Uncovering student learning in courses for non-science majors

Nicola C. Barber, Austin D. Hocker, Eleanor V. H. Vandegrift
Science Literacy Program, University of Oregon

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Introduction

Courses for non-science major students provide critical opportunities to share the value of science and promote a scientifically literate populace. To understand the content and goals of these courses, we looked at syllabi and final summative assessments of 15 non-science majors courses affiliated with the University of Oregon's (UO) Science Literacy Program (SLP). SLP courses emphasize creating active learning environments where science is interesting, engaging, and relevant to students. Faculty hope to create opportunities for students to engage critically with complex topics so students can grow as scientifically literate global citizens. We determined the emphasis of these non-science majors courses by coding syllabus learning goals and final assessments based on 1) Bloom's cognitive levels (2,3,5,6); 2) Next Generation Science Standards (NGSS) Science Practices (7,8); 3) NGSS Crosscutting Concepts (7,8); and 4) Science Literacy Behaviors (1).

Method

Three raters scored each item on summative assessments from 15 non-science majors courses affiliated with UO SLP in the following categories: 1) Bloom's taxonomy cognitive level (2,3,5,6); 2) NGSS Science Practices (7,8); 3) NGSS Crosscutting Concepts (7,8); and 4) Science Literacy Behaviors (1). After practicing reaching consensus on one assessment, two raters scored each assessment independently. A weighted mean Bloom's score for each assessment was calculated based on the average Bloom's level between raters and relative point value of each question (5). Nominal data was weighted to reflect percent of assessment points that mapped to each category and then averaged between raters. Intraclass correlation (ICC) or Fleiss' Kappa revealed moderate inter-rater reliability (Table 1). All syllabus learning goals and objectives were coded by at least two raters together to reach consensus.

Table 1: Three-reviewer inter-rater reliability scores

	Value	Confidence Interval
Bloom's, ICC	0.657	(0.54, 0.76)
Sci Practices, Fleiss' Kappa	0.373	
CCC, Fleiss' Kappa	0.247	
Sci Lit Behavior, Fleiss' Kappa	0.479	

Which cognitive levels are assessed in SLP courses?

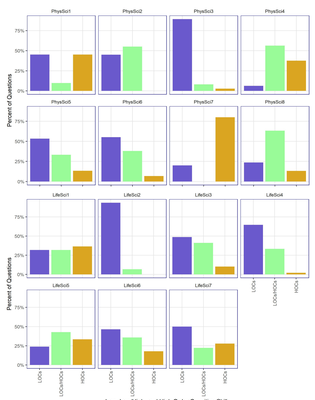

Figure 1. Percent of final assessment points at different cognitive levels in introductory Life Sciences (seven from Biology and Human Physiology) and Physical Sciences (eight from Astronomy, Chemistry, Earth Sciences and Physics) courses.

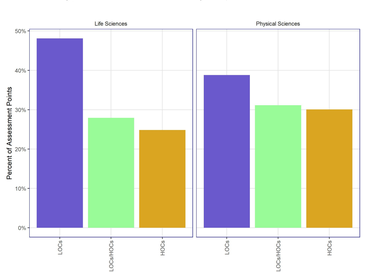

Figure 2. Percent of final assessment points at different cognitive levels in introductory Life Sciences (seven from Biology and Human Physiology) and Physical Sciences (eight from Astronomy, Chemistry, Earth Sciences and Physics) courses.

Bloom's Taxonomy

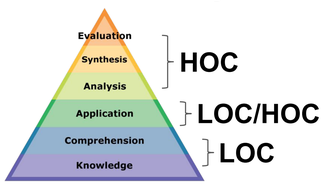

Figure 3. Bloom's taxonomy of cognitive levels. Lower order cognitive skill levels (LOCS). Higher order cognitive skill levels (HOCS) (4). LOCs were defined as mean Bloom's scores of 1.0-2.0, LOC/HOCs 2.5-3.5, and HOCs 3.0-6.0.

Cognitive level alignment of syllabus learning goals and final assessments

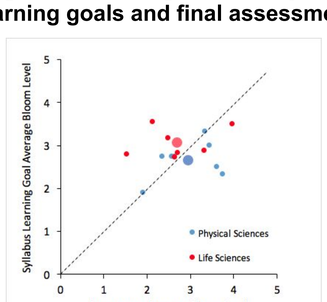

Figure 4. Relation of cognitive levels between stated syllabus learning goals and objectives and final assessment questions.

Science Practices, Crosscutting Concepts, and Science Literacy Behaviors

The Framework/NGSS Science Practices and Crosscutting Concepts were developed through an iterative process with public review by an expert panel of scientists and science educators as the foundation for K-12 science education and standards (7,8). We used these two dimensions because they were designed to capture science literacy across the scientific disciplines and are now integral components of non-science majors prior science education. There are frequently multiple overlapping Science Practices and Crosscutting Concepts in assessment items and learning goals and objectives and items were coded for the top three categories for each dimension. The Science Literacy Behaviors were developed by an iterative process with UO science faculty and graduate students who contributed potential science literacy behaviors (1). The list of behaviors was further refined through student confidence surveys. The Science Literacy Behavior list was analyzed through a principal component analysis so each of the individual items is representative of science literacy as a whole.

Which Science Practices are assessed in SLP courses?

Science Practices

SP1. Asking questions (for science) and defining problems (for engineering).
SP2. Developing and using models.
SP3. Planning and carrying out investigations.
SP4. Analyzing and interpreting data.
SP5. Using mathematics and computational thinking.
SP6. Constructing explanations (for science) and designing solutions (for engineering).
SP7. Engaging in argument from evidence.
SP8. Obtaining, evaluating, and communicating information.

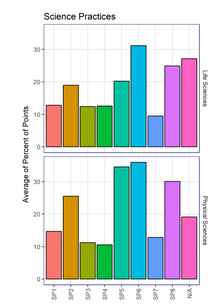

Figure 5. Distribution of assessment points that align to Science Practices for Life Sciences (seven) and Physical Sciences (eight) courses.

Which Crosscutting Concepts are assessed in SLP courses?

Crosscutting Concepts

CC1. Patterns
CC2. Cause and effect: Mechanism and explanation
CC3. Scale, proportion, and quantity.
CC4. Systems and system models.
CC5. Energy and matter: Flows, cycles, and conservation.
CC6. Structure and function.
CC7. Stability and change.

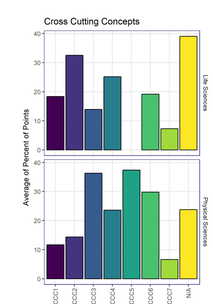

Figure 6. Distribution of assessment points that align to Crosscutting Concepts for Life Sciences (seven) and Physical Sciences (eight) courses.

Which Science Literacy Behaviors are assessed in SLP courses?

Science Literacy Behaviors

SLB1. Approaches societal issues from skeptical and critically reasoned perspective.
SLB2. Is aware of common societal issues that might be addressed by application of skeptical and critically reasoned perspective.
SLB3. Can critique claims and make information decisions.
SLB4. Can separate credible scientific information from opinion, conjecture, fabrication, and embellishments in advertisement.
SLB5. Identifies assumptions.
SLB6. Seeks out good information upon which to base decisions and opinions
SLB7. Understands how science works (e.g. the "process" of science, how scientists ask and answer questions using the scientific method).
SLB8. Understands science as presented in popular media (e.g., at level of The New York Times).

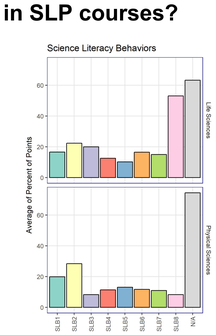

Figure 7. Distribution of assessment points that align to Science Literacy Behaviors for Life Sciences (seven) and Physical Sciences (eight) courses.

Use of science practices associated with Bloom's levels

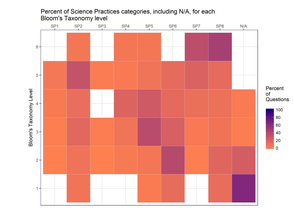

Figure 8. Heatmap showing the alignment to Science Practices of each level of Bloom's Taxonomy for final assessment questions. (Rows total 100%).

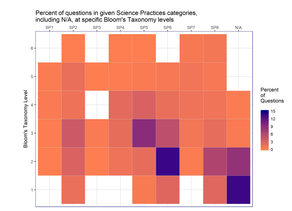

Figure 9. Heatmap showing the distribution of all questions aligning to a particular Science Practice and cognitive level. (Entire grid sums to 100%)

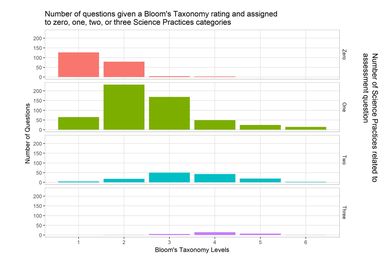

Figure 10. Assessment questions that align to more science practices require more higher order cognitive skills.

Science Literacy Behaviors are emphasized in syllabi more than assessments.

	Percentage aligning to ≥ 1 Science Literacy Behavior
Syllabus Goals	86.1 ± 19.1%
Assessment Points	43.9 ± 4.4%

Limitations

- This analysis only captures final, summative assessments. Other Science Practices, Crosscutting Concepts, and Science Literacy Behaviors may be emphasized in other course assessments.
- Although we found a moderately high level of interrater reliability for the Bloom's analysis, the interrater reliabilities for the Science Practices, Crosscutting Concepts, and Science Literacy Behaviors were moderately low.

Conclusions

- SLP instructors have reasonable alignment between cognitive level on syllabi and final assessments. Greater alignment than published data (5).
- Questions incorporating multiple science practices are associated with higher cognitive levels, which could be useful for future assessment development.
- Life Sciences and Physical Sciences have similar distributions of cognitive levels with a larger fraction of application questions in Physical Science courses.
- Science Practices are similarly distributed across Life and Physical Sciences with the exception of more math and computation in Physical Sciences and a lack of questions related to energy and matter in Life Sciences courses.
- Science Literacy Behaviors are emphasized in syllabi but less so in final summative assessments.

Future Questions

- What cognitive levels, Science Practices, Crosscutting Concepts, and Science Literacy Behaviors do students experience across all course summative assessments not captured in the final exams?
- How do different types of questions (MC, T/F, long answer) align with cognitive level and content?
- Are there Science Practices, Crosscutting Concepts, and Science Literacy Behaviors that are often emphasized in particular disciplines within Life Sciences and Physical Sciences?

Acknowledgements

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