Introduction

Effective education begins with a plan and is evaluated by assessment of learning. Principle 2 at Indiana University Northwest has several learning outcomes. Of interest here are those related to the section on the sciences where students are expected to

- recognize and understand how scientific theories are formulated, tested, and validated.
- approach problems using scientific methods, which include: defining parameters of problem, seeking relevant information, subjecting proposed solutions to rigorous testing, and drawing conclusions based on the process.

In general education science courses, one can teach and assess these outcomes most readily in laboratory sections.

Methods

To assess the level of student achievement of these outcomes in Biol L100 labs, an introductory general biology course for non-majors, we identified questions on the lab final practical exam that related to general biological knowledge and others that related to understanding and application of the scientific method. For the lab final of spring 2011, we chose two lab sections and designated questions 1-38 as general biological knowledge and questions 39-44 as related to the scientific method. For the latter, questions involved general application of the scientific methods (e.g. asking if a scientist can “prove” a hypothesis correct) as well as application to specific lab research they performed (e.g. do the data collected “prove” the hypothesis).

The sample size of students was 30. We determined the percentage of students getting each question right and calculated mean and standard deviation of percentage correct for questions 1-38 and the same for questions 39-44. We then compared the statistical significance of any difference in means by a two-tailed t-test (two-tailed because we had no a priori prediction of how well we were teaching general content vs. scientific method material).

Sometimes statistical tests on percentages can be misleading if data values are consistently near 100% (certainly desired!) but that was not the case here. Also, there has been a tradition of data transformation of percentage data, specifically \( \arcsin \sqrt{\text{proportion}} \); however, recent analyses suggest this transformation is not valid. Therefore, we used untransformed data (percentage of students getting a question correct).

We also compared number of students scoring >73% (i.e. those of a grade C or greater) and the number scoring <73% (C- or lower) for each part of the exam. The pattern in data were tested by a chi-square test of independence.
Results

The mean correct for questions 1-38 was 58.2% (sd=16.0) and the mean correct for questions 39-44 was 65.0% (sd=15.0). On the face of it, these percentages suggest that students performed better on the questions related to their understanding of and application of the scientific method. However, the t-value=0.98 with a $p \approx 0.15$, which is $>0.05$ suggesting the trend is not statistically defensible.

The following table compares students scoring above or below 73% on each part.

<table>
<thead>
<tr>
<th>Section of the Exam</th>
<th># Students Scoring &lt;73%</th>
<th># Students Scoring &gt;73%</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Questions</td>
<td>23</td>
<td>7</td>
</tr>
<tr>
<td>Sci. Method Questions</td>
<td>19</td>
<td>11</td>
</tr>
</tbody>
</table>

The chi-square test of independence has a $\chi^2 = 1.27$ with df=1 and $p>>0.10$. This result suggests that the proportion of students earning a grade of C or better was statistically equal on the general questions compared to the scientific method questions.

Interpretation

It appears that students do not answer questions on the scientific method any better than they do questions of general content. Furthermore, the percentage correct is low for either set of questions.

Implications for Assessment

While it is comforting that students do not perform worse on questions concerning knowledge of and application of the scientific method, our data do not support the converse. And percentage correct for all questions is too low. This analysis suggests that we should discuss how we are teaching both content and the scientific method. We should also consider increasing the number of questions on the scientific method, because only 6 questions makes it difficult to detect a statistical trend. Also, we should aim to include all labs, in order to increase our student sample size well above 30.

Assessment During Spring 2012

For the final exam of Spring 2012, we included all lab sections (95 students). This sample size is much larger than our previous analysis (30). We used the same methodology described above. Students scored correctly the “methods” questions at a rate of 72.2%. The “general content” questions were scored correctly at a rate of 64.8%. Both of these percentages are well above those in the previous assessment, suggesting that students are performing better in the 2012 spring semester on the lab final exam. A t-test comparing these percentages gives a $t=0.97$, $p\sim 0.2$, suggesting that students score equally well on the two types of questions.

Most encouraging is the increase in percentage correct for both types of questions, especially that the method questions have moved into the C grade range. Perhaps our attention to assessing both types of learning has improved our overall teaching effectiveness.
But what is not readily apparent from the larger data set is the variation among instructors! For example, one instructor teaching two sections had 90% of her students get the scientific methods questions correct, while another instructor in his two sections had 59%! I would interpret this to be two things operating: the latter instructor is harder and has less emphasis on scientific method instruction! Therefore, it is clear we need to even out instruction and ensure that all instructors emphasize instruction of the scientific method.