**Using Alignment and Reflection to Improve Student Learning**

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Greater participation, and the associated increase in student diversity, has changed university education worldwide. The old ways of teaching a small number of well-qualified committed students do not work as well with large classes and more diverse student needs. This essay documents one approach to this challenge. It involves understanding student needs and preferences better, developing a range of ways to deliver learning and assess the results, and finally reflecting on the outcomes. The annual process of reflection allows changes that improve alignment of course aims with their delivery and assessment, and results in improved student learning and perception of the subject.

**INTRODUCTION**

Increased participation in university-level education worldwide in the late twentieth century (Scott 1995) involved a change from education for the elite to education for the masses. In the UK, participation increased from 6% of under-21s in the 1960s to about 43% of 18–30-year-olds in 2003. At the same time, funding per student in the UK fell by 36% in real terms between 1989 and 1997 (Department for Education and Skills 2003). Increased participation means greater diversity in student abilities, experiences, preconceptions and misconceptions, learning expectations, and career intentions (Archer and Hutchings 2000; Leathwood and O’Connell 2003; Jones and Thomas 2005). In this diversity with fewer resources, there are challenges. How can they be successfully addressed?

An added challenge: how to help students engage with a subject they consider boring (see 1998 student comments on mineralogy in Table 1)? Students must learn much factual mineralogical information that they will need to succeed in subsequent petrology and geochemistry courses (e.g. chapter 3 in Bransford et al. 2000, for a discussion of knowledge transfer), even if some may consider such knowledge irrelevant to today’s students (Eaton 1995).

This essay is based on the changes made to improve a first-year University of Liverpool course in which mineralogy is introduced together with aspects of petrology and geochemistry. Almost all of the enrolled students are geoscience or ocean science majors, though the majority have never studied geology before. My solution involved determining how my students wanted to receive learning material while making sure they understood what was expected of them in terms of commitment, how I would help them learn, how assessments would demonstrate it had happened, and how this course would help them in the future.

This approach, I subsequently learned, had much in common with Biggs’ theory of Constructive Alignment (Biggs 1999, 2003), which has had great credence at all levels of UK education. Biggs’ premise is that curricula should be designed so that the learning activities and assessment tasks are aligned with the intended learning outcomes (e.g. an essay is a great tool to assess students’ ability to evaluate concepts such as uniformitarianism, but not a good tool to assess their ability to recognise minerals). Reflection on what happened will help formulate modifications, which in turn will improve alignment and promote better learning (was the assessment unintentionally confusing in some way?). The constructive part means that students construct their own learning from the learning activities (e.g. active learning or problem-based learning), rather than just being guided by an expert (e.g. lecture). My course design took on the concept of alignment, but did not take a strictly constructivist approach. My instinct was to guide students through their learning (lectures) and give them opportunities to practise the required skills (formalised practicals) rather than use a purely constructivist learning approach. In recent publications on guided versus constructivist approaches (e.g. Jervis and Jervis 2005; Kirschner et al. 2006), it has been suggested that the advantage of guided over unguided problem-based approaches begins to diminish only when learners have sufficiently high prior knowledge to provide their own “internal” guidance. First-year students need help and guidance.

**GET TO KNOW YOUR STUDENTS’ LEARNING PREFERENCES**

Diversity can be ethnic or cultural, but in education it includes variations in student learning styles and preferences. Most teachers know, anecdotally, that different students learn differently. Much research has been done on this topic (e.g. Kolb 1984; Gardner 2000; Entwistle 2001), and studies suggest that learning-style differences do affect how learning takes place, such that some students may be advantaged or disadvantaged by a particular learning mode (i.e. lecture). However, setting up individualised learning for each student’s preferences is not the answer pedagogically or logistically (see Coffield et al. 2004 and Draper 2005 for excellent reviews). A better approach is to bear in mind student diversity but not be a slave to it; as Sadler-Smith...
(2001, p. 300) noted, student and teacher awareness of learning preferences can help in “enabling individuals to see and to question their long-held habitual behaviours”. In other words, individuals can be taught to reflect on why they select a particular learning style or strategy, to understand if it was the right choice, and to change if necessary. It is no longer good enough to say, “I see recent graduates from my courses talking at international conferences so my teaching must be OK”. These are the students who will succeed however they are taught and are not representative of the whole student body. The challenge is to enable all students to succeed, and for this, educators need to “question their long-held habitual behaviours”.

My department uses the VARK questionnaire (Fleming and Mills 1992, http://www.vark-learn.com) as part of its new-student induction programme. VARK is a simple questionnaire that assesses preferences for four sensory modes of learning (Visual, Aural, Read/write, and Kinaesthetic) through 16 everyday questions. For example, if someone asked you for directions somewhere, would you draw a map (visual), tell them (aural), write a list of instructions (read/write), or take them there (kinaesthetic)? After answering the questions, students apply a simple algorithm to ascertain their preference, which may be unimodal if they choose one particular type of preference (e.g. read/write) or a more complex polymodal preference. Figure 1 summarises the diversity of VARK outcomes for 114 Liverpool Earth science students surveyed in 2001, using an earlier 13-question version of VARK. 29% of students showed single preferences, with most being kinaesthetic. Multimodal preferences were more common, but none of the students expressed a bimodal visual–aural preference (videos?), and listening generally scored low. This mix of learning-mode preferences – 24% of students have preferences that do not include kinaesthetic and 42% prefer not to read (Fig. 1) – suggests that learning delivery should be multimodal. Although the same caveats apply as for learning styles discussed above, recent technological developments make it easier to design teaching for multimodal delivery, and this approach was adopted.

**Figure 1** Exploded pie chart summarising 114 student responses to the VARK questionnaire. V = Visual, A = Aural, R = Read/write, K = Kinaesthetic. Single letters represent unimodal student preferences (e.g. 4% have a visual learning preference); double letters indicate bimodal preferences (e.g. 13% have a read/write–kinaesthetic learning preference); triple letters indicate trimodal preferences; and VARK indicates no preference.

### Designing a Multimodal Course

The learning outcomes in introductory mineralogy are constrained by what students need to know, understand and be able to do before taking up subsequent petrology courses. In particular, they should (1) know the properties of common rock-forming minerals, (2) understand common classification schemes for minerals and rocks, (3) understand how minerals may be interpreted to infer geological conditions and processes, (4) know how to use a hand lens and a petrological microscope and (5) acquire the skills needed to be able to recognise minerals and make proper drawings of them in hand specimen and thin section.

To find out if these outcomes were achieved, an existing paper-based multiple-choice examination was converted to run as a computer-aided assessment (CAA) in January 2000 using the TRIADS engine (Boyle 2002; Mackenzie et al. 2004). Some other types of questions were added, taking advantage of text-entry, drag-and-drop, hot-spot and sequencing facilities in the TRIADS engine, for example, to test for understanding of mineral and rock classification schemes, the determination of plagioclase composition from extinction angles, and features in hand-specimen and thin-section images. The CAA primarily addressed learning outcomes 1 to 3, above. All questions in the CAA were objectively graded with multiple-choice questions negatively scored, in line with departmental policy. Thus, a correct answer to a multiple-choice question with four possible answers would score 100%, an incorrect answer – 33.3% and no answer 0%. The CAA was worth 60% of the course credit and ran as a formal time-limited examination in a large computer laboratory. Outcomes 4 and 5 were assessed via work completed by students in a practical handbook and in a 45-minute thin-section examination in the last practical session. Marks were awarded using subjective grade descriptors, and will be referred to henceforth as coursework marks.

Having decided on the intended course outcomes and how to assess them, it was then straightforward to devise the curriculum. The mineralogy course consists of 12 lectures and 6 three-hour practical sessions, and the design aim was to deliver the material in a variety of sensory modes: predominantly visual–aural–read/write in lectures and visual–read/write–kinaesthetic on the Web and in practicals. Lectures were converted to PowerPoint to make use of digital resources, such as the Open University virtual microscope, movie clips of microscope images and 3D animations of crystal lattices (Fig. 2). This format “livened them up” and helped guide student understanding of difficult concepts, such as the interaction of polarised light with minerals and the plagioclase binary phase diagram (see Dutrow 2007 this issue for other examples of visualisations). PowerPoint presentations are available with other resources on the Liverpool Virtual Learning Environment, before, during and after lectures, to help students with a read/write modal preference. Lectures favour students with visual–aural–read/write preferences.

Practicals allow students to work through the lecture material and learn how to use a petrological microscope and a hand lens. A shortage of study material for the number of students involved (60–110) requires practical sessions to be run in parallel (e.g. a third of students study olivine and orthopyroxene, another third study clinopyroxene and amphibole and the rest study garnet and micas). It also requires students to share the material in groups of about four, which fosters collaborative learning. One outcome of this arrangement is that students may study the practical material before or after the relevant lecture. The 60-page practical handbook provided to each student is thus a key tool.
component. It enables students to study a group of minerals in a practical before the relevant lecture. It provides information on course structure, a glossary of terms, standard mineral abbreviations, how to describe minerals in hand specimen and thin section, and how to use minerals to classify igneous and metamorphic rocks. Subsequent chapters cover each of the practical sections: olivine and orthopyroxene, clinopyroxene and amphibole, phyllosilicates and garnet, feldspars, quartz and calcite, and opaque/ore minerals. Students can record their own observations (e.g. FIG 3), and they are reminded that the handbook will be their personal resource to help them transfer their knowledge and skills when they move on to petrology courses.

REFLECTING ON STUDENT PERFORMANCE

Five years’ worth of data have been collected both for student performance in assessments and for student perceptions of the course, and reflection on these data has been key in improving the course. In my approach to analysing assessment marks, I use student performance in concurrent courses as a pseudo-independent variable: the “independent grade” (it is assumed that assessment in all concurrent courses is a valid independent measure of each student’s overall academic ability). Since mineralogy is 1/16 of a student’s first year of study, the independent grade represents the remaining 15/16 year of study. Reference comparisons are made against related courses taken by the same students (referred to as courses X, Y and Z) to check that any changes are not just cohort related (e.g. is one cohort significantly better than another across all courses?). For reference, assessment in course X comprised a final examination covering knowledge, technical ability and problem solving; course Y used the same 60 multiple-choice question examination each year; and course Z used a combined theory and practical examination.

In the first year of the redesigned mineralogy course (1999–2000), the CAA examination produced a wide range of marks with about 25% failure (mainly due to poor marks in negatively scored multiple-choice questions, which students complained about bitterly), whereas the coursework assessment produced a narrower range of marks with few failures (FIG. 4, year 2000). The CAA and coursework marks in 2000 (FIG. 4) show ordinal interaction (regression lines have different slopes but do not cross within the data range), consistent with some learning-style or teaching-preference effect (Draper 2005). Although coursework marks were generally higher, they correlated poorly ($R = 0.44$) with independent grade marks (FIG. 5), and the CAA correlated little better ($R = 0.56$). Combining the coursework and CAA marks (40:60) to produce an overall mineralogy course mark gave the best correlation with the independent grade ($R = 0.62$), but worse than reference courses X and Y in FIGURE 5. This poor outcome was not expected, and reflection led to the formulation of two interventions.

First, many of the low-scoring multiple-choice questions in the CAA were replaced with multiple-response questions that required no negative scoring. For example, the multiple-choice question “Which mineral has the composition $\text{BaSO}_4$?” (answer: barite) can be recast as “Which elements are normally present in the mineral barite?” with the student selecting the elements from a matrix of 24 element choices.
The question does not indicate how many correct choices there are. The correct choices (Ba, S and O in this case) score 100% (33.3% for each), whereas incorrect choices score minus half the score of a correct choice (-16.7% in this case). A student selecting just the three correct items would get 100%, three correct and one incorrect 83%, just two correct 67%, two correct and two incorrect, 33% and so on. An overall negative score is awarded zero. Each multiple-response question thus provides a range of marks, not the usual binary range in multiple-choice questions. Details of question item analysis and changes are discussed in Boyle (2002).

Second, marking the practical handbooks revealed a number of common student misconceptions. Both “good” and “poor” students were adversely affected by ambiguous instructions, which needed to be revised to improve clarity.

For example, in a section asking students to record hornblende pleochroic colour variations using drawings in three circles, the following instruction proved ineffective:

“Sketch the three orientations (one basal and two prismatic) showing the three colours (shade or label them) together with cleavages in the correct orientation. Indicate optic orientations of the minerals in each sketch.”

Reflection resulted in a much better instruction:

“Find a single field of view that shows a basal section (two cleavages at 124°) and a range of prismatic sections. Check that all three pairs of pleochroic colours are seen when the stage is rotated. Sketch and label the same field of view in different orientations to illustrate colour changes. You will need at least two sketches, but may need three. Indicate optic orientations of the minerals in each sketch. Remember, pleochroism is seen in plane-polarised light (PPL).”

Assessment results for 2001 (Figs. 4 and 5) show improved student performance in the CAA, with a much-reduced failure rate. The coursework and CAA grades also correlated better with the independent grades (R = 0.60 and 0.64 respectively), and the overall mineralogy module grade correlation improved to R = 0.8 (greater than reference courses X, Y and Z). The interventions had a positive effect on measured student performance; changes to the assessment materials made them better aligned with the intended learning outcomes. This process of reflection on outcome, individual question performance and possible ambiguity in the handbook has been repeated annually. Correlations of mineralogy assessment results with independent grades have generally improved from 2000 to 2004 (Fig. 5). Interestingly, while the CAA generally ranks students better than coursework, combining the two into a final course grade consistently provides better ranking, indicating both assessment methods are necessary.

Ordinal interaction between coursework and CAA is less evident in later years (smaller angle between slopes in Fig. 4), but coursework grades are still higher. This is particularly so for lower-ability students, whose better performance at coursework than final examination implies they benefit most from task-based and problem-solving approaches to learning rather than recall-knowledge approaches. By contrast,
the most able students perform well with both approaches. See Threadgill 1979, for an interesting mathematical-logic study in which she concludes (p. 343) “…educators might be better advised to ask higher order questions of low ability students, and be less concerned about the type of questions given to high ability students, who are often better able to function regardless of the instructional questioning technique”.

Comparison with related modules (X, Y and Z in Fig. 5) indicates the general improvement in the performance of mineralogy students from 2000 to 2004 is not cohort related, and so must reflect real changes in the mineralogy course. The student view in 2002, collected after their CAA examination, was almost universally positive (see Table 1). I do not believe there is one single change that has had more effect than any other. Rather, it is the system-style approach entailed in seeking alignment that has resulted in a better course, which is also appreciated and seen as fair by students.

Last, it is noteworthy that other strategies continue to be used to address this same problem (see Journal of Geoscience Education, volume S2, number 1, 4). More and more university teachers are recognising something needs to be done and are looking at ways to improve (e.g. Brady et al. 1997; Dutrow 2004; Dyar et al. 2004; Wulff 2004). Virtually all higher education mineralogy, petrology and geochemistry teachers are trained researchers. They could improve their course performance by using their research skills to analyse and understand the effects that teaching and assessment have on student learning and perception of their subject (see also Manduca 2007 this issue).

My recommendations include the following: 1) use a questionnaire like VARK to understand student needs and question your own beliefs, 2) think about how the different parts of a course align with each other, 3) be aware that different styles of assessment can grade students differently, 4) reflect using science research skills to analyse what happened and initiate changes to be made (even small ones), 5) be multimodal in teaching and assessment.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>SOME FEEDBACK COMMENTS ILLUSTRATING STUDENT PERCEPTION OF FIRST-YEAR INTRODUCTORY MINERALOGY IN 1998 AND 2002</th>
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</thead>
<tbody>
<tr>
<td>1998</td>
<td>2002</td>
</tr>
<tr>
<td>Could do with livening up somehow.</td>
<td>A good course. Could have been dull, but wasn’t.</td>
</tr>
<tr>
<td>At best the content was “dry”.</td>
<td>Found the teaching material very good compared to some other courses.</td>
</tr>
<tr>
<td>Not the most interesting course I am doing.</td>
<td>Great presentation, keep access to lectures on the web.</td>
</tr>
<tr>
<td>Lectures were quite boring and hard to follow, often using new complex terminology – difficult to grasp.</td>
<td>Content presented clearly on the net, but not in lectures.</td>
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REFERENCES


