Assessment of General Physical Science Education
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The Department of Physical Sciences is continuing to shift assessing student learning outcomes in the general education courses away from content-based assessment tools and toward process-based assessment tools. While many faculty members have adopted this philosophy years ago, the transition to having full scale adoption of a process that includes a single assessment tool to acquire this data has been long, and spring 2021 was the first semester where every general education physical science course was assessed with a process-based tool. The assessment was repeated in spring 2022 with the goal of comparing these years, starting to collect sufficient samples to determine trends, and evaluating the reliability of the assessment.

The Assessment Tool

The most prevalent tool utilized for general education physical science courses in higher education is the Lawson Classroom Test of Scientific Reasoning (CTSR) developed by Anton Lawson in 1978 and subsequently revised until 2000. While prevalence does not necessary correspond with efficacy, it has also been extensively validated and administered to multiple institutions. This data is warehoused in the PhysPort website and is constantly being updated by participating faculty members and institutions. Administering this tool allows the department to compare our assessment results with similar courses at other universities, in addition to benchmarking them against our program-level outcomes. Capturing this data provides an excellent starting point to building a strong general education assessment foundation.

This tool measures scientific reasoning across six domains 1) conservation of matter and volume, 2) proportional thinking, 3) probabilistic thinking, 4) correlational thinking, 5) control of variables, and 6) hypothetical-deductive reasoning. These skills are essential components to science courses and are typically included when defining scientific reasoning. These sills also align with the department’s program-level learning outcomes: 3) Analyze and interpret data using mathematics and computational thinking and 4) Construct explanations and engage in arguments from evidence.

Deployment System

This assessment had been administered by some professors at the section level. However, these data sets were primarily used by the instructor in appraising lesson plans and instructional techniques. In order to improve the reliability of the data and measure program outcomes, scaling the data acquisition to include more sections was necessary. This goal also aligns with the objective to move general education assessment to the departments. The challenges with this goal have been coordinating and integrating faculty members into the process. Coordinating an assessment that occurs roughly at the same time point in several sections, modalities, colleges, and teaching schedules posed a difficult undertaking. While this large-scale coordination was attempted in the past it proved cumbersome, difficult to implement and unlikely to be sustainable.

In fall 2020 the Learning About STEM Student Outcomes (LASSO) platform was piloted as a potential candidate for a large scale assessment data acquisition tool. This system was specifically designed for this type of deployment in administering, analyzing, and reporting assessment outcomes. It has 32 assessment instruments to choose from and is open source. This system was piloted with five sections across two classes. Unfortunately, the pilot was unsuccessful. At most, 1 student completed the assessment in each of the piloted sections. The platform is part of The University of Colorado’s Learning Assistant Alliance which had questions that were not pertinent to our student body and the assessment was being ignored due to coming from an external institution.

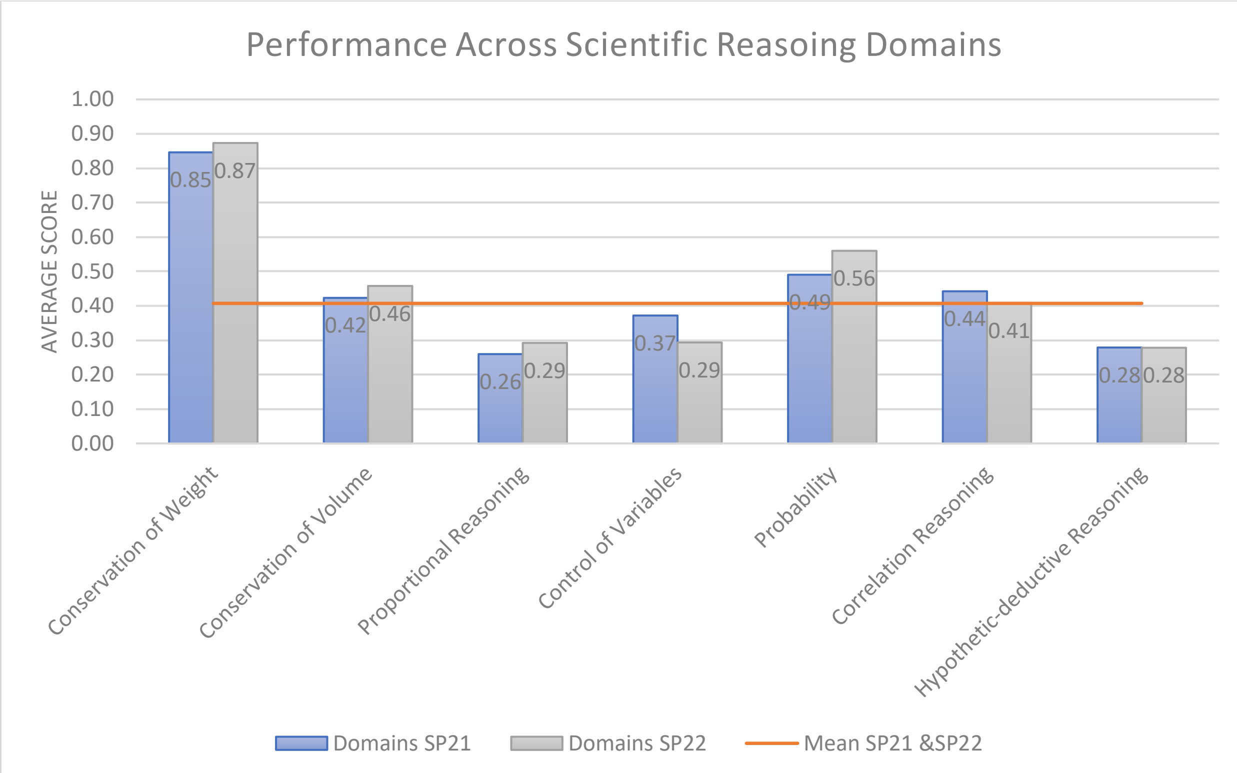
Although it is was clear that the LASSO system had limitations that prevented it from being incorporated into the department’s assessment process, the overarching process it used was still appealing. Therefore, a similar platform was developed within the Office 365 application suite. Utilizing Forms, Excel, Outlook, and Power Automate an instrument could be created, emailed to all of the students, and results stored in central location. Additionally, the form and email message could be customized for our students and be sent from the department liaison who could respond to questions or concerns. This system was developed and piloted in Fall 2021 and deployed to all students in Spring 2021 and Spring 2022.

Results

In spring 2022 there were 28 sections of Physical Science classes with 593 students initially enrolled. At the time of the assessment 434 students were enrolled across these sections. This was a significant decrease from the previous year's enrollment of 850 initial students and 638 students enrolled at the time of assessment. A total of 27 students completed the assessment giving these results a margin of error of 18% at a confidence level 95%. The spring 2021 assessment achieved a 10% margin of error where a 5% margin of error is the *de facto* gold standard and the goal of the assessment committee. The increase to 18% is partly due to the drop in enrollment which requires a larger fraction of the students to participate in the survey. Additionally, when reviewing student participation, not performance, there were clusters from specific sections. While the announcements to participated in the survey are sent to all students, there is reliance on faculty members to encourage student participation. This effect may be explained by some faculty members providing more encouragement to students.

Similar to previous assessments there is not sufficient data or knowledge of confounding variables to perform comparative analysis to external institutions or internal institutional dimensions (course, modality, etc) this assessment does allow us to compare relative performance across the six scientific reasoning domains. Additionally, as this was the same survey that was administered in the previous year, a historical timeline can start being recorded and both spring 2021 and spring 2022 can be compared.

Despite the low sample in spring 2022 the results were strikingly similar with the mean performances both being a 41%. These results show further evidence that appears contrary to anecdotal evidence in the department. It is often discussed that student's scientific reasoning is higher than their mathematics background. However, in these results from both assessments, students appear to be performing relatively well in conservation and probabilistic thinking, while their understanding of how to control for variables and hypothetic-deductive reasoning is significant lower. This type of reasoning is key in experimental design and to a large part of the scientific method. Seeing these same results at two snapshots one year apart is suggesting the assessment is reliable and this performance is gap is real. As mentioned in the previous year's report there may be significant difference between these performances in lab and non-lab classes, this point may need some reflection in the department and possibly retooling of laboratory practices. However, the shift to remote teaching may be affecting these some domains. Some possible solutions could be requiring students to perform more experimental setup, develop more open-ended problems, or even potentially even having students design their own experiments.



As this instrument has been validated in several education settings, it was not necessary to analyze its efficacy. However, an analysis of independence of the performance across these domains was conducted with a correlation matrix analysis. This analysis shows any dependencies within these domains. This could illustrate that particular classroom assignments have a larger effect on a subset of these domains. This analysis showed more moderate correlations across these domains than the previous year. However, the smaller sample size may be the predominant reason.

	Conservation of Weight	**Conservation of Volume**	**Proportional Reasoning**	**Control of Variables**	**Probability**	**Correlation Reasoning**	**Hypothetic-deductive Reasoning**
Conservation of Weight	1.00	0.35	0.18	0.42	0.29	0.01	-0.08
Conservation of Volume	0.35	1.00	0.50	0.68	0.41	0.33	0.07
Proportional Reasoning	0.18	0.50	1.00	0.60	0.51	0.66	-0.21
Control of Variables	0.42	0.68	0.60	1.00	0.67	0.38	-0.13
Probability	0.29	0.41	0.51	0.67	1.00	0.40	-0.09
Correlation Reasoning	0.01	0.33	0.66	0.38	0.40	1.00	-0.34
Hypothetic-deductive Reasoning	-0.08	0.07	-0.21	-0.13	-0.09	-0.34	1.00

Additionally, this new process allows disaggregation of the data by course, session, modality, or demographics. While this type of analysis is planned for future reports, additional safeguards need to be addressed first to ensure confidentiality and anonymity.

Conclusion

In spring 2021 the first large scale administration of a single assessment instrument across all of the general education courses offered in the Department of Physical Science was conducted. This was achieved by developing an online administration and acquisition platform in the Office 365 suite. The acquired results met the 10% margin of error at a 95% confidence level and showed the strengths and weaknesses of our students learning across six domains of scientific reasoning. This assessment was repeated in spring 2022. While there was a significant decrease in participation, the results were similar. While students initially appear to be performing relatively well in conservation and probabilistic thinking, their understanding of how to control for variables and hypothetic-deductive reasoning is significant lower. Based on the increased confidence in the reliability of the assessment, it will be administered in both the fall 2022 and spring 2023 terms. This may help to understand if there are differences in student learning between academic terms. Additionally, the larger number of time samples will provide invaluable information as classes and students transition from all the effects of the pandemic. This will allow us to better know if these results are “baseline” or “pandemic baseline”. Working from that, the department can implement techniques to improve how to control for variables and hypothetic-deductive reasoning as these domains are key in experimental design and the scientific method.