General Education-Level Student Learning Outcomes Area C, Natural Sciences Requirement Assessment

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Area C: Natural Sciences Requirements
Upon completion of this coursework, a student will be able to:
1. communicate scientific ideas and theories effectively
2. demonstrate an understanding of the scientific method
3. apply models to explain the behavior of commonly occurring phenomena
4. evaluate how measurement errors impact the application of scientific models

Group Insights and Reflections
What we’ve discovered through the assessment process:
• Most, if not nearly all, people do not know of the existence of the GE-level SLOs for the Associates Degree.
• Many people, who were then shown these SLOs, did not fully understand SLO #4 and subsequently there were various interpretations of it.
• When there was assessment of SLO #4 being done, it was most frequently being done in a laboratory context and thus predominantly only showed up in those courses that have a lab component.
• Of the courses that are a strict lecture only, or within the lecture component of a combination course, there were very few direct assessments of SLO #4 and was predominantly only being treated as a concept to give ‘lip service’ to within the lecture materials and thus no actual assessment of the SLO was being performed.

Our Recommendations and Actions based on our observations:
• The GE-level SLOs for the Associates degree needs to reach a broader audience. We therefore suggest that these SLOs are sent to the Departmental Chairpersons on a regular basis. More specifically, when a course that falls within Area C is about to undergo a revision to its Course Outline of Record, the Department Chairperson and the COoR Outline Preparer should be made aware of these GE-level SLOs.
• The inclusion of the assessment of this SLO needs to reach into more courses, especially those without a laboratory component. We therefore suggest that Department Chairpersons, in consultation with their faculty, should consider whether or not this is an important part of the curriculum within their respective domains. If it is, then the inclusion of some assessments within their courses needs to be addressed. If not, then perhaps this SLO can be modified or even removed.
• Some of us will be specifically implementing assessments of SLO #4 as a result of participating in this group, while others are will be discussing the SLO at departmental meetings to determine its applicability and examine current COoR Major Learning Outcomes for modification.
• Since there does not exist a mechanism whereby courses are removed from this GE-level SLO list, we suggest that SLO #4 undergo a revision to alleviate some of the widespread interpretations of it. Specifically we suggest that it be broaden in scope and context to lend itself to quantitative interpretations, but also qualitative interpretations.
• We also recommend that a survey be administered to Department Chairpersons designed to ascertain their knowledge of the GE-level SLOs and how applicable these SLOs are to each of their respective domains.
Lastly, we recommend offering a professional development workshop during Flex-Days to build awareness and a culture around these GE-level SLOs.
Specific Examples and/or Comments Concerning Area C Courses

ANAT 14
Students are not specifically assessed on their understanding of this SLO.

ASTR 1, 4, 14, 17, 18, 19
Students are not specifically assessed on their understanding of this SLO.

ASTR 16 (Lab)
1. Currently, the best possible precision with which we are able to measure the parallaxes of stars is a precision of ± 0.001 of an arcsecond. Assume this is the accuracy of the parallax measurement of the star in question #2 above. In other words, the star’s parallax angle might be a little as 1.319” or as much as 1.321”. What, then, is the closest possible distance in parsecs that the star might be to us? What is the greatest distance it might be to us?

Additionally, there is a technique called “spectroscopic parallax.” The method of spectroscopic parallax estimates the distances to stars by the energy distribution of the light emitted by the stars (the “spectra” of the stars) to estimate how much total light they emit. Then the distances to the stars are estimated by comparing this estimate of how much total light they emit to how bright or faint they appear in Earth’s sky. Spectroscopic parallax is therefore not a true parallax measurement at all, but it is a useful alternative method for estimating how far away stars are. Spectroscopic parallax can be uncertain in its estimate of a star’s distance by as much as 30%, but the method has the same ±30% reliability for any observable star at any distance from Earth.

1. Compare the result of your calculation to the direct measurement you made with your meter sticks. They will probably not be exactly the same, but they should be close. Comment.

2. Calculate the % difference between the calculated and the measured distance to the object. Here’s how to do that:
   \[
   \text{% difference} = 100\% \times \frac{\text{calculated value} - \text{measured value}}{\text{measured value}}.
   \]

3. Assuming you made no mistakes in your calculation, the difference in your results arises from unavoidable inaccuracies in your measurements. Taking parallax measurements of this sort is tricky business. All factors considered, how accurate do you feel it was possible for you to be with your measurements? Describe at least three significant problems that you encountered while trying to take your measurements. Do you feel that the % difference between your results can be accounted for by the difficulties you were experiencing? In general, does the parallax method appear to work well for determining distances? Summarize and comment in a short paragraph.

BIO 9
Per our conversation, BIO does not have a SLO that meets this specific requirement (although we do have SLOs that we are tracking). We are open to creating SLOs that meet GE guidelines/needs, so please keep us in mind if there is a next step to this process. We'd be happy to work with you.

BIO 11
I have the students write up two papers where they have made measurements and then analyze the data. They sometimes discuss errors in measurement and how that caused a misinterpretation of the data.

INSERT PAPER DOCS HERE
BTEC 120
The following survey is administered to the class at the end of the semester. The survey is anonymous and students are encouraged to answer truthfully. To encourage full participation, students will be granted extra time on an exam if all surveys are completed and returned. \textit{[Only Applicable Excerpts Included - tmrc]}

The following “learning outcomes” are specified in the official course outline for this 5-unit lecture/lab course. Estimate the level of learning for each outcome from 1 to 10, with 1 being low and 10 being high \textit{(this survey and its results will not impact your course grade)}.

\textbf{Circle a number from 1 (didn't learn much) to 10 (learned alot)}

\begin{itemize}
    \item E. Apply critical thinking in data analysis including statistical and graphical analysis, and in the interpretation of the experimental results.
    \begin{itemize}
        \item 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10
    \end{itemize}
    \item G. Describe and interpret the fundamental importance of molecular and cell biology in the fields of medical pharmaceutical, agricultural, and environmental science.
    \begin{itemize}
        \item 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10
    \end{itemize}
    \item H. Assess and discuss the value and consequence of the application of the techniques of molecular cell biology on the fields of medical, pharmaceutical, agricultural, and environmental science
    \begin{itemize}
        \item 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10
    \end{itemize}
\end{itemize}

CHEM 110
Students are not specifically assessed on their understanding of this SLO.

CHEM 32
The concept of buffers is an important concept in biological chemistry. The body’s pH must be kept at about 7.14 in order for the human body to survive. In lecture, the concept of a buffer is discussed. In the lab, students are asked to prepare their own buffer, measure the properties of the buffer, and using these techniques, determine if several types of common medications are behaving as buffers or not.

Students are taught how to calibrate and use pH meters in order to measure changes in pH upon addition of acids and bases to their buffer solutions. To prepare their buffer solutions, students must carefully measure the volumes of the chemicals used.

To decipher if students understand what a buffer is the following attached lab question was asked on a quiz. After going over the results, a similar type of question will be asked in lecture on their comprehensive final exam.

Preliminary results are as follows (based on 31 students):
All parts a, b and c correct: 13 students (42 %)
Parts a and b correct: 8 students (26 %)
Parts a and c correct: 5 students (17 %)
Only part a correct: 22 students (71 %)
All incorrect: 3 students (10 %)

Part a) correct: 29 students (94 %)
Part b) correct: 14 students (45 %)
Part c) correct: 9 students (29 %)

\textit{Lab quiz 2 given during the Fall 2011 semester}

4. A tablet of an unknown drug X was dissolved in 100 mL of distilled water. 30 mL of this solution was placed into a beaker and labeled solution 1 and another 30 mL of the same solution was placed into a
beaker and labeled solution 2. To solution 1, you added 0.1 M HCl and to solution 2 you added 0.1 M NaOH. In the table below, you recorded the following information:

<table>
<thead>
<tr>
<th></th>
<th>Initial pH</th>
<th>pH after 10 drops of 0.1 M HCl</th>
<th>pH after 25 drops of 0.1 M HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>solution 1</strong></td>
<td>7.43</td>
<td>7.41</td>
<td>7.40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Initial pH</th>
<th>pH after 10 drops of 0.1 M NaOH</th>
<th>pH after 25 drops of 0.1 M NaOH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>solution 2</strong></td>
<td>7.44</td>
<td>7.45</td>
<td>8.98</td>
</tr>
</tbody>
</table>

a) Based on the above information, is drug X behaving as a buffer after the addition of 10 drops of HCl and 10 drops of NaOH? Clearly explain your reasoning.

b) Based on the above information, is drug X behaving as a buffer after the addition of 25 drops of HCl and 25 drops of NaOH? Clearly explain your reasoning.

c) If your answers to part a and part b above indicate a difference in the behavior, provide a reasonable explanation as to why the behavior changes.

**Same type of question, second version**

4. A tablet of an unknown drug X was dissolved in 100 mL of distilled water. 30 mL of this solution was placed into a beaker and labeled solution 1 and another 30 mL of the same solution was placed into a beaker and labeled solution 2. To solution 1, you added 0.1 M HCl and to solution 2 you added 0.1 M NaOH. In the table below, you recorded the following information:

<table>
<thead>
<tr>
<th></th>
<th>Initial pH</th>
<th>pH after 10 drops of 0.1 M HCl</th>
<th>pH after 25 drops of 0.1 M HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>solution 1</strong></td>
<td>7.43</td>
<td>7.41</td>
<td>6.03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Initial pH</th>
<th>pH after 10 drops of 0.1 M NaOH</th>
<th>pH after 25 drops of 0.1 M NaOH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>solution 2</strong></td>
<td>7.44</td>
<td>7.45</td>
<td>7.43</td>
</tr>
</tbody>
</table>

a) Based on the above information, is drug X behaving as a buffer after the addition of 10 drops of HCl and 10 drops of NaOH? Clearly explain your reasoning.

b) Based on the above information, is drug X behaving as a buffer after the addition of 25 drops of HCl and 25 drops of NaOH? Clearly explain your reasoning.
c) If your answers to part a and part b above indicate a difference in the behavior, provide a reasonable explanation as to why the behavior changes.

**BUFFER SOLUTIONS**

Buffer solutions are aqueous solutions that keep a constant pH (therefore, a constant concentration of $H^+$) upon the addition of small amounts of acid ($H^+$) and base ($OH^-\)$. Buffer solutions can be designed to have any pH value.

To create a buffer solution in the laboratory, you need two ingredients (in addition to water). A buffer is made of up a weak acid and its salt (conjugate base) or a weak base and its salt (conjugate acid).

A weak acid is an acid that does not completely dissociate in water. For example, hydrofluoric acid, HF, is a weak acid. Its’ dissociation can be written as follows:

$$HF \text{ (aq)} \rightarrow H^+ \text{ (aq)} + F^- \text{ (aq)}$$

A solution of only HF contains mostly HF (aq), and very little $H^+$ (aq) and $F^-$ (aq). We can also write the dissociation of HF in water as follows:

$$HF \text{ (aq)} + H_2O \text{ (l)} \rightarrow H_3O^+ \text{ (aq)} + F^- \text{ (aq)}$$

Either equation is okay. The second equation shows that HF donates an $H^+$ to water to form $H_3O^+$, thereby forming $F^-$. In this equation, HF and $F^-$ is a conjugate acid/base pair, whereas $H_2O$ and $H_3O^+$ form the other conjugate acid/base pair. NOTE: $F^-$ (aq) is the conjugate base of HF (aq).

For a solution to be a buffer, one must mix a weak acid with its’ corresponding salt. The corresponding salt is an ionic compound that gives the conjugate base of the weak acid upon dissociation in water.

NaF (aq) is a salt that will dissociate to give $F^-$ (aq) in water. It happens to be a strong electrolyte, but that doesn’t really matter. What is important is that it delivers the conjugate base of HF.

$$NaF \text{ (aq)} \rightarrow Na^+ \text{ (aq)} + F^- \text{ (aq)}$$

When the weak acid HF is mixed with its’ corresponding salt, NaF, we have the following expression (it looks identical to the weak acid alone, but the concentration of $F^-$ is much greater!)

$$HF \text{ (aq)} \rightarrow H^+ \text{ (aq)} + F^- \text{ (aq)}$$

Having a large amount of the weak acid and its’ salt is what makes a buffer solution. The $H^+$ concentration must remain constant upon addition of $H^+$ or $OH^-$. When acid, $H^+$, is added to a buffer solution comprised of HF and NaF, the concentration of $H^+$ remains the same because $F^-$ will react with the added $H^+$, keeping the original amount of $H^+$ the same.
The concentrations of F\(^{-}\) and HF will change, but the concentration of H\(^{+}\) remains the same. When base, OH\(^{-}\), is added to a buffer solution comprised of HF and NaF, the concentration of H\(^{+}\) remains the same because HF will react with the added OH\(^{-}\), thereby keeping the H\(^{+}\) constant. If no HF were present, the OH\(^{-}\) would react with the H\(^{+}\) to form water, thereby decreasing the amount of H\(^{+}\).

\[
\text{OH}^{-} (aq) + \text{HF} (aq) \rightarrow \text{H}_{2}\text{O} (l) + \text{F}^{-} (aq)
\]

The concentrations of HF and F\(^{-}\) will change, but the concentration of H\(^{+}\) remains the same. The amount of water formed in the above reaction is very small in comparison to the amount of water present in the solution.

Listed below are some examples of the components that can be mixed to form a buffer solution.

a. HF and NaF  
b. HF and BaF\(_2\)  
c. H\(_2\)PO\(_4\) and LiH\(_2\)PO\(_4\)  
d. H\(_2\)CO\(_3\) and KHCO\(_3\)  
e. HSO\(_4\)^{1-} and SO\(_4^{2-}\)  
f. NH\(_4\)OH and NH\(_4\)Cl

**GEOG 10**  
Students are not specifically assessed on their understanding of this SLO.

**GEOG 49**  
Students are not specifically assessed on their understanding of this SLO.

**GEOL 10**

As a member of this committee, I generated a set of questions to use in my own course that address the GE SLO we chose to focus on this semester as well as informally interviewing colleagues about their methods of assessing this SLO. In speaking with colleagues, specifically teaching Geography, Geology and Physics, it became obvious immediately that most faculty are unaware of these SLOs.

**Errors in Measurement SLO #4 Questions**

1. A geologist misidentifies a blue schist as being a mica schist. How might this error impact his or her interpretation of the geologic history of that region?
2. Determining an accurate age for Earth was a challenge until the mid 20\(^{th}\) Century. Throughout the 19\(^{th}\) Century, measurements were wildly inaccurate and typically far too young. Describe how these errors in measurement affected other scientific models being developed at that time.
3. During weathering, some of the radiogenic lead in a zircon escapes. How will this affect U-Pb dates for that zircon?
4. During a study of an off-shore fault, geologists underestimate the amount of vertical offset the fault is capable of. What type of hazard might be missed by this error in measurement?
5. A geologist makes an error in measuring the dip of a gold bearing vein. Assuming his measurement is too low, how will this error affect efforts to locate the same bed below the surface?
Above are samples of new exam questions I generated to begin assessing student learning outcomes for general education SLOs in my courses. The first question appeared on my second exam. Responses were scored for this project using the following rubric:

<table>
<thead>
<tr>
<th>Points</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No answer or answer does not recognize rock types as metamorphic.</td>
</tr>
<tr>
<td>1-2</td>
<td>Answer recognizes that misidentification of rocks will affect interpretation.</td>
</tr>
<tr>
<td>3-4</td>
<td>Answer also recognizes rock types are metamorphic.</td>
</tr>
<tr>
<td>5-6</td>
<td>Answer also recognizes model that explains formation of blue schist as different from mica schist and correctly predicts error.</td>
</tr>
</tbody>
</table>

Results aggregated for both sections appear below:

<table>
<thead>
<tr>
<th>Points</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 points</td>
<td>19%</td>
</tr>
<tr>
<td>1-2 points</td>
<td>38%</td>
</tr>
<tr>
<td>3-4 points</td>
<td>34%</td>
</tr>
<tr>
<td>5-6 points</td>
<td>9%</td>
</tr>
</tbody>
</table>

This preliminary analysis suggests that a greater emphasis on this domain is needed. My goal is to see at least 80% in the upper two categories.

**GEOL 11**
Students are not specifically assessed on their understanding of this SLO.

**GEOL 18**
Students are not specifically assessed on their understanding of this SLO.

**MB 12**
Per our discussion last week Microbiology 12 (lec/lab) meets the area C requirement. I am attaching a word document that may help you in the assessment of SLO 4. I hope that you find this example relevant and useful.

1. Students are expected to prepare a serial dilution of a food sample and prepare pour plates to generate a quantitative assessment of colony forming units (CFUs) of bacteria per gram or ml of original sample. Raw and pasteurized milk samples are used for comparison.
   a. Students are instructed in the aseptic use of serological pipettes, dilution calculations and scientific notation. Students learn the impact that errors of measurements in various areas can have upon their results: incorrect reading of pipette meniscus; improper preparation of dilutions; carry over of excess solution during pipetting; improper evacuation of pipette; excess heat in pour plate leading to inviability of bacteria; improper aseptic technique and the possibility of increased numbers of bacteria due to contamination
   b. Assessment: students are graded based on their ability to competently demonstrate the above techniques. They are also asked to perform dilutions and plating in triplicate and to average results and omit outliers. Students perform independent plate counts and only compare results with team members at the conclusion of the experiment to avoid experimental bias. Different teams perform the experiment on like samples and compare results upon conclusion of the methods to see if there are
significant differences in plate counts. Specifically grading is based upon aseptic use of pipettes, pour plating and calculations involving serial dilutions and plate counts. Plates with < 25 CFU’s are disregarded as statistically insignificant and can be due to pipette errors or contamination alone. Plates with >250 CFU’s are considered too numerous to count. Students must express results in terms of numbers of CFU’s per original gram/ml of sample and in scientific notation. Students generate a report whereby they must identify the various aspects of error listed above and the impact that they may have upon their results.

**OCAN 1**
Students are not specifically assessed on their understanding of this SLO.

**PHYC 10**
Students are not specifically assessed on their understanding of this SLO.

**PHYC 40**
Students are not specifically assessed on their understanding of this SLO.

**PHYC 41**
Students are not specifically assessed on their understanding of this SLO.

**PHYS 12**
Each lab exercise requires students to analyze data collected by the entire class and to write a report including conclusions based on their related hypotheses. They are asked to consider why the results of each experiment are what they are which often leads to the discussion of measurement error. I do not have this written out. Instead, I go over it as a mini lecture/chalk talk at the beginning of the semester in lab. I do not address this in the lecture portion of the course.

**P SC 11**
Students are not specifically assessed on their understanding of this SLO.