Zambezia (1991), XVIII (ii).

RESEARCH REPORT

SURFACE PROCESSES VS. INTERNAL ACTIVITY: STUDENT LEARNING STRATEGIES IN THE EARTH SCIENCES

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This study investigates some of the learning strategies of undergraduate students at the University of Zimbabwe. Two problems were identified which gave rise to this investigation. Firstly, lecturers frequently complain that students read very little and appear to have difficulties in analysing and absorbing information from textbooks, and in integrating what they read with their lecture courses. Several educationalists have commented that the O-level English examination, a requirement for entry to the university, does not ensure adequate preparation for the demands of study at undergraduate level, particularly in the area of reading for learning (McGinley, 1985; Fry, 1985). It appears that students may enter the university with reading strategies that are not sufficiently flexible to exploit tertiary-level textbooks successfully. The second, more specific, problem became apparent during the teaching of a second-year course in structural geology, when students had difficulty in assimilating and applying information about features in deformed rocks, collectively known as fabric. At this level, the topic is conventionally taught by pure description based on a classification of fabrics. There is, however, no standard classification and schemes differ principally in the distribution of features between categories.

We decided, therefore, to investigate the difficulties that the second-year geology students appeared to experience in their learning of this topic. These undergraduates had completed a year of general degree study of which one-third consisted of a general introduction to fundamental aspects of earth sciences, the remainder comprising two other subjects from biology, mathematics, chemistry, physics, statistics or geography and including three half-day field trips. In the second year, geology is taken with one other subject. Therefore, all students in the study group had had a grounding in basic geology, and had chosen it as one of their major degree subjects.

METHODS

The students were introduced to the subject of fabric by a lecture illustrated with slides of the main fabric elements. They were then asked to read the

relevant sections of two popular structural geology textbooks. One of these, *An Outline of Structural Geology* (Hobbs *et al.*, 1976), is a standard undergraduate text that has been in widespread use since 1976. The other, *Foundations of Structural Geology* (Park, 1989), is a much shorter and more modern textbook but is aimed at the same level of readership. One focus of this study was on the students' responses to the significant differences in style and content between the two texts. We set four exercises, shown in Figures 1 to 4, to consolidate their learning and to assess their use of the textbooks. The results of this study are based on an evaluation of the students' answers to these four exercises in conjunction with other results from course work in structural geology.

In the first exercise, we asked the students to make a classification of fabric based on chapter headings and sub-headings from the textbooks. Figure 1 shows a template provided for this exercise based on one book (Park, 1989), in which some elements of the classification were given as examples. The students were required to construct the classification from the second book (Hobbs *et al.*, 1976), without guidance, and then to compare the two schemes in terms of their usefulness. Next, we asked them to compile a table giving the properties of each fabric element in one of the classifications (Fig. 2). Column headings for the table were provided, using a number of semi-technical terms that were employed in the textbooks.

In the third exercise we asked the students to make careful sketches of five rock samples showing different fabrics, and then to compile a table of the properties of each sample using column headings similar to those in the previous table (Fig. 3). Finally, we set a vocabulary familiarization exercise designed to test their comprehension of both the technical and semi-technical terms used throughout their study of fabric (Fig. 4).

DISCUSSION OF RESULTS

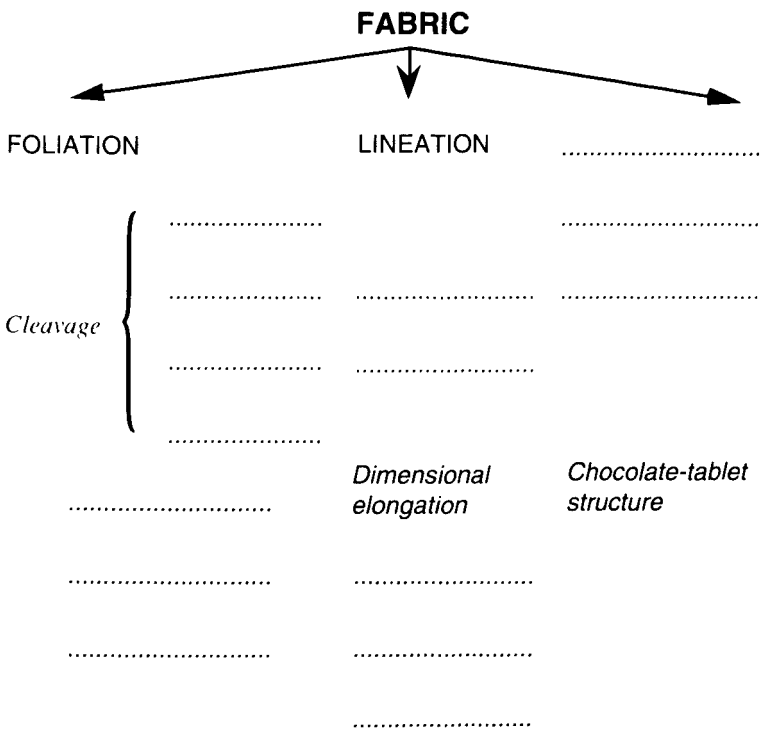
As many of the details of the results are of interest only to geologists, this discussion will concentrate on those features of student performance in the exercises which indicate general problems with learning a new topic.

As mentioned above, the topic of fabric is concerned primarily with the classification of rock features. The most striking weakness in the students' performance in the various exercises was that very few students indicated adequate ability to apply this overarching concept. They appeared to have concentrated on processing individual items of information without relating them to the nature of the classificatory methodology. This manifested itself in a variety of ways.

Firstly, students showed a marked lack of flexibility in their approach to the classification exercise (Fig. 1). Most students achieved a correct classification based on the headings of the first text (Park), which also reflected the approach taken in the lecture. Many students, however, found it extremely difficult to produce an alternative classification, despite the fact that full support was provided in the section headings of the alternative text (Hobbs *et al.*). A large number of students even omitted

Figure 1: FABRIC EXERCISE 1 (CLASSIFICATION SCHEMES)

Use the section headings and subheadings from Park, Chapter 3, to complete the following classification scheme of fabric elements:



Draw up a similar table from Hobbs *et al.*, Chapters 5 and 6, and compare the two schemes. Which one do you find more useful? Can you suggest any alterations or improvements?

Figure 2: FABRIC EXERCISE 2 (PROPERTIES OF FABRIC ELEMENTS)

Draw up a table with the following headings for all the fabric elements that you have identified in your preferred classifiction of fabric elements. Entries for slaty cleavage are shown as an example.

Fabric element	*Planar/ linear*	*Penetrative/ spaced*	*Scale at which homogeneous*	*Processes involved in formation*	*Rock type or fabric feature*
Slaty cleavage	Planar	Penetrative	Microscopically homogeneneous	Flattening, rotation, growth of new grains	Slate

Figure 3: FABRIC EXERCISE 3 (SAMPLE DESCRIPTION)

Examine the samples A, B, C, D and E. Make a careful drawing of each one with scale and labels. Make a table with the following headings. Fill in a separate row for each element where there is more than one fabric element in a sample.

Grain Size Definitions:
Very Coarse Grained – 16 mm – Coarse Grained – 4 mm – Medium Grained – 1 mm – Fine Grained – 0.1 mm – Very Fine Grained – 0.01 mm – Ultra Fine Grained

Sample	*Miner-alogy*	*Grain size*	*Planar/ linear fabric element*	*Pene-trative/ spaced*	*Scale at which homo-geneous*	*Name, description of fabric element*	*Fabric (L, L>S, L–S, S>L, S)*	*NAME OF ROCK*

Figure 4: FABRIC EXERCISE 4 (VOCABULARY)

1 What do you understand by **fabric** ?
What does it tell you about the history of a rock ?

2 What general term is used for the processes leading to **foliation** and **lineation**?
Give examples of the specific mechanisms which may produce these features.

3 **Penetrative, spaced, pervasive, non-penetrative**. What are these words used to describe ?

4 In structural geology we use the words **homogeneous/heterogeneous** to describe .....
What contrasting characteristics do they describe ?
Explain why the same sample may sometimes be described as homogeneous and sometimes as heterogeneous.

5 What might be the opposite of **preferred orientation**?
What information does **preferred orientation** give the structural geologist?
In what way are grains oriented in a **strong preferred dimensional orientation** ?

6 Draw diagrams to illustrate the difference between **planar** and **linear** fabrics.

7 **Planar discontinuities** is a term covering several fabric elements.
Give two examples.
What is the shape of the discontinuity ?

8 Suggest a term opposite to '**localized in their distribution**'.

9 If a term is **non-genetic**, it means that it tells us nothing about the .....
of what it describes.
Is the basis of the classification in Park genetic or non-genetic ?
Is the same true of the classification in Hobbs *et al.*?

the major section headings from Hobbs *et al.* completely, presumably because they did not occur in Park. This suggests not only an unwillingness to consider alternatives to an established mental approach to a topic but also a lack of appreciation of a classificatory system as a cognitive and practical tool rather than a 'fact'. Moreover, it indicates that students were not making an effort to obtain an overview of a chapter of text before starting reading. This is further suggested by the fact that a number of students, in their classification based on Park, created categories from terms mentioned early in the text but which the author did not use as headings. In other words, the students were arbitrarily creating their own classificatory system from the detail of the text rather than using the support to learning provided by the author. This tendency to ignore the structural support provided in a textbook has been reported in other subject areas (Morrison *et al.*, 1991). A less significant, but still interesting, example of a failure to appreciate the author's system of headings was the attempt to create two categories from the author's single heading 'rods and mullions'. This suggests that the students concerned were processing what they read at word level rather than grasping the inclusive concept.

Secondly, students showed confusion between different levels of abstraction in the classificatory process, exhibiting a tendency to provide concrete examples when abstract categories were required. This was demonstrated in the classification exercise, in which some students presented 'ooids, spherulites and pebbles' as a separate category instead of seeing them as examples of shape fabric foliations, as they are presented in Park. This tendency was also noticeable in the vocabulary exercise (Fig. 4), in which some students attempted to define terms by giving examples of members of the category rather than by providing a definition based on an abstraction of their characteristics (Lynch *et al.*, 1985). For example, 'fabric' was defined in terms of specific examples of fabric, such as 'the structural arrangement of grain aggregates and mineral grains through a rock body' or 'the alignment of minerals within a rock'. The correct definition, as given in Park, is at a higher level of generality: 'the geometrical arrangement of all the structural elements within the rock body'. Students also found difficulty in understanding the level at which classificatory terms are applied. When asked to explain 'what contrasting characteristics' are described by the terms 'homogeneous/heterogeneous' in structural geology, students failed to answer in terms of generalized characteristics and, instead, identified concrete examples of what the terms might describe, such as 'lineation and/or foliation', or produced such vague attempts as 'outcrop and hand-specimen characteristics'. These examples of confusion of classificatory levels suggest that the students have a very weak grasp of the classificatory principles involved.

Thirdly, students exhibited distinct weakness in their ability to apply the relevant descriptive and classificatory vocabulary. A particularly marked example was widespread confusion in the application of the terms 'planar' and 'linear', which demonstrates a lack of recognition of these terms as crucial criteria in the classificatory process. This confusion was shown in the table of properties exercise (Fig. 2) and further reflected in the practical class, where students made an incorrect choice between

these terms when classifying the specimens (Fig. 3). In the vocabulary exercise (Fig. 4), the same problem with 'planar/linear' occurred, with examples of linear discontinuities being given as examples of planar discontinuities. In the practical class the ability to 'follow through' the choice of the descriptive term from fabric description to rock identification was weak. For example, the fabric of a specimen might be correctly identified as 'schistocity' but the rock would not be named as 'schist'. Again, the key role of these terms in classification appeared to have been missed.

Moreover, the students had difficulty in answering questions which asked for the antonyms of terms used in the texts, and resorted to wild guesses instead of systematic choices. For example, when asked for the opposite of 'preferred orientation' within the context of the topic (Fig. 4, Question 5), replies such as 'contrasting', 'inverse' and 'non-preferred' were offered instead of the correct 'random orientation'. Similarly, when asked to suggest the opposite of 'localized in their distribution' (Question 8), several students chose the term 'delocalized', apparently transferring a term from chemistry with no thought about its applicability in this geological context. The inability to supply opposite terms in a system of classificatory criteria clearly suggests a weakness in understanding that system. It is clear that students giving answers such as those quoted were approaching the vocabulary of the texts as labels to be learned rather than as concepts to be internalized and eventually made operational in classification.

A tendency to apply descriptive terms to inappropriate nouns, apparently based on a loose 'word association', was also observed. Typical of this tendency was the suggestion from several students that geologists use the words 'homogeneous/heterogeneous' to describe 'scale' (Question 4). The correct answer is 'fabric', and the choice of descriptive terms may depend upon the 'scale' at which the specimen is being examined; for example, a fabric may appear 'homogeneous' at the level of description of an outcrop in the field but be clearly 'heterogeneous' when viewed at hand-specimen scale. The loose association made by the students between the descriptive terms and the concept of scale suggests a failure to grasp the relationship between the terminology and the classificatory system.

The fourth area of difficulty was associated with the question of whether the classification systems set up for fabric are purely descriptive or include 'genetic' criteria, i.e. are based on the geological processes which are believed to have created the various fabric elements. Students had no difficulty with the meaning of the term 'genetic', correctly filling the gap in Question 9 with the word 'origin'. Yet they were much less confident in their application of the term when discussing the classification systems. The systems are based purely on descriptive criteria, but limited implications of origin can also be drawn. Students found it difficult to grasp the distinction between classificatory criteria and additional information about processes. When asked whether the classification of fabrics they had drawn up in the first exercise was genetic or non-genetic, approximately two-thirds answered incorrectly that the basis was genetic. Furthermore, some students stated that they preferred Hobbs *et al.* to Park because it used a 'genetic' basis for classification. This interpretation is in direct contradiction to an explicit statement in the text.

Moreover, students had difficulties with questions which asked them to deduce evidence of origin; the table-of-properties exercise asked for this in relation to each fabric element, and an example was given (Fig. 2). Many students answered this part of the exercise by compiling a number of general terms such as 'flattening', 'compression', 'extension', 'stress' and 'strain', when much more specific terms, which were available in the texts, were required. Vocabulary questions probing these areas were answered either at a purely descriptive level or in the most general terms. This aspect had not been stressed in the lecture but was mentioned frequently in both texts, sometimes discussed explicitly, sometimes implicit in such vocabulary items as 'produced by', 'origin', 'resulted', 'controlled' and 'as a result'.

Students also showed a tendency to assume that a descriptive characteristic, such as 'preferred orientation', would imply an identical 'cause' in the area of structural geology as it would in another geological context. 'Preferred orientation' is also important in the description of sedimentary rocks, where it is usually produced on the earth's surface by running water in unconsolidated materials, compared to its production by tectonic strains in a solid state at some depth in the crust in the context of structural geology. Students assumed that it indicated identical processes in both cases. A thorough understanding of the type of processes at work in producing fabric would have made the student aware that such an interpretation was impossible. Again, students were reacting to terminology at the 'label' level, rather than working at understanding its meaning in a specific context.

All these observations underline the impression that many students possessed a very weak concept of fabric classification. While most had acquired one approach to the topic, and recognized much of the relevant vocabulary, their ability to operate independently within the system of fabric classification, appreciating alternative approaches and the way in which criteria are applied, was distinctly limited. The evidence of this study suggests that students read textbooks in ways which fail to facilitate interaction between their previous knowledge and the new information available in the text.

CONCLUSIONS

The evidence presented here suggests that second-year students of geology at the University of Zimbabwe are processing information from lectures and reading their textbooks extremely superficially, concentrating on linguistic formulae rather than on conceptual content. These reading and learning strategies, as expected from research elsewhere (Cohen *et al.*, 1979), lead to a weakness in grasping the cognitive structure of a topic and subsequent difficulty in applying this information. It seems likely that similar problems will exist in other subject areas. It would appear desirable, therefore, for lecturers to plan their courses so as to promote learning at a deeper level.

Explicit attention should be drawn to the overall cognitive structure of the information being presented so that students will be more likely to

activate this structure in processing detailed facts and thus achieve a more global grasp of the topic. This should both facilitate the learning of the details and, more significantly, give students greater independence in applying the information.

The problems of comprehension and learning identified in this study suggest that the teaching of even a subject such as 'fabric', the content of which is conventionally presented in purely descriptive terms at this level, may be more effective if attention is paid to formation processes and some concepts of genesis. It appears that students search for such explanatory concepts — sometimes highly imaginatively — to assist them in their learning. This is not surprising, since description without explanatory background can seem extremely arbitrary. Moreover, the learning of pure description tends to encourage rote learning rather than flexible, applicable learning (Bransford *et al.* 1984).

It also appears important that emphasis should be placed on the way a topic reflects the methodology of the discipline, rather than on a set of facts to be memorized. In the topic discussed, students clearly needed assistance to grasp the idea of alternative classificatory systems as tools for interpreting and understanding diverse geological features. Again, an *explicit* emphasis on the understanding and use of such methodological concepts as classificatory systems seems desirable.

One problem which immediately presents itself is that students are unlikely to adopt flexible approaches to their subjects while the availability of a variety of books is limited. In these circumstances, it becomes even more imperative that lecturers promote flexibility of approach to topics through their lectures and assignments. It is also clear that the University must make every effort to ensure the availability of as wide a range of source materials as possible. This is reinforced by the fact that students seemed equally divided between preferring the simple and brief approach of Park, and the detail and a certain amount of discussion about genesis given by Hobbs *et al.* Encouragement to consult a variety of sources would allow individuals to find the approach to the topic most suited to them.

Our evidence also implies a need for exercises and assignments which will lead students to apply the information they have been given rather than simply to memorize it. It is necessary for both staff and students to have feedback on the extent to which students have grasped the deeper basis of a topic in addition to surface facts and linguistic formulae. In the particular context of the earth sciences, it is essential that students be required to apply their learning not only in the laboratory but, most importantly, in the field, so that their verbal learning has a firm methodological support.

The clear need for assisting students in developing a more flexible approach to reading and learning is already tackled in Communication Skills classes for selected first-year students and, in the Faculty of Science, in a six-week lecture course for all first-year science students on Skills for Studying Science. Strategies are taught which aim to increase the students' interaction with texts, such as consciously evaluating the relationship between the information in the text and what has been gained from lectures and other sources. Students are encouraged to analyse what they

have read and to test their comprehension by, for example, identifying any classifications and constructing a tree-diagram, or identifying processes and constructing flow charts. However, time is limited and the large number of students involved imposes constraints on the amount of feedback possible from individuals. Students clearly require more training in how to read textbooks flexibly and in ways which will promote deep learning. This will be best done when reading instruction can be integrated with subject study, perhaps through co-operation between subject lecturers and Communication Skills Centre staff. Students respond best to study-skills training when it is clearly integrated with subject learning.

This study also raises the issue of the acquisition of academic vocabulary within and across subject areas. Students appear to acquire a very superficial familiarity with new vocabulary, which is frequently limited to its meaning in the context where it is first encountered. It has been suggested elsewhere that the assumption of familiarity with a word may interfere with 'widening the group of ideas which that word represents' for the learner (Presst, 1980, 79). This is particularly noticeable with semi-technical vocabulary, which may be used in a variety of fields with somewhat different realizations. This problem should be addressed by both subject and communication-skills teaching, through strategies to ensure that students acquire the ability to use vocabulary actively in a variety of contexts and see its relationship to the concepts and methodology of a given subject.

The issues raised by this study indicate that many students tend to employ surface strategies in reading and learning, and that they have difficulty in grasping the deeper concepts underlying topics and in applying information learned. It is suggested that lecturers can assist students to learn more effectively by adopting teaching strategies that draw more explicit attention to conceptual aspects of topics and by ensuring that opportunities are provided for the learning to be applied. Such measures are not easy to put into practice with large classes, but it is essential that some way is found to promote greater application of learning in students, or the University will be turning out graduates whose ability to apply their learning flexibly in the challenges of professional life will be minimal.

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