Scientific Literacy Assessment Summary

Executive Summary

During the Spring 2019 semester, the Drake Curriculum Analysis Committee (DCAC) reviewed the Scientific Literacy (SL) Area of Inquiry (AOI) by analyzing student self-perceptions of academic engagement and perceived learning gains, and by initiating a faculty review of student work in the AOI. The SL AOI consists of the following outcomes: (1) scientific methods, (2) scientific reasoning, (3) scientific theories, (4) interrelationships between human societies and the world, and (5) relevance of science.

1. Apply the methods of science for the generation, collection, assessment, and interpretation of scientific data and/or phenomena.
2. Use scientific methods and ways of thinking to solve problems.
3. Describe scientific theories on cognitive and behavioral, intellectual, or physical development.
4. Articulate the interrelationship of the development of human societies with the natural world around them.
5. Articulate the relevance of science to the global community in order to serve as active stewards for the natural environment.

Drake students rate their perceptions of their abilities to "read and understand scientific writings written for an informed lay audience" lower among the suite of general education skills and abilities (62% of undergraduates reported "strong" or "very strong" skills on the 2018 Drake Student Survey). However, students' perception of their skills significantly change ($p<0.05$) throughout their time at Drake and the growth in students' perception of their skills for scientific literacy is higher than most of the other skills ($d=0.42$; 2nd highest).

Faculty review of student work revealed basic competence of learning outcomes. Faculty largely found that students are able to understand (method, theories) and apply (reasoning, relationship, relevance) a body of scientific knowledge; however, on their own students are less able to go deeper beyond what faculty explicitly ask of them or make connections amongst disparate material. During the AOI workshop, faculty discussed that the primary challenge for this AOI is to encourage deeper investigation or higher-order learning about scientific concepts. Barriers toward achieving this goal include: (1) the difficulty of balancing content and skills or "the body of knowledge" with the "why," (2) the number of students earning the AOI through intro courses, and (3) large class sizes. Some ways to achieve this goal include: (1) integration of concepts, (2) effective pedagogies, and (3) intentionality in thinking about the needs of non-majors.

To address these concerns, DCAC has developed the following recommendations.

Concerning course development,

1. Examine curricular practices that enhance all students' abilities to apply scientific concepts.

2. Investigate curricular practices that ensure the best pathways for non-major students.

Concerning pedagogy and practice,

3. Provide opportunity for faculty to learn new pedagogies and develop skills, including scaffolding, inquiry/problem-based learning, and case studies.
4. Provide best practices and resources (assignment design, course activities) to aid faculty in developing or improving AOI courses. Examples include the Case Study Resource Bank and the BlackBoard Community of Practice.

Concerning resources,

5. Investigate non-major pathways through the Scientific Literacy AOI to ensure that non-majors have expanded course options that provide the opportunity to develop the ability to apply scientific concepts.
6. Embed peer mentors in large science classes to allow faculty more time to spend on the application of knowledge, rather than learning the body of knowledge.

Overview

The Drake Curriculum promises to provide students with a meaningful liberal arts education through three components: a First-Year Seminar, a set of Areas of Inquiry (AOI) requirements, and a Senior Capstone. Our institution maintains a commitment to inquire into the consequences of our work with students, something Lee Shulman described as a "pedagogical imperative."[1]

To provide evidence of student learning in the Drake Curriculum, the Drake Curriculum Analysis Committee (DCAC) regularly performs on-going inquiry of the Drake Curriculum. During the Spring 2019 semester, DCAC analyzed the Scientific Literacy (SL) AOI. Drake students will "meaningfully interpret and evaluate scientific information for personal and professional applications as engaged citizens"[2] through (1) scientific methods, (2) scientific reasoning, (3) scientific theories, (4) interrelationships between human societies and the world, and (5) relevance of science.

1. Apply the methods of science for the generation, collection, assessment, and interpretation of scientific data and/or phenomena.
2. Use scientific methods and ways of thinking to solve problems.
3. Describe scientific theories on cognitive and behavioral, intellectual, or physical development.
4. Articulate the interrelationship of the development of human societies with the natural world around them.
5. Articulate the relevance of science to the global community in order to serve as active stewards for the natural environment.

DCAC provides evidence of student learning in this AOI through direct and indirect data.

Student Self-perceptions of Skills

Student self-reported data from several sources provide valuable context to understand challenges in particular skill areas. Student self-reported data is pulled from the 2018 Drake Student Survey (DSS), and the 2013-2017 Foundations of Learning Assessment (FLA).

On the 2018 DSS, 62% of Drake undergraduate and P1-P2 students reported "Strong" or "Very Strong" skills in reading and understanding scientific writings written for an informed lay audience. This is slightly lower than student perceptions from the 2017 DSS (65% "Strong" or "Very Strong").

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[1]Shulman, L. S. (2003). No drive-by teachers. Carnegie Perspectives. Retrieved from http://www.carnegiefoundation.org/perspectives/no-drive-teachers

[2] The Drake Curriculum: Scientific Literacy. (n.d.). Retrieved April 20, 2019, from https://www.drake.edu/dc/areasofinquiry/scientificliteracy/

Drake students' perception of their skills in scientific literacy significantly change throughout their time at Drake. Results of the 2013-18 Longitudinal Panel study show significant growth ($p<0.05$) in students' self-reported skills over their Drake experience. In addition, results show that students indicate greater growth over their Drake experience for scientific literacy than most of the other skills ($d=0.42$; 2nd highest). The 2013-18 Longitudinal Panel Study compares students' self-reported skill on institutional learning outcomes from before entering Drake to at least a year into their Drake experience. See Appendix B for full results.

Faculty Review of Student Work

In Fall 2018 and Spring 2019, DCAC worked with a select group of SL AOI faculty to develop criteria and levels of performance per criteria based upon on the existing SL AOI outcomes. During the Spring 2019 semester, Drake University faculty teaching in the SL AOI reviewed samples of student work and explored student skills in scientific literacy. DCAC aggregated results to focus on Drake's overall effectiveness in supporting student learning.

DCAC solicited samples of student work from AOI faculty and selected 27 representative samples from 9 different courses or sections that covered all major content areas, including biology, chemistry, environmental science, neuroscience, physics, psychology, and STEM education.

In Spring 2019, faculty used the criteria and levels of performance described above to evaluate student work. The SL criteria include the following:

- Scientific Method
  - Does the student apply the methods of science for the generation, collection, assessment, and interpretation of scientific data and/or phenomena?
- Scientific Reasoning
  - Does the student use the scientific method and ways of thinking to solve problems?
- Scientific Theories
  - Does the student describe scientific theories on cognitive and behavioral, intellectual, or physical development?
- Interrelationships
  - Does the student articulate the interrelationships of the development of human societies with the natural world around them?
- Relevance of Science
  - Does the student articulate the relevance of science to the global community in order to serve as active stewards for the natural environment?

The approximately 50 faculty who teach in this AOI were invited to participate and three AOI faculty agreed to participate. Because of a small sample size, this analysis will focus on the qualitative feedback faculty provided specific to each learning outcome.

Faculty review of student work showed two important points:

1. Basic proficiency across outcomes (especially (1) scientific method and (2) scientific reasoning), but on their own students are less able to go deeper than what was explicitly asked for.
2. Less representation of outcomes for (3) scientific theories, (4) interrelationships, and (5) relevance. For the SL AOI, not all courses are required to meet all five outcomes or criteria. For a more in-depth discussion of this discussion, see Appendix C appended to this report.

Faculty reviewers identified the following consistent characteristics of student work per criteria. Included below are also exemplar quotes from faculty.

- *Scientific Method*: Students demonstrate proficiency in completing the steps of the scientific method, but may need prompting to go deeper and consider why they implement the steps of the scientific method.
- *Scientific Reasoning*: Students demonstrate proficiency in using the scientific method to provide solutions to scientific and experimental problems. Students may need prompting to go further.
- *Scientific Theories*: Assignments provided less of a window into how students may explicitly describe scientific theories. Although students demonstrated the application of theory in many cases, they either were not able to articulate it or acknowledge it.
- *Interrelationships*: Students understand the interrelationships of the development of human societies with the natural world around them on a surface level, but may need prompting to go further.
- *Relevance of Science*: Students understand the relevance of science to the world around them on a surface level, but may need prompting to go further.

Faculty Discussion of Teaching in the Scientific Literacy AOI

On April 16, 2019, DCAC held an AOI Workshop on the Scientific Literacy AOI to engage AOI faculty around the results of the faculty review of student work.

Faculty in attendance discussed that the primary challenge for this AOI is to encourage deeper investigation or higher-order learning about scientific concepts. Faculty discussed that scientific literacy is both a body of knowledge and the application of this body of knowledge to generate new knowledge by making connections. Students are able to understand the body of knowledge, but may struggle with mobilizing these concepts for a deeper investigation and generation of new knowledge.

Faculty discussed the following barriers to achieving this goal

- The difficulty of balancing content and skills or "the body of knowledge" with the "why." In order to get to a deeper application of the body of knowledge, students need a foundation on which to build. Faculty discussed the struggle of balancing these often competing interests as well as students' relative disinterest in getting to the skills portion ("they just want to memorize") or discomfort when asked to discover and not given explicit instructions ("just tell me what to do").

- Intro courses. Many SL AOI courses are intro courses offered for majors where faculty need to cover specific content in order to prepare students for future classes. Non-majors who may not need this content for future classes, may not have an opportunity to develop the skills of scientific literacy.
- Large classrooms. Many SL AOI courses are lower level courses taught in large lecture classrooms where it is often difficult to achieve these outcomes, or have space for application-based assignments or activities.

Faculty discussed the following as opportunities to enhance achievement of this goal:

- Integration of concepts. More focus on integrating concepts within a course and within larger curriculum may encourage students to connect content and skills.
- Effective pedagogies. These include scaffolding, team/problem based learning, and use of case studies. These pedagogies help students integrate concepts so that they can understand the why of a scientific concept and not just the how or why.
- Intentional thinking about "what a non-major needs for scientific literacy." Non-majors don't particularly need content-specific knowledge. AOI courses should develop a conceptual understanding of science, and the skill to evaluate relevant scientific data.

Conclusions & Recommendations

Through student self-reported perceptions, faculty review of student work, and in-depth faculty discussions about student learning in this AOI, DCAC discovered that faculty grapple with how to encourage students to think further about science and apply scientific concepts to generate new knowledge. Faculty specifically wrestle with whether or not current curricular practices provide the opportunity for these deeper learning and ensure the best pathways for non-majors. To address these concerns, DCAC has developed the following recommendations.

Concerning course development,

1. Examine curricular practices that enhance all students' abilities to apply scientific concepts.
2. Investigate curricular practices that ensure the best pathways for non-major students. These models might include:
    a. Capping large intro courses
    b. Requiring just lab courses to meet outcomes #1 and 2
    c. Seminar-style courses
    d. Encouraging more interdisciplinary courses, not specific to majors
    e. Limiting AOI courses to upper classmen

Concerning pedagogy and practice,

3. Provide opportunity for faculty to learn new pedagogies and develop skills, including scaffolding, inquiry/problem-based learning, and case studies.

4. Provide best practices and resources (assignment design, course activities) to aid faculty in developing or improving AOI courses. Examples include the Case Study Resource Bank and the BlackBoard Community of Practice.

Concerning resources,

5. Investigate non-major pathways through the Scientific Literacy AOI to ensure that non-majors have expanded course options that provide the opportunity to develop the ability to apply scientific concepts. Data pertinent to this investigation might include:
    a. Students per course in SL AOI compared to other AOIs
    b. Non-majors in SL AOI courses compared to other AOIs
    c. Course load per faculty teaching AOI courses
6. Embed peer mentors in large science classes to allow faculty more time to spend on the application of knowledge, rather than learning the body of knowledge.

Appendix A

Data for Student Self-Perception of Skills

Students complete several institutional surveys that provide data about their self-reported perceptions of their own learning. These surveys include the Foundations of Learning Assessment taken before their Drake experience, and the Drake Student Survey taken in the spring. These data are compared in the Longitudinal Panel Study that examines students' change in their perceptions of their skills over time.

Table 1: Percent of Drake students (undergraduate and P1-P2 students) who have "Strong" or "Very Strong" skills in the educational goals of Drake, compared to previous years. (Source: 2018 Drake Student Survey)

Item	2018	2017
Read and understand scientific writings written for an informed lay audience	62%	65%

Table 2: Select Mean Scores from 2013-18 Longitudinal Panel Study ("How have you or your abilities changed in each of the following areas since coming to Drake?" 1=Much Worse, 5=Much Better). *Significance*: *=<.05, **=<.01, *Effect Size*: 0.30-0.50=Moderate

	Pretest Mean (FLA)	Posttest Mean (DSS)	2018		2017		2014	
			Sig.	Effect Size	Sig.	Effect Size	Sig.	Effect Size
Read and understand scientific writings written for an informed lay audience	3.33	3.80	**	0.42	**	0.44	**	0.34

Appendix B

Longitudinal Panel Study (2013-18)

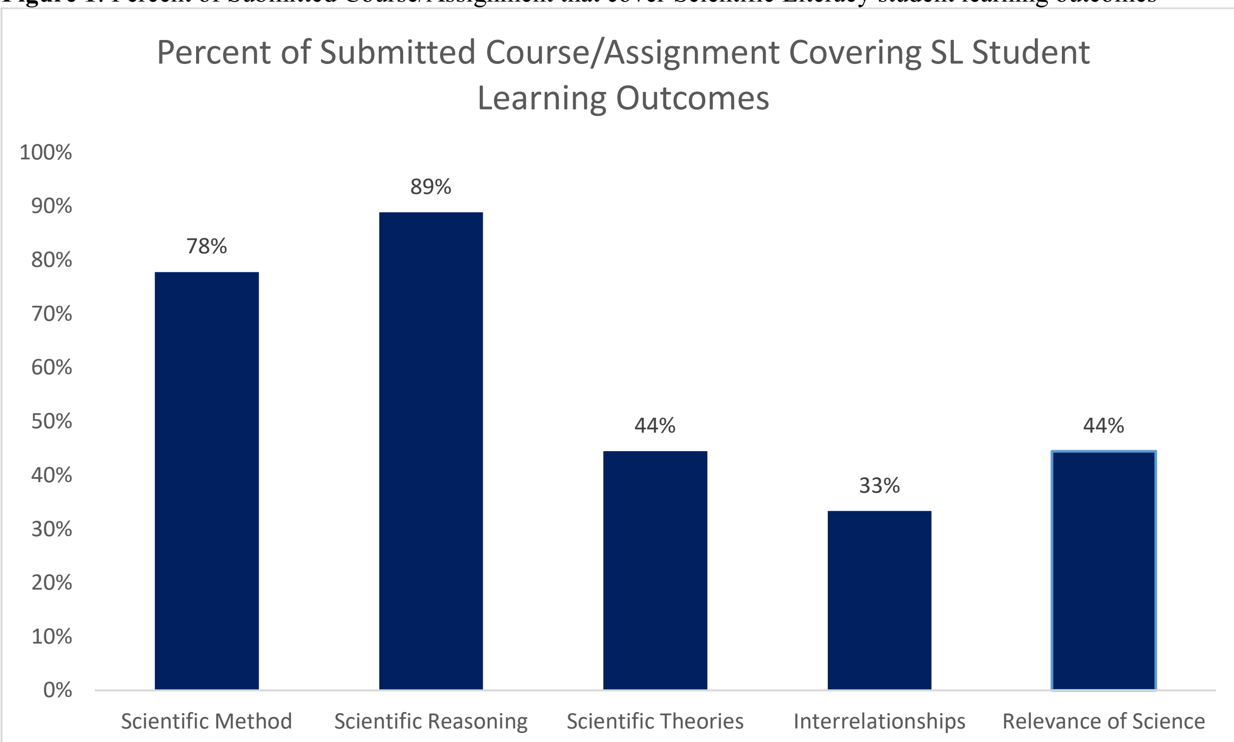
The Longitudinal Panel Study examines how students' perceptions of their skills change over time.

		Pretest Mean (FLA)	Posttest Mean (DSS)	95% Confidence Interval of the Difference		Repeated Measures Mean Comparison				2017 Comparison		2014 Comparison	
				Lower	Upper	t	df	Sig. (2-tailed)	Effect Size (*d*)	Sig. (2-tailed)	Effect Size (*d*)	Sig. (2-tailed)	Effect Size (*d*)
Pair 1	Ability to read carefully	4.12	4.26	.200	.086	4.94	796	.000	0.18	0.001	0.13	0.604	0.02
Pair 2	Employ evidence effectively in writing	3.85	4.20	.417	.295	11.54	794	.000	0.41	0.000	0.36	0.000	0.33
Pair 3	Construct reasoned arguments	3.92	4.25	.390	.269	10.67	795	.000	0.38	0.000	0.34	0.000	0.20
Pair 4	Evaluate reasoned arguments	3.95	4.25	.360	.239	9.69	793	.000	0.34	0.000	0.31	0.000	0.25
Pair 5	Evaluate the quality or reliability of information	3.86	4.23	.433	.304	11.25	791	.000	0.40	0.000	0.45	0.000	0.32
Pair 6	Understand the ethical issues related to use and misuse of information	3.86	4.31	.517	.379	12.69	794	.000	0.45	0.000	0.36	0.000	0.26
Pair 7	Create or interpret art (ex. Sculpture, painting, music, theatre)	3.00	3.06	.143	.030	1.29	790	.197	0.05	0.033	0.08	0.687	0.02
Pair 8	Understand the historical, political, and social connections of past events	3.58	3.75	.238	.096	4.60	790	.000	0.16	0.027	0.09	0.091	0.07
Pair 9	Analyze differences between industrialized and developing areas of the world	3.54	3.79	.322	.174	6.58	789	.000	0.23	0.001	0.13	0.320	0.04
Pair 10	Understand the perspectives and experiences of people who are different than you	4.00	4.23	.291	.159	6.70	789	.000	0.24	0.000	0.19	0.854	0.01
Pair 11	Read and understand scientific writings written for an informed lay audience	3.33	3.80	.541	.387	11.79	792	.000	0.42	0.000	0.44	0.000	0.34
Pair 12	Execute appropriate mathematical operations for a given question	3.75	3.77	.091	.048	0.61	788	.541	0.02	0.476	0.03	0.821	0.01
Pair 13	Ability to use educational experiences to analyze civic and global issues.	3.56	3.92	.430	.292	10.34	794	.000	0.37	0.000	0.40	0.000	0.23
Pair 14	Knowledge of how to participate effectively in the democratic process.	3.53	3.78	.332	.178	6.53	795	.000	0.23	0.000	0.46	0.008	0.11
Pair 15	Communicate effectively with people from other cultures and backgrounds.	3.79	4.12	.399	.255	8.92	794	.000	0.32	0.000	0.35	0.005	0.12
Pair 16	Articulate a vision of my own values, ethics, or core beliefs	4.09	4.23	.215	.076	4.09	790	.000	0.15	0.014	0.10	0.039	0.09
Pair 17	Apply understanding of ethical issues when developing solutions	3.80	4.15	.424	.294	10.79	793	.000	0.38	0.000	0.33	0.000	0.25
Pair 18	Ability to integrate skills and knowledge from different sources and experiences	4.01	4.29	.347	.222	8.96	793	.000	0.32	0.000	0.29	0.000	0.19

Appendix C
Coverage of Scientific Literacy Learning Outcomes

Faculty who submitted student work for review in the SL AOI also indicated the specific learning outcomes that corresponded to their assignment. This analysis of outcome coverage is shown in Figure 1 below.

Figure 1: Percent of Submitted Course/Assignment that cover Scientific Literacy student learning outcomes



This limited analysis of coverage of student learning outcome may indicate that Scientific Literacy (SL) AOI courses overly rely on learning outcomes (1) Scientific Method and (2) Scientific Reasoning. Because the courses analyzed came from a convenience sample of faculty who provided student work, DCAC requested AOI submission forms from approved SL AOI from the previous five years (2014-2018). However, in that time frame, only five courses have applied for the Scientific Literacy AOI, and no pattern could be determined.