PHYSICAL SCIENCE DEPARTMENT

Unit-Level Assessment Liaison Report

Spring 2016

Liaison Project Start Date (Semester/Year): Spring 2016

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Department Buy-In and Outcome Definition

Chemistry

Because of the transition between assessment liaisons because of Prof. Allan Wilson's sabbatical, one of the main tasks for the department was to continue the implementation of the assessment plan in the chemistry discipline that Prof. Wilson had developed in prior semesters. Because of the relatively large number of faculty (both part-time and full-time) teaching chemistry in the Physical Science department, much of the assessment work conducted at the beginning of the semester involved coordinating the chemistry assessment activities, which involved administration of the assessment instruments to be described in Section II as pre-tests, among the faculty of the department. This involved carefully explaining the goals of the assessment practices as initially communicated to the chemistry faculty by Prof. Wilson at the end of the Fall 2015 semester.

Another aspect of administrating the chemistry assessments was addressing common questions that the faculty had about the instruments themselves; one of the most prevalent questions that the part-time chemistry faculty had was if they were allowed to review and analyze the results of the pre-tests after they had been completed by their students. After realizing that this was a common request, it was decided to make it clear that faculty were allowed and encouraged to review their own pre-tests results prior to submitting them to the liaison for compilation and analysis. We hope that this accommodation made it easier for adjunct faculty to be more willing to participate in the assessment efforts and allayed any fears that the assessments would be used to evaluate individual faculty. By the end of the initial assessment period that was completed by the second week of the semester, all but one of the chemistry faculty who taught a course that aligned with a selected pre-test participated in the assessment effort.

In terms of defining outcomes to be assessed, the chemistry assessment plan consists of utilizing existing exams produced by the American Chemical Society (ACS) Division of Chemical Education Institute that cover a wide variety of topics typically found in the undergraduate chemistry curriculum. Because these exams come from an external source, the current effort involves administering these exams to measure student understanding of chemistry that is expected to have been gained from a formal education in chemistry (such as a high school or college level chemistry course). Furthermore, the assessments are also being administered to gauge which of the current student learning outcomes contained in a respective chemistry course are addressed by a given ACS exam, which will help the department determine if (a) a different assessment instrument would be more appropriate to assess student learning in a given class, and (b) if the current set of student learning outcomes should be revised to accommodate the particular set of concepts and ideas contained in a given ACS exam.

Physics

In 2012, the physics discipline across the district finalized a multiyear effort to revise and standardize the student learning outcomes (SLOs) of the physics offerings in place at each of the City Colleges. This district-wide effort to develop SLOs was focused on the revision of individual courses and focused primarily on the content within each of the physics courses; in other words, these SLOs describe the abilities and skills a student should have after successfully acquiring an understanding of the physics concepts taught in a given physics course (i.e. classical mechanics, classical electromagnetism, etc.)

Alongside this effort, the physics faculty at Harold Washington College implemented and later revised an assessment plan that has now been in place for several years; the development of this assessment plan was driven in large part to help the Harold Washington physics faculty assess the proposed (and now finalized) SLOs that were being discussed and revised at district-level discipline meetings. The creation of our assessment plan was facilitated by many factors, but some of the most important resources that have informed this assessment effort come from results published by the Physics Education Research (PER) community.

For the past four years, the two full-time faculty members primarily responsible for teaching physics at Harold Washington have implemented the physics discipline assessment plan, which generally involves collecting pre- and post-test data from the appropriate sections of physics courses using the conceptual and attitudinal surveys detailed in Section II of this report. In the fall of 2015, we have expanded these assessment efforts to also include part-time faculty who now regularly teach the opening courses of the algebra-based and calculus-based introductory physics sequence (Physics 221 and Physics 235, respectively). While some of the logistics of administering the pre- and post-tests need to be streamlined to facilitate easier data analysis by the assessment liaisons, these are relatively minor details that are in the process of being addressed with clearer and more precise instructions to the adjunct faculty. While some of the adjunct faculty in physics have expressed some concerns about the amount of class time dedicated to administering the assessment instruments, they have to this date fully participated in the assessment plan by administering the pre- and post-tests and sharing their assessment data with the appropriate faculty in the department.

Assessment Research and Design

Chemistry

As previously mentioned, the assessment tools currently utilized in the 100 and 200-level chemistry courses originate from the ACS Division of Chemical Education, which are comprehensive instruments intended for summative assessment of undergraduate chemistry students. As such, these instruments are widely used at many institutions to allow comparisons of the performance of students at various points along the typical undergraduate chemistry curriculum; for example, many institutions use these instruments as the final exam for the appropriate chemistry course (e.g. First-Semester General Chemistry or Second-Semester Organic Chemistry). While there are definite advantages for using the ACS exams for assessment at Harold Washington College (i.e. they allow for comparisons to national norms and are quite detailed and thorough in their treatment of the course material), these instruments are quite time-consuming to administer; many of the ACS exams require about 50-60 minutes of class time, and some ACS exams require almost 2 hours to administer. Furthermore, none of the ACS exams can be administered online, which is an increasingly accepted practice in the science education community if the appropriate safeguards to maintain the integrity of the assessment and their results are adhered to. Therefore, while the department is continuing the practice of basing our chemistry assessment practices on ACS exams, we will begin to reconsider the use of these instruments for assessment purposes in the near future, particularly as we begin to analyze the assessment results from Spring 2016.

Some initial research has uncovered alternative instruments that may be suitable for use as pre- and post-test assessments for both Chemistry 121 and Chemistry 201, which together comprise a majority of our course offerings in the chemistry discipline each semester. For example, the Chemistry Conceptual Inventory (CCI) is a 22-question multiple-choice instrument tailored toward students enrolled in the first-semester of general chemistry and was created to elicit responses based on the common alternate conceptions about several important topics discussed in first-semester college chemistry (Mulford & Robinson, 2002). This instrument is widely referenced in the chemical education field, and the smaller number of questions and intended audience would make it easier to administer as a pre- and post-test without involving as much class time as the current ACS exams require.

Physics

As previously mentioned, the assessment instruments used in physics have not been customized or home-grown tools; instead we have been able to take advantage of the research in physics education and utilize instruments that are research-based, have been studied using appropriate statistical analysis and interviews with undergraduates and experts in the field, and have been administered at many different colleges and universities. For example, in both Physics 221 (algebra-based classical mechanics) and Physics 235 (calculus-based classical mechanics), we have administered the Force Concept Inventory (FCI) (Hestenes, Wells, & Swackhamer, 1992), which is the most widely used concept inventory to probe student understanding about forces and motion in both secondary and higher education. In the second-semester of the algebra-based physics sequence (Physics 222), the electricity and magnetism portion of the course is surveyed using the Conceptual Survey of Electricity and Magnetism (CSEM) (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001), while in the calculus-based electricity and magnetism course we have used the Brief Electricity and Magnetism Assessment (BEMA) (Ding, Chabay, Sherwood, & Beichner, 2006).

The department assessment plan in physics is designed not only to measure gains in conceptual understanding, but also shifts in students' attitudes about physics and physics courses. This is conducted by utilizing a research-based Likert scale survey that allows us to compare the student response to a Likert item to the "favorable" response that an expert in physics might provide. In prior years the physics discipline had originally used the Maryland Physics Expectations Survey (MPEX) (Redish, Saul, & Steinberg, 1998) as the probe of student attitudes; over the past two semesters we have replaced the MPEX with a similar instrument that was intended to improve the wording of questions and to probe additional student beliefs about physics. This instrument is commonly known as the CLASS (Colorado Learning Attitudes about Science Survey) (Adams et al., 2006), and variants of this instrument have been developed for other science disciplines such as chemistry and biology. Some of the questions from the CLASS were selected for use in the recent Natural Science general education assessment; in the physical science department we are utilizing the entire instrument. By administering this instrument as a pre- and post-test, we can measure the shifts in students' beliefs from "novice-like" to "expert-like", which is a typical analysis method used to compare student attitudes at the beginning and end of a given science course.

Pilot Assessment Tools and Processes

Chemistry

Because of the department's prior experience using the aforementioned ACS exams for various purposes (primarily enabling placement strategies for Chemistry 121 and 201), the repository of ACS exams for other topics in the undergraduate chemistry curriculum was a natural option for the initial round of assessment. However, the chemistry faculty realize that the ACS exams may not be the most suitable instrument for unit- or program-level assessment here at Harold Washington College, which is why the initial results of the assessment will be useful to help the department determine if alternative assessment instruments might be a better fit for our particular student population. In the meantime, the department has standardized on a reproducible procedure for assessing the full array of chemistry courses using the existing ACS exams (which are under constant revision by the chemistry education community). This process is described in the next section, which provides more details about the specific instruments used in a given chemistry course.

Physics

As previously mentioned, the assessment practices of the physics discipline have been in place for some time; the typical assessment process for the semester is to administer the previously described conceptual and attitudinal surveys as both pre- and post-tests. By administering the same instrument at the beginning and end of the semester, matched data sets (i.e. data from students who completed both the pre- and post-test) can be used to quantify learning gains on an individual student basis; however, the department only uses these individual learning gains to determine the average learning gain for a given course (which usually is comprised of a single section with the exception of Physics 221 and 235, which typically involve two sections per semester). In the 2015-2016 academic year, the department introduced two new assessment instruments to probe student learning in the third-semester calculus-based physics course (Physics 237): the Heat and Temperature Conceptual Evaluation (HTCE) (Thornton & Sokoloff, 2001) and the Quantum Physics

Conceptual Survey (QPCS) (Wuttiprom, Sharma, Johnston, Chitaree, & Soankwan, 2009). These newly discovered instruments will now allow the department to claim that every "core" physics course in the discipline has an appropriate research-based instrument suitable for use as a pre- and post-test.

Determining learning gains through pre- and post-testing allows the department to compare our assessment results at Harold Washington with the results that have been published in the literature from comparable institutions. More specifically, we define learning gain in terms of the average *normalized gain* (Hake, 1998) which is a quantitative measure of how much students learned as a percentage of their potential learning:

$$< g > = \frac{< \text{post} > - < \text{pre} >}{100 - < \text{pre} >}$$

where brackets indicate class averages. The normalized gain is commonly described as amount of conceptual knowledge gained by the students divided by the amount they potentially could have learned. By administering the appropriate pre- and post-test in a given physics course, it is possible to calculate the normalized gain for a given physics course; this information can then be used as evidence to support specific curriculum reforms or compare physics programs from one institution to another. More granular analysis can be done to look at normalized gains from a demographic standpoint, which is a common research strategy in the physics education research community. This can allow the department to investigate how the effect of specific curriculum reforms on students based on their gender, prior coursework, educational background, or some other demographic differentiator.

Administer Specific Assessment

Chemistry

During the 2015-2016 academic year, several versions of examinations published by the ACS Examinations Institute were administered at both the beginning and the end of the semester in Chemistry 121, 201, 203, 205, 207, and 212. Each chemistry course was assigned a corresponding exam to be administered before formal instruction that primarily involved material that students would be expected to have learned in the prior chemistry course, with the exception of Chemistry 121, which is a course that requires no previous chemistry instruction and therefore was not assigned a corresponding pretest. An instructive example is the pre-test for Chemistry 201. This course utilizes the ACS Toledo Exam as its pretest; this exam is used as a placement exam at many undergraduate institutions and includes questions that probe mathematical background, general chemistry knowledge, and specific qualitative chemistry knowledge.

Almost all of the relevant chemistry sections chose to participate in the assessment at the beginning of the Spring 2016 semester; the same sections that participated at the start of the semester also agreed to administer a different ACS exam at the end of the semester. The ACS exam selected as a post-test at the end of Spring 2016 had also been previously administered at the end of the Fall 2015 semester. The posttest was also selected from the ACS exam repository of standardized assessment instruments for a particular undergraduate chemistry course and was chosen with the intent of probing what a student had learned in the course they had just completed. Therefore, in many cases the post-test chosen for a given course was used as the pre-test for the subsequent course in the chemistry sequence (e.g. the Chemistry 203 pre-test was also used as the Chemistry 201 post-test).

Because different exams were used as the pre- and post-tests in chemistry, while we can determine the percentage of students who correctly answered a particular question or group of questions that can be clustered together, we cannot directly calculate a normalized learning gain as previously described in the description of the physics assessment plan. However, we can use these instruments to determine a baseline measurement for student understanding on relevant chemistry topics at both the beginning and the end of a given chemistry course, as well as compare our results to national averages of students who took the same exams as part of their undergraduate chemistry curriculum. Further data analysis will help the department determine if the current strategy of using different instruments as pre- and post-tests should be revised in favor of one where we use the same instrument as both the pre- and post-test, which would allow for a direct calculation of normalized learning gain.

Physics

During the 2015-2016 academic year, at Harold Washington College there was at least one section offered of one of the "core" physics courses in either the algebra-based sequence (Physics 221 and Physics 222) or the calculus-based sequence (Physics 235, 236, and 237). Each course administered a pre- and post-test at the beginning and end of the respective semester; the only exception was in the case of Physics 237, which contains three somewhat distinct topics in the course outline that are only loosely connected. Therefore, two pretests were administered in Physics 237: one at the beginning of the semester before the start of formal instruction in thermodynamics (the HTCE), and another one (the QPCS) after ten weeks of instruction had elapsed but before any formal instruction in 20th century physics had begun. Both of these instruments were again administered as post-tests at the end of the semester. Each physics course also administered the CLASS instrument as a pre- and post-test, as the CLASS is intended to survey student attitudes about learning physics independent of the specific physics content addressed in a course.

By administering these instruments as pre- and post-tests, the department is able to directly calculate normalized gains (in the case of the conceptual surveys) or determine attitudinal shifts (in the case of the attitudinal surveys). One opportunity for the department can be to compare and contrast the different approaches to assessment selected by the chemistry and physics discipline and discuss among the department the advantages and disadvantages to each approach.

Data Analysis

Chemistry

A significant amount of student data has been collected at the end of the Spring 2016 semester, and we hope to produce some analysis of this data during the summer of 2016. This analysis will hopefully assist the department in refining our assessment protocol in chemistry before the start of the Fall 2016 semester.

Physics

The analysis of the assessment data gathered during the 2015-2016 academic year is progressing; this analysis has been recently assisted by the discovery of an online tool that will allow for easier data management, assessment scoring, and statistical analysis and visualization. The PhysPort Data Explorer (currently in open beta at http://physport.org/DataExplorer) will also allow the data from Harold Washington College to contribute to a nationwide database of assessment results. These results will help inform physics instructors across the nation make sense of their own results by analyzing and searching for national patterns in assessment data. While we look forward to becoming more familiar with this tool, we can also report on prior results of assessment data in physics.

After determining the normalized gain for the appropriate instrument for either first-semester physics (the FCI) or second-semester physics (either the CSEM or the BEMA, depending on the physics course), we have determined the typical normalized gain in first-semester physics at Harold Washington ranges from 30% (typical for Physics 221) to 45% (typical for Physics 235). These results compare favorably to the average normalized gain of 22% for a wide variety of physics courses taught throughout the United States and Canada using traditional lecture methods. However, a similar large-scale survey of courses taught using interactive engagement methods usually demonstrate higher normalized gains (39% on average).

A similar disparity between the algebra-based and calculus-based sequence is found when looking at the second semester; in these courses Harold Washington students usually exhibit normalized gains that range from 20% on the CSEM (for Physics 222) to 40% on the BEMA (for Physics 236). Once again, the gains shown in the calculus-based sequence are in line with the results that have been published by universities using interactive engagement techniques in their physics courses (typical normalized gain of 40%) while the gains demonstrated by our algebra-based physics students at the low end of the range of normalized gains that have been reported in the literature (15% to 40%). However, the published studies of the assessment instrument used in second-semester algebra-based physics do not distinguish between teaching methods when reporting their results.

Analysis of the attitudinal surveys previously conducted in physics courses at Harold Washington demonstrate that students exhibit the behavior found in most physics classes nationwide at all levels of instruction, in which students' beliefs typically worsen or at best remain unchanged. In other words, by the end of the typical physics course, students generally provide fewer favorable responses, as their beliefs about problem solving, sense making, and connecting physics to the real world become less common to those of experts. These results are independent of the instrument used to probe these beliefs about physics. The only positive result we can take from the attitudinal surveys is that our physics courses typically show no shift in favorable responses, which suggest students' beliefs do not change much during their one to two semesters of physics. One analysis described our assessment data in this way: "Your zero shift means you are not doing any harm to your students' beliefs, which is better than what happens in most physics classes."

Supporting Evidence-Based Change (Use of Findings)

The current state of assessment data in first-semester physics has allowed the physics faculty to identify the need to promote some of the active-learning techniques developed by the PER community (such as peer instruction, clickers, or cooperative problem solving), which have shown to produce higher normalized gains. This is especially true in the case of the Physics 221 course, where enhanced efforts to mentor and support adjunct faculty teaching this course are planned as a direct response to some of our assessment data. Similarly, the difference in performance between the algebra-based and calculus-based physics students on the electricity and magnetism assessments suggests the need to be more proactive about implementing within the Physics 222 curriculum the research-based teaching methods that have shown to produce increased student learning gains. As for the potential reforms in the chemistry discipline, a plan of action will await more detailed analysis of the assessment data that we have collected from the 2015-2016 academic year.

Success Factors

Prior to the start of the 2016-2017 academic year, it is planned for the unit-level liaisons that contributed during the previous academic year to share our assessment results and determine a course of action for both the future assessment activities of the department as well as the dissemination of these results throughout both the department and the college. This will enable us to build on the increased awareness within the department among all faculty about the importance of assessment in the physical sciences.

The recent series of workshops on assessment held on April 8th were also quite productive; both Prof. Philip Vargas and Prof. Anthony Escuadro presented a brief workshop highlighting some of the assessment practices adopted by the Physical Science department. While attendance at the two workshops was light, it seemed that many of the participants were genuinely interested in the types of data analysis we employ to make sense of our assessment data. Many participants also openly asked how these techniques could be employed in their own discipline.

Recommendations

Beyond the aforementioned recommendation of wider dissemination of our assessment practices, one of the main priorities for the department will be to evaluate our assessment processes among the different disciplines, weigh the strengths and weaknesses of the various approaches, and look for opportunities to improve them using the shared knowledge of the department. We also look forward to the prospect of introducing the attitudinal surveys currently used in the physics courses among the chemistry courses as well. This will allow us to expand our plans to look more carefully at the attitudinal results we currently possess from our physics courses to see if there are demographical trends in the shifts of students' beliefs that can inform more targeted curricular reforms.

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