Development of a Suite of Concept Inventory Tests for Use in General Chemistry Courses

Background
A recent national survey has shown that instructors of chemistry courses believe that conceptual understanding is one of the most important outcomes of a chemistry education. Often though, this conceptual understanding is tested through examinations that are predominately algorithm-oriented, the assumption being that success on an algorithmic exam is an indication of conceptual understanding. This assumption has come increasingly under attack, particularly in light of research that demonstrates that students can perform calculations correctly while having conceptual difficulties. There is hence a need for tests that assess a students’ conceptual understanding separately from their algorithmic skill. A few such exams do exist, however they indicate only that a conceptual difficulty exists and do not give an indication of the specific misconception that is causing the difficulty. More useful are instruments that allow a determination of whether or not students have a scientifically correct conceptual understanding and also indicate what misconceptions the student holds. With this information, instructors can determine the effectiveness of their instruction and also alter their teaching methods appropriately to address the students’ misconceptions.

One successful example of this kind of diagnostic instrument is the “Force Concept Inventory” (FCI). The FCI is a 29-question multiple-choice test that covers basic concepts from Newtonian mechanics in which the distractors are based on the most commonly held misconceptions as determined by interviews and open-ended problems. This instrument has proven very successful in identifying conceptual difficulties students have and has become the most extensively used diagnostic in physics education. My proposal is to develop, validate, and disseminate a suite of multiple-choice tests, similar to the FCI, that will assess the conceptual knowledge of students and diagnose their misconceptions across five general chemistry topics. The proposed instruments will also provide a means of assessing different pedagogical methods.

Development
Instrument Content
Each conceptual inventory will focus on one of the topics which are listed in Table 1.

<table>
<thead>
<tr>
<th>Table 1 Topics for Concept Inventory Tests</th>
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<tr>
<td>Stoichiometry</td>
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<td>Atomic Structure</td>
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<td>Gas Laws</td>
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<td>Phase Changes</td>
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<td>Equilibria</td>
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These topics were chosen because of their relevance to the general chemistry curriculum and to the existence of a previous research into misconceptions in these areas, with the exception of atomic structure. However much of this research used high school students as subjects so misconceptions common to college students may not have been documented. To address this, open-ended problems, free-response questions, and interviews will be utilized to obtain a more complete list of misconceptions.
Instrument Design

Each topic will be decomposed into the general concepts that comprise it, e.g., the topic “Equilibrium” may be decomposed into the concepts:

- Rates
- Dynamic Nature of Equilibrium
- Equilibrium Constant
- LeChatelier’s Principle

Each concept in turn can be further decomposed into specific concepts that the student must understand in order to be considered having conceptual understanding. For example the general concept “Dynamic Nature” may be broken down into the specific concepts:

1. Equilibrium is when the forward and backward rates are equal.
2. Both forward and backward rates occur simultaneously.
3. The forward and backward rates are never zero.
4. The same macroscopic state is arrived at regardless of direction of approach.
5. Equilibrium is reversible.

Once the specific concepts are identified, the known misconceptions can be matched with a specific concept. As an example, eleven misconceptions about equilibrium have been documented and the ones that are relevant to specific concept #2 are:

- The forward reaction must go to completion before the reverse reaction commences.
- Dynamic equilibrium is a “back and forth” oscillation between reactants and products.

Several multiple-choice questions addressing each misconception will then be developed, with distractors based upon each misconception. Using several questions aimed at the same misconception will allow a pattern of conceptual difficulty to be detected and so one may interpret consistent errors on those questions as an indication that a students holds that particular misconception.

Validation

After an inventory has been developed, correlation coefficients among the questions that comprise it will be calculated to ensure that questions which are intended to target the same misconception in different manners do in fact address this same misconception. The instruments will then be piloted by a small group of voluntary students who are enrolled in a general chemistry course. External validity will be determined by correlating the scores of this pilot group on the inventory with their responses on essay questions, quizzes, and interviews. Any needed revisions will be made and the instrument will be re-validated; this cycle will continue until validity is achieved.

Project Growth

Future plans involve developing similar inventories for topics such as bonding, thermodynamics, and electrochemistry. To accomplish this, research into the misconceptions that students have about these subjects must be undertaken. Preliminary results of the research into
student understanding of demonstrations that I am currently involved with has already provided some background that will be useful in a more thorough investigation of misconceptions of these topics.

Bibliography