Inventorying Conceptual Understanding of Basic Biology Ideas

Kathleen Fisher & Kathy Williams
(with Dianne Anderson & Mike Smith)

Assessment Methods and Foci

Fisher explored naive conceptions about evolution and especially natural selection over a period of 5-7 years. This was culminated in the Ph.D. work with Dianne Anderson to produce both the Conceptual Inventory of Natural Selection (CINS) and a series of concept cartoons on natural selection. Interviews were conducted with major and non-major biology students to assess the validity of the natural selection items. The items were also completed by several biology faculty with unanimity on the choice of correct response.

Since 2001, Williams and Fisher have taken primary responsibility for programmatic assessment of biology learning among biology majors at SDSU. Over the last 3 years, Dianne Anderson at Point Loma Nazarene University and Mike Smith at Mercer University, as well as faculty at SDSU and local community colleges have been key collaborators on the development of assessment instruments ("subtests") focusing on naïve conceptions in the following areas:

- Natural selection (involving minor modifications of CINS)
- Cell Division (the biggest challenge being to create questions to assess understanding without using technical genetics language that could trigger fact-recall responses)
- Osmosis and Diffusion (involving minor modifications of earlier items developed by Odom and Barrow)
- Energy & Matter Transformations (the least developed to date)

Most subtests contain paired items, in which one item poses a question and the following item asks for your reasoning. Others, like CINS present an authentic scenario and pose questions about it. In all cases, items are designed to help us learn how our students are thinking about specific essential concepts.

We also have begun developing items on the nature of science and have tested some in recent classes. In addition, our biology colleagues would like us to expand to include items addressing a larger view of cell division (including regulation), as well as molecular biology. We plan to conduct systematic interviews with students this year to help validate our items.

Assessment Instruments and Administration

Assessments are administered as ungraded pre- and post-tests in upper division core courses in biology at San Diego State University. In addition, we have some data from lower division non-major and major courses including general biology and microbiology for pre-nursing students, collected at SDSU and local community colleges.

Since the relevant classes are large, we divide the students into subgroups, and each subgroup receives a different subtest. Thus, students are answering questions on topics not necessarily closely related to the topics covered the course. This is because the Biology Department is interested in learning about the basic capacities and knowledge of our biology students to help us improve the whole biology curriculum, including biology, chemistry, math, and physics courses. Our goal is to analyze results using covariates indicating such things as which courses students previously completed, campus where lower division prep was completed, and learning methods used in the prior courses as well as in their “current” course.

Initially subtests were deployed on paper and graded using ParScore, but soon after, we began using web-based tools. At first we used an SDSU survey service, since our course management system (Blackboard) was not adequate. Beginning this semester **we** are using the new Blackboard testing feature which is supposed to provide item responses (unlike previous versions). Data have been collected and evaluated for each test item using point bi-serial and difficulty values.

Analysis of Results

We use the term “diagnostic test” to describe a multiple choice test in which the incorrect responses reflect common naive conceptions (aka “pre-conceptions” or “misconceptions”). Diagnostic tests seem to be ideal tools for programmatic assessment for the following reasons. The average score of a diagnostic test is much lower than that on a traditional test, the scores tend to be stable across a given group, and gains (improvements) are made slowly. Our test results confirm our expectations, in that a) biology majors perform better than pre-nursing students who perform better than other non-majors, b) university students perform better than community college students, and c) in any sequence (major or non-major), students generally perform a little better with each successive year in school.

Diagnostic tests also can reveal striking differences between classes of a single subject taught by different instructors or among different semesters, as ours have shown. And perhaps most importantly, diagnostic tests can give valuable feedback to individual instructors about what big biology ideas were learned successfully and which were not. Our challenge will be to generate interest among the faculty of our department to actually use the data we provide to modify their curricula and instruction.

Current Status

In our first few semesters, we were modifying test items with each successive pre-test and post-test to improve their effectiveness. We also have been adding one new course into the assessment loop each semester. Thus, focusing on the stable data, by the end of this academic year we will have, 3 years (six semesters or six pre- and post-tests) of data for Biology Major Course A, 2 years for Biology Major Course B, and one year for Biology Major Course C, and accompanying data from introductory Biology courses for some subtests. We have found that radar graphs (in MS Excel) are excellent means for representing and comparing results.

Three graduate students working with Dianne Anderson at Point Loma Nazerene University will begin helping with more detailed data analyses of the Osmosis and Diffusion, Cell Division, and Natural Selection data sets. In addition they will conduct interviews with students regarding their interpretations and reasons for selecting particular responses on those subtests.

A Note on Big Ideas in Basic Biology

Some processes, such as osmosis/diffusion and cell division, are considered trivial by biology faculty because they assume that by now college students have learned them. In fact, we understand that California has just removed photosynthesis items from their standardized biology test "because students learn that in middle school." Yet nothing could be further from the truth, as shown by many studies, including ours. These processes are so fundamental that they affect many higher levels of understanding in physiology, genetics, medicine, climate change, etc. Thus we think of these as some of the Big Ideas, or critical concepts, in basic biology that are essential to constructing accurate higher-level knowledge and skills.

Natural selection is probably the single most misunderstood idea in all of evolution, and thus is a Big Idea or critical concept that binds all of biology together. Transformations of matter and energy appear to be total mysteries for large parts of our populations, and deep understanding of those concepts is central to science knowledge also. Even simple state changes are not comprehended by many. So there is much work to be done in these areas to understand how our students are thinking about biology, chemistry, and physics learning. We have elected to focus our energies on understanding how our students are thinking about those Big Ideas

Right now it seems, as suggested by Kathy Garvin-Doxas, we fall into two categories: 1) those who are involved or have been involved in the development of instruments that assess or measure students' conceptual understanding, and 2) those who work to develop pedagogies that enhance students' conceptual-level understanding in the biological sciences. Ideally, we want to establish close ties between conceptual-level assessment and conceptual-level instruction so that each can inform the other.