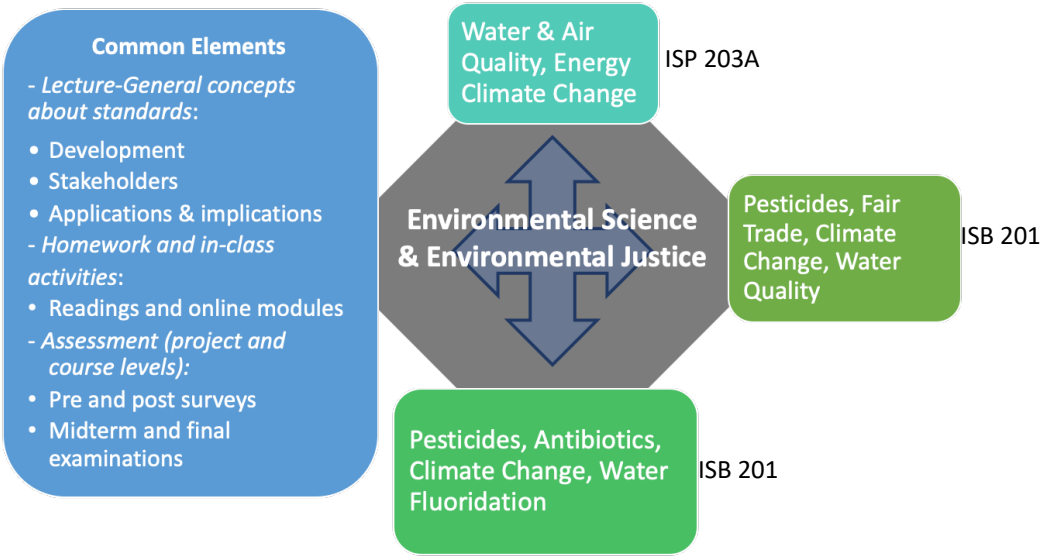

Figure 1. The left column highlights common elements of instruction; course-specific themes are included in the boxes.

II. Summary Analyses: Midterm and Final Exams

The focus of the target courses was environmental science and environmental justice, but each course approached and emphasized the subjects using different perspectives. Students enrolled in the target courses completed midterm and final examinations. These exams were common across the courses. Appendix 1 includes a summary of the questions for each of the exams. Table 2 shows the exam questions and their alignment to the standard-related learning goals.

It is important to note that the objective of these analyses was not to determine the "correctness" of the responses, rather to determine if there was increased awareness and understanding relative to standards and standardization processes. We looked for changes in the responses (from midterm to final) that demonstrated added complexity in relation to standards and standardization processes.

Table 2. Alignment between the exam questions and the standard learning goals.

Standard-related Learning Goals	Midterm Question*	Final Question*
Description of standards	Describe what technical standards are AND provide an example of a technical standard *related to water quality (ISP)* or *related to pesticides (ISB201)*	If you were able to implement a Technical Standard to combat [*water quality concern (ISP) or climate change (ISB)*] as head of the Michigan Department of Environmental Quality (MDEQ), what would that standard be?

Standard-related Learning Goals	Midterm Question*	Final Question*
Role of science in the development of standards	Describe or explain the role of science in the development of [*water ISP or pesticide (ISB)*] standard	Clearly explain the science that would justify your decision in adopting / developing this specific standard and how it would target [*water quality concern (ISP) or climate change (ISB)*]
Role of stakeholders in the development of standards	Describe three stakeholder groups associated with [course-chosen] standard	List and clearly describe THREE significant Stakeholders with diverse perspectives that would be influenced/impacted and why they would care.
Ethical implications associated with standards and standardization processes	Describe how implementing or NOT implementing technical standards can have ethical implications for certain groups in society	Explain and predict two implications (ethical, economic, social, etc.) associated with the development and implementation of that Standard.

* When relevant, the distinction between the courses (ISP and ISB) is noted in brackets.

A. Coding Process

Our coding process was designed to help us determine instances where students augmented their ideas and used more complex arguments in their responses (i.e. incorporating more elements related to standards and standardization processes).
For each of the standard-related learning goals, we categorized the exam responses based on their level of complexity, going from those that offered a basic/general response to more complex responses that included additional information related to standards. Each response was assigned a *numerical code* from 0 to 3 (Table 3).

Table 3. Criteria for Response Complexity

Criteria (numerical code)
Vague response, unrelated to the question, or "I don't know (**0=Too vague**)
Provides a general/basic description. (**1=Basic**)
Mentions types of systems/processes likely to be influenced by standards. (**2=Medium**)
Mentions potential implications for people & environment, and/or mentions the potential effects of using the standard. (**2=Medium**)
Response incorporates several aspects of standards and standardization processes. (**3=High**)

To illustrate the coding process, table 4 presents one exemplar question from the midterm (related to description of standards) and one exemplar question from the final exam (related to

the role of science) and shows exemplar student responses with the assigned numerical codes indicated in parenthesis.

Table 4. Exemplar Responses for Midterm and Final Exams

Midterm* (numerical code)	Final** (numerical code)
"Technical standards are the standards that determine the quality of water" (0); "It can't be toxic especially for the food than [sic] people can eat" (0); "Technical standards are instructions to a certain item, a way to use it or how to do something. It given [sic] instructions on the accuracy of something. An example would be a pipe that transforms water has instructions to go with it to test the accuracy of the water" (1); "Technical standards are rules (laws) for quality to ensure a certain level. One example is limiting presence of lead in water to a certain (low) amount of ppm."(1); "A pesticide used in lakes in the United States is causing fish to turn from male to female, and vice versa. Europe has found and banned high usage of the pesticide, to preserve wildlife." (2); "One standard associated with pesticides is that bottles of pesticides give specific directions for how much to spray and where in order to minimize pesticide drift (which is when pesticides end up in places they were not meant to, like residential areas, and could possibly cause harm to people, animals, and the environment)." (3); "Technical standards are often voluntary measures companies + organizations adopt in order to meet safety requirements, streamline production, as well as a slew of other reasons. An example of a technical standard related to water quality is that the EPA has standards for what levels of lead, copper, etc. can be in drinking water in order for it to be considered safe for consumption."(3)	"By controlling and decreasing waste going into bodies of water, we can protect the water quality. Less harmful waste in lakes the better the lake." (1); "Methane and CO2 both are a byproduct of cars, by making cars hybrid less methane and CO2 would be emitted into the air, reducing greenhouse gases." (1); "CO2 has a high GWP, which means it can absorb a lot of heat, which will lead to warmer temperature. Trees pull in CO2 during the photosynthesis. Having a tree/plant a tree in your yard would help remove CO2 from the atmosphere, less CO2 in the atmosphere leads to less warmer climates." (2); "fertilizers are a big problem for water quality/ marine life. Run off or fertilizers culturally eutropicate [sic] water + polluting our waters acting like natural fertilizers to algae causing an increase in blooming. As algae blooms it takes up a lot of O2 leading to hypoxia cause marine life to die off creating a positive feedback loop" (2); "I would need scientists to conduct water surveys and experiments in order to see how much point source pollution there is in our water, where it's mainly coming from and how much of a reduction would be beneficial but still realistic for the companies polluting. This would help reduce the contamination of Michigan's drinking water."(3); "Snow has the potential to reflect about 95% of light back into space, avoiding being trapped into the atmosphere, as where black asphalt reflects about 3% - 5%. Reflecting 95% of light (heat) 'into space is much better for keeping temperatures consistent than absorbing 95% of light (heat), where it will be trapped. More so by increasing reflectivity, we are not removing GH gasses from the atmosphere but decreasing the amounts of heat in the atmosphere able to be trapped by high GWP chems [sic]." (3)

* Midterm exam question: Describe what technical standards are AND provide an example of a technical standard related to water quality (ISP) or related to pesticides (ISB201). ** Final exam question: Clearly explain the science that would justify your decision in adopting/ developing this specific standard and how it would target [water quality concern (ISP) or climate change (ISB)].

B. Results and Discussion

In this section we present the results from the analyses of the midterm and final exams. We collected a random sample of student exams from each section across the courses (table 1). For each of the standard-related learning goals: Description of standards; Role of science; Role of stakeholders; and Ethical implications (see Table 2), we calculated the frequencies of the response complexity criteria (table 3). 0 = Too vague; 1 = Basic; 2 = Medium; and 3 = High

As depicted in Figure 1 for the four standard-related learning goals students' responses largely fell into the basic and medium complexity categories. The "description of standards" learning goal has the highest percentage of responses under the medium complexity category (46%). For all standard-related learning goals a small percentage of the responses fell under the high complexity category with "ethical implications" and "role of science" learning goals showing 5% of the responses in this category.

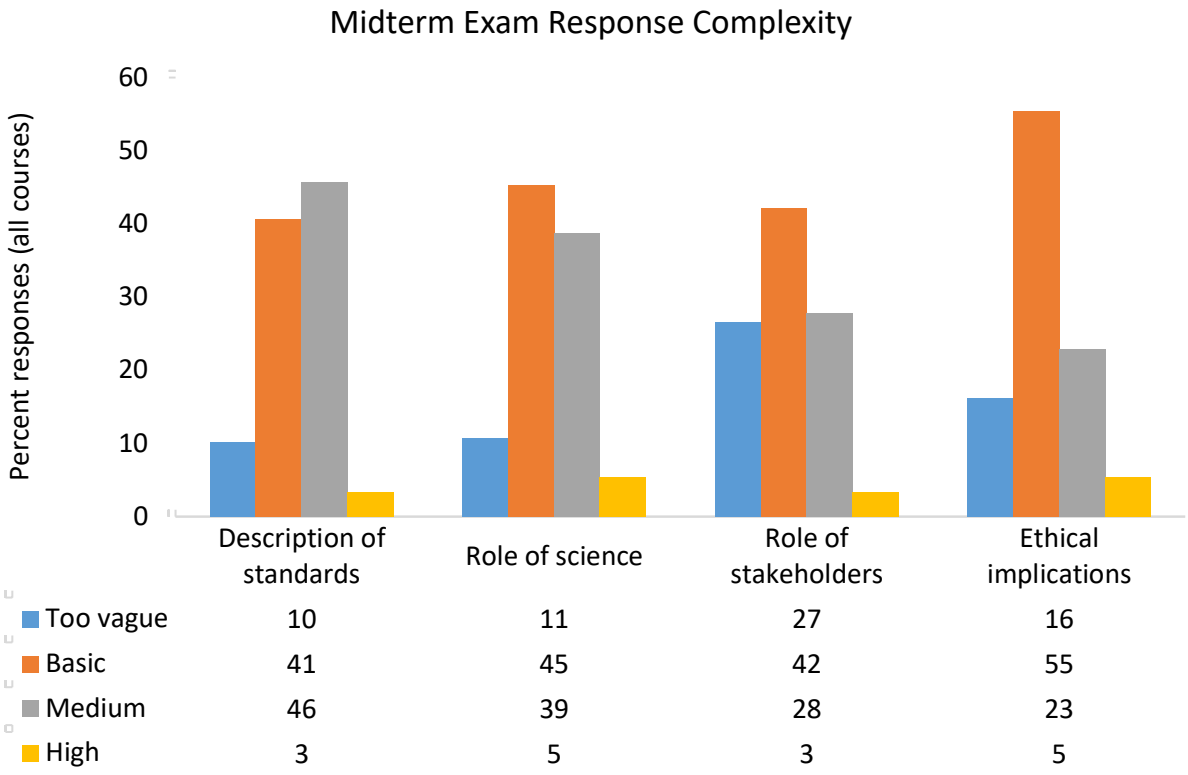

Figure 1. Midterm exam (summative all courses). The percentages were calculated based on the total responses for each of the standard-related learning goals (Ns= 59; 75; 45; and 74 for each respective standard-related learning goal left to right).

The results for the final exam (Figure 2), show that for all the standard-related learning goals there are no responses under the “too vague” category as compared to the midterm percentages for that category. In addition, for the “role of science” and the “role of stakeholders” standard-related learning goals the results indicate higher percentages of responses shifting towards the medium and high response complexity categories.

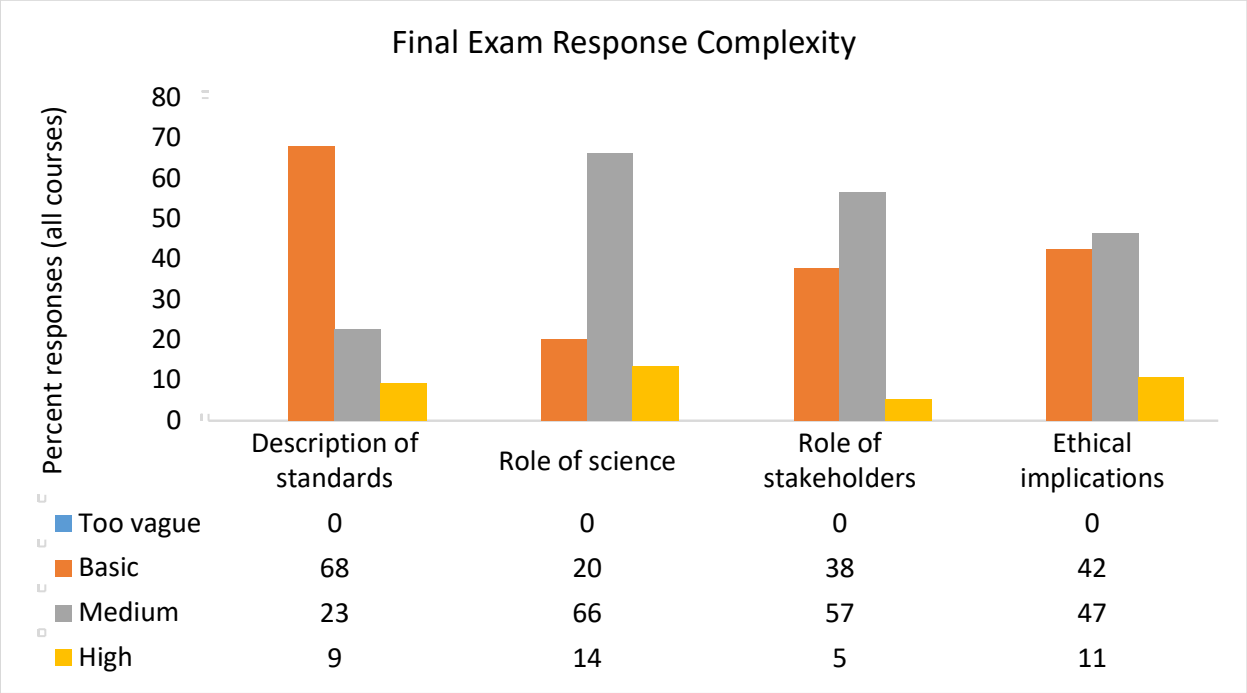

Figure 2. Final exam (summative all courses). The percentages were calculated based on the total responses for each of the standard-related learning goals (Ns= 75; 74; 74; and 73 for each respective standard-related learning goal left to right).

To determine changes in response complexity from midterm to final examinations we compared the results for each of the standard-related learning goals (Figures 3a to 3d). Across the learning goals there is a gain in response complexity from the midterm to the final.

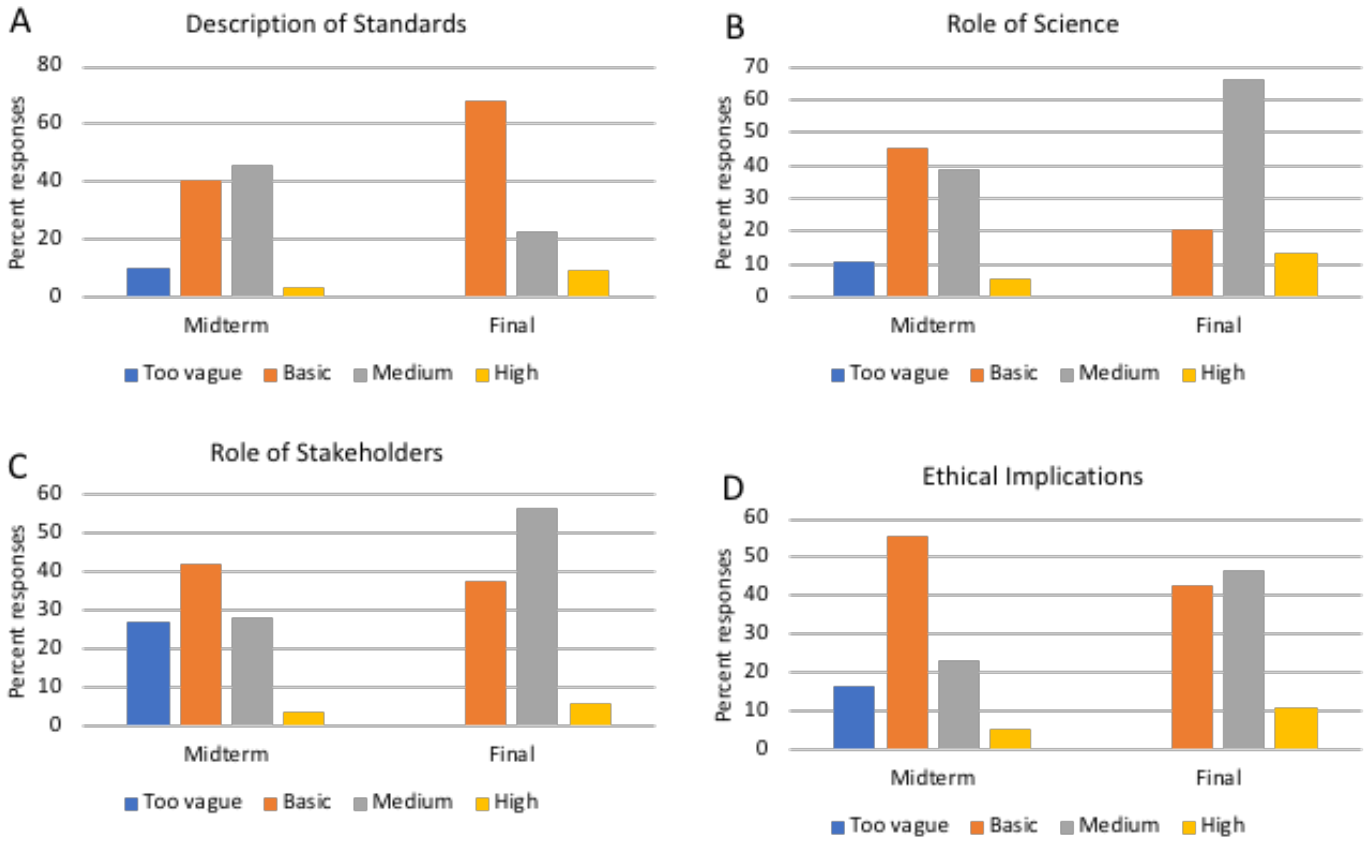

Figure 3 A - D. Comparison between midterm and final exams across the standard-related learning goals.

Taken together these results indicate that for all of the standard-related learning goals there seems to be a shift in the distribution of the complexity of responses towards more complex responses when comparing the midterm and the final exams. This is also apparent in the response examples that we included in table 4.

We are in the process of writing a paper to submit to the *Journal of College Science Teaching*. In this publication we will compile the results of all the data analyses including surveys, student artifacts and instructional modules.

Appendix 1

The content for the examinations used in the assessment is summarized in the table below.

ISB201_01

- Midterm:
    - Identify and describe 2 distinct Standards that are likely in place relative to the use and application of pesticides in this situation. For each, explain the possible role that science would have played in its development. For each, identify 3 distinct stakeholders who would likely have hoped to provide input for the determination of that specific standard and an indication as to why it would be of interest to them.
    - Relative to the creation of standards in this scenario, what ethical concerns might exist for the way standards are developed or implemented?

ISB201_02 & 04

- Midterm:
    - Describe one specific standard associated with pesticides, list/briefly describe three stake holder groups associated with that specific standard
    - Explain the role of science in the development of that standard
    - Describe one specific 'ethical' concern associated with the way this standard was developed or implemented.

ISP203A_01 & 03

- Midterm:
    - Describe what technical standards are AND provide an example of a technical standard related to water quality.
    - Describe the role of science in the development of technical standards
    - Describe how implementing or NOT implementing technical standards can have ethical implications for certain groups in society.

Final Exam: The questions were common across the three courses. Students were asked:

1) If you were able to implement a single Technical Standard to combat a [*water quality concern (ISP203A_01&03); climate change for ISB201 all sections*] as head of the Michigan Department of Environmental Quality (MDEQ), what would that standard be?
2) Clearly explain the science that would justify your decision in adopting / developing this specific standard and how it would target your [course-specific, see bracket above] concern.
3) List and clearly describe THREE significant Stakeholders with diverse perspectives that would be influenced / impacted and why they would care.
4) Explain and predict two implications (ethical, economic, social, etc.) associated with the development and implementation of that Standard.