Exam script analysis—A powerful tool for identifying misconceptions

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As part of a wider study of student understanding (Read, George, King and Masters 2004), a detailed analysis of the Semester 1, 2003 CHEM1405 (Chemistry 1 for Veterinary Science) examination was carried out. This analysis used both quantitative (statistical) and qualitative methods. Qualitative analysis focussed on evidence of misconceptions and commonalities in student approaches, both correct and incorrect. While university exams are primarily used for summative assessment purposes, this poster paper is intended to highlight some of the other information available from exam script analysis.

On the surface, the exam appears to have been an effective, if perhaps too easy, test for students in the CHEM1405 unit of study. Unscaled exam marks ranged from 30% to 95%, with a mean mark of 70.8% and a median of 73%. While there is some evidence of skew towards higher marks, the distribution remains approximately normal, with 68.8% of marks within one standard deviation of the mean, and 95.7% within two standard deviations. Beyond supporting the conclusion that the exam may have been too easy, and showing that it fulfilled its purpose as a summative assessment tool, these results are not terribly informative, and certainly do not tell the full story of the exam.

The exam itself can be divided into four approximately equally weighted sections—multiple choice and short answer questions in both general/inorganic (hereafter 'inorganic') and organic chemistry. Figure 1(a) shows the results from the short answer section, classified into exam grade bands, and Figure 1(b) shows the scatterplot of individual marks in the short answer sections.

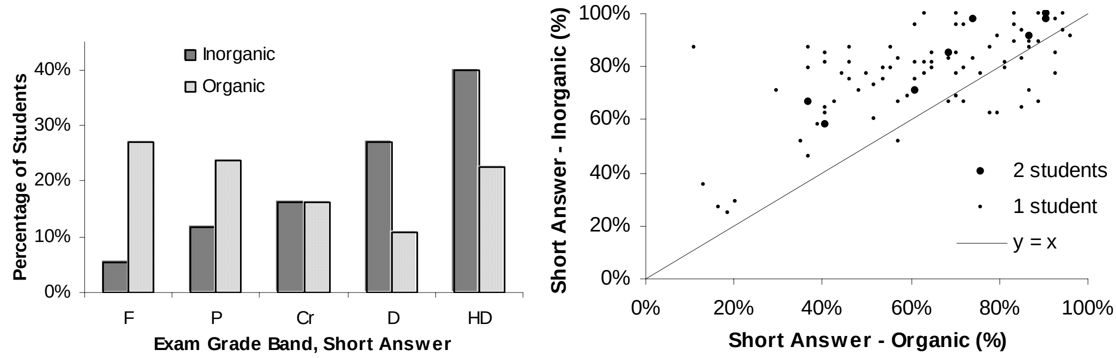

Figure 1. (a) Distribution of exam grade bands and (b) Scatterplot of marks in the short answer sections of the exam.

It is can be seen from Figure 1(a) that the marks are not normally distributed within the short answer sections, and that student performance in the inorganic section (modal HD) was considerably better than in the organic section (modal F). This is confirmed by the scatterplot, Figure 1(b), where the 95% confidence interval of the mean ratio of inorganic to organic (I:O) mark is 1.30 ± 0.08, after excluding the outlier (I:O = 7.88). In other words, students' scored on average about 30% more marks in the inorganic short answer section than they did in the organic short answer section.

Incorrect answers can also provide significant insight into the misconceptions held by students. Consider, for example, the multiple choice question: 'Which of the following elements is *unlikely* to be redox active in biological systems?' The options were (A) Li, (B) Fe, (C) V, (D) Mn, and (E) W.

Figure 2(a) shows the distribution of answers given for this question. In Figure 2(b), students have been classified by overall exam grade performance, and the rate at which the correct answer (A) was given by each group is shown. So, for example, of students who failed the exam none got this question correct, while 50% of students who scored HD (mark = 85+%) got the question correct.

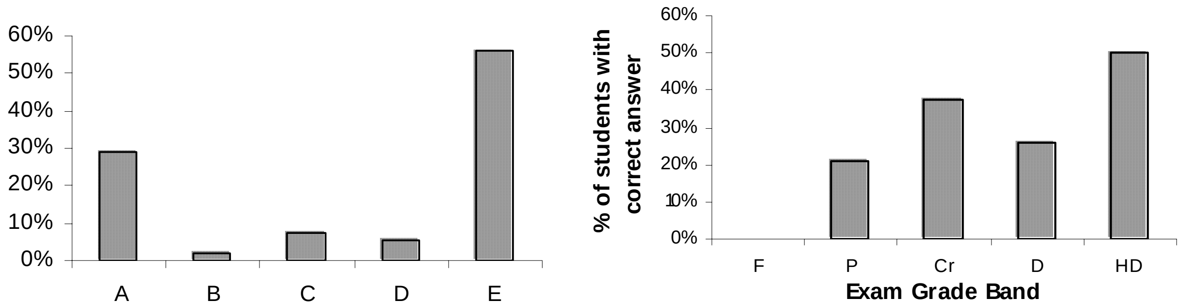

Figure 2. (a) Distribution of answers and (b) Rate of correct answer for the above multiple choice question.

It is clear that students systematically chose tungsten over lithium as the answer to this question, and that there was some weak correlation between performance on this question and overall performance. However, the popularity of the tungsten answer also points to the existence of misconceptions regarding the redox properties of both lithium and tungsten in a biological setting.

Questions on osmotic pressure and acid/base chemistry also pointed to misconceptions regarding these concepts. In the case of osmotic pressure, 76% of students could correctly calculate the osmotic pressure of a glucose solution, but 40% of this group could not report the answer correctly, offering a variety of incorrect units (e.g., atm L^{-1}, atm K^{-1} mol^{-1}, L K^{-1} mol^{-1} and even MJ mol^{-1}). In the case of acids and bases, 77% of students could correctly write equations showing what happens when acid or base is added to a named buffer system—suggesting a good understanding of buffers. Despite this fact, when asked to calculate the pH of an ascorbic acid solution (given K_a), more than half attempted to use the Henderson-Hasselbalch equation, which suggests that the understanding of buffers is much weaker than the marks on the buffer question would suggest.

One organic chemistry question asked about the amino acid cysteine (Cys) and Cys-Cys, its dipeptide. Amongst students who correctly drew the amino acid, 47% could not draw the dipeptide. Around half of this group offered answers which did not contain a peptide link, or did not conserve the molecular structure of Cys, or failed to follow bonding rules. These answers suggest that misconceptions persist in students' understanding of fundamental chemical principles, well beyond the area being directly examined in this question.

Analysis of exam scripts allows us to identify both problems with exam structure and misconceptions held by students. Knowledge in both of these areas can be used to guide improvements in future instructional courses, materials and assessment tools.

References

Read, J.R., George, A.V., King, M.M. and Masters, A.F. (2004) Students' perceptions of their understanding in Chemistry 1 for Veterinary Science. *Proceedings of the UniServe Science Symposium on the Scholarly Inquiry into Teaching and Learning*, Sydney: UniServe Science.