Evaluating constructivist based methods to teach senior undergraduate geoscience classes

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Introduction

Traditionally geoscience subjects have been taught using a top down, transmission approach. We have attempted to use a more interactive approach to teaching and learning by placing the responsibility for learning squarely on the shoulders of the students. One of the main aims of using such an approach was to encourage the students to reflect on their knowledge about the Earth System and to challenge their thinking about it. This approach is based on the idea that learning is about changes in conceptions (Ramsden, 1988):

> Learning should be seen as a qualitative change in a person's way of seeing, experiencing, understanding, conceptualizing something in the real world – rather than as a quantitative change in the amount of knowledge someone possesses. (p. 271)

Our role as teachers was to encourage students to become deep rather than surface learners. That is we wanted our students to develop a firm understanding of what they learned so that they could relate what they learned to concepts they already had, and then develop these concepts, rather than regarding learning as a series of discrete occurrences, done to achieve a short term requirement.

The teaching approach used in this subject was based on constructivist principles of learning. In the last two decades science education has been greatly influenced by a constructivist approach to learning and teaching. Constructivist learning theory acknowledges that all learners (including children, scientists and teachers) construct their own ideas about their world (Biddulph and Osborne, 1984; Fensham, 1989; Osborne and Wittrock, 1985; von Glasersfeld, 1989). Learners actively 'construct' knowledge and meaning from their interpretation of what is happening around them, based on their own experiences and understandings. Learning is regarded as an interpretive process that entails challenging and enriching one's own thinking.

Although many researchers agree that no one teaching approach is always the most suitable, they also agree that a constructivist epistemology is an important underpinning for effective teaching, and that it demands a teaching style which differs greatly from the traditional 'chalk-and-talk', teacher centred, transmission approach (Fensham et al., 1994; Kirkwood and Symington, 1996; Wadsworth, 1997).

In an attempt to put these pedagogical skills into practice and evaluate their effectiveness, an action research project was devised for the subject Global Systems. The subject is a final year, final semester subject for students doing an Applied Science degree in environmental management at the University of South Australia. The subject was revamped so that it took into account the students' views. It encouraged interpretive discussions and de-emphasised the traditional content driven approach to the subject. In a deliberate change of role, the lecturer's role moved to facilitator, and the student's role changed from that of absorber of knowledge to active participant who takes responsibility for her/his learning.

Teaching methodology

There is enormous scope in the content that could be covered by a subject such as Global Systems. It was acknowledged that the scope was too great for the time-frame allocated to the subject and so the design of the subject focused on encouraging the students to think about their learning, to assess their own needs and to then explore an area of interest. To facilitate this process the students were introduced to a number of different teaching strategies. These strategies focused on:
- eliciting the prior knowledge of the students;
- providing a range of exploratory activities which were designed to challenge the students' thinking; and
- providing opportunities for the students to raise questions and then investigate an area of interest.

The prior knowledge of the students
An introductory workshop was used to ascertain what the students already knew about the topic 'the Earth System'. This activity served two purposes. Its first purpose was to challenge the students' thinking in ways that made them consider what they *already* knew, and then what they *wanted* to know about the Earth System. Its second purpose was to collect information that would assist us to plan future workshops and lectures. Five questions were posed and each student answered the five questions on separate pieces of paper (Table 1). The students' answers were then collected question-by-question and each set was collated and summarised by a group of students. Each group then reported back to the whole class and a brief class discussion was held about each report.

What do YOU think?

1. **What do you think the term "Earth System" means?**

2. **What are three (3) things that are currently having an impact on the Earth System?**

3. **What are two (2) things that have occurred in the Earth's past that have had an impact on the Earth System?**

4. **What are two things that could be done to protect the Earth System?**

5. **What are two (2) things about the Earth System that you would like to know more about?**

Table 1. Questions to ascertain the students' prior knowledge about the Earth System

The exploratory activities
The exploratory activities were designed to challenge the students' ideas and encourage them to formulate questions related to the topic. Two sets of exploratory activities were conducted. The first activity made links to concepts that the students had been introduced to in previous subjects. Each student was asked to sketch and label the features of a rock sample that they were given. They were encouraged to simply draw what they could see without attempting any interpretation. After completing their sketches the lecturer helped the students to interpret features of the rock that could elicit information about its formation. This was done as a class activity. The interpretation process was used as a means of linking this exercise to the activities in the coming field trip.

The second set of exploratory activities took place in a four-day field trip to the Flinders Ranges in South Australia. The purpose was to demonstrate the evidence that has been used to develop a model for the evolution of the Earth System during its early history. The students were taken to

outcrops where important evidence could be observed and were told about the evidence and how it had been interpreted. The field trip involved numerous stops at locations significant to the evolution of the Earth System. In previous years this field trip was conducted as a 'show-and-tell', where the students were taken to a series of outcrops, shown the evidence and told what it meant. At the completion of the field trip the students were required to complete an assignment that required them to describe and further investigate one of the features visited.

In this new approach a problem solving task, or some other kind of activity that required the students to work in groups, was set at each location. After their initial explorations the solutions to these challenges were discussed as a class and responded to by the tutors. At the conclusion of each session the students were asked to record the things they had learned, and any questions they had, in their notebooks.

Notebooks had been provided to the students as a means of encouraging their metacognitive processes. The students were asked to use their notebooks to record their questions and ideas, as well as their field notes and sketches. The field notes were to be recorded on the right-hand pages and their questions and queries on the left-hand pages. As well as providing the students with a mechanism for reflecting on their learning, the notebooks also provided us with a means of gaining some insight into the development of their thoughts and understandings about the Earth System. The notebooks were non-assessable but were collected and read during the field trip.

Questions and investigations
The notebook questions were a pivotal part of the teaching and learning approach. Each morning of the field trip the students were asked to review their list of questions and to classify them as 'little questions' or 'big questions'. The little questions were those that they thought could be answered immediately by the tutors. The big questions were those they believed needed a more thorough, research-based answer. The class was then split into groups to work with a tutor. Each student was asked to raise one of the 'little questions' and these were used to facilitate group discussion. In many cases the answering of the questions generated others.

The 'big questions' were the focus of the final workshop session of the fieldwork. The students were asked to review their list of questions and to identify one or two that were likely research questions. These were not necessarily the questions they would research, but questions that were of interest to them and which may be of interest to others in the group.

Each question was recorded on a separate card. Each student read one of her/his questions to the class and clarified it where necessary. The class then classified the question according to its key idea and the card with the question on it was stuck on the wall to become part of a set of related questions. When all of the questions had been classified the students were asked to form interest groups based on one of the sets of questions. The groups discussed the list of questions, with the intention being that each student would select one as an individual research topic. During the following two weeks groups of students met with the lecturer to refine their questions and to ensure there was enough relevant literature and resource material available to support the students in successfully answering their questions.

Evaluating the teaching and learning process

It was decided that the most suitable way to evaluate the success, or otherwise of this approach to teaching and learning was to ask the students themselves. Their responses would assist us to make decisions about how we might improve the quality of teaching, and facilitate learning, the following year. The evaluation was done using two different methods: a questionnaire to all students; and a focus group interview with a randomly selected group of students. Although data were also collected

through anecdotal records, field notes, and student logs, only the results of the student questionnaire and the student interviews are reported here.

The questionnaire

The use of student evaluation questionnaires is well supported in the literature and is probably the most widely used method for obtaining student feedback in university education today (Moore and Smith, 1994; Ramsden and Dodds, 1989). Whilst recognising the limitations of a questionnaire (Gardner, 1995; Theall and Franklin, 1991) we considered it worthwhile to use one, at the same time heeding Ramsden's (1992) warning:

> Students are in an excellent position to provide information about the quality of instruction. Valid methods of collecting such data exist [however] it is wise to be circumspect about using student ratings to make judgements on teaching quality and to recognise their complications as well as their virtues. (p.229)

The questionnaire consisted of two parts: a summative/ratings part; and a formative/diagnostic part as described by Moore and Smith (1994),

> The value of the student summative/ratings questionnaire is its capacity to capture the scope of a course or subject succinctly in a series of statements that can be rated, ranked or weighted quickly by students.

In this project the summative/ratings questions were designed to sum up the overall quality of the subject by asking students to rate the worth of its various features using a 7 point Likert-type scale. 20 questions were asked. These were grouped to gather information about:
• the overall effectiveness of the teaching methodology (1 question);
• teaching characteristics of the staff (organisation, enthusiasm for teaching, empathy for students, encouraging participation); and
• perceived ability of staff to facilitate learning (stimulated interest, gave clear explanations, made effective use of teaching technologies).

Figure 1 shows the results of a sample of these questions. The scores for the 20 questions ranged from 5.32 (taught in a way that facilitated my learning) to 6.0 (had enthusiasm for teaching). We recognise that there is nothing intrinsically valid about attaching numbers to these individual questions but have done so because it is helpful to us as a diagnostic tool in the context of an action research approach.

In addition to the summative evaluation questions two open-ended (formative) questions were included in the questionnaire to which the students were asked to write discursive responses. These were:
'What were the best aspects of this approach to teaching?' and
'In what ways could this approach to teaching be improved?'

These were used to help diagnose what particular practices, materials and activities needed to be retained or modified. The questions for the formative part were constructed using guidelines provided by Ramsden and Dodds (1989, p42-46).

About half of the students answered one or both of these questions and their responses were helpful in that they helped to put the summative responses into context, particularly where a student had chosen the disagree end of the scale.
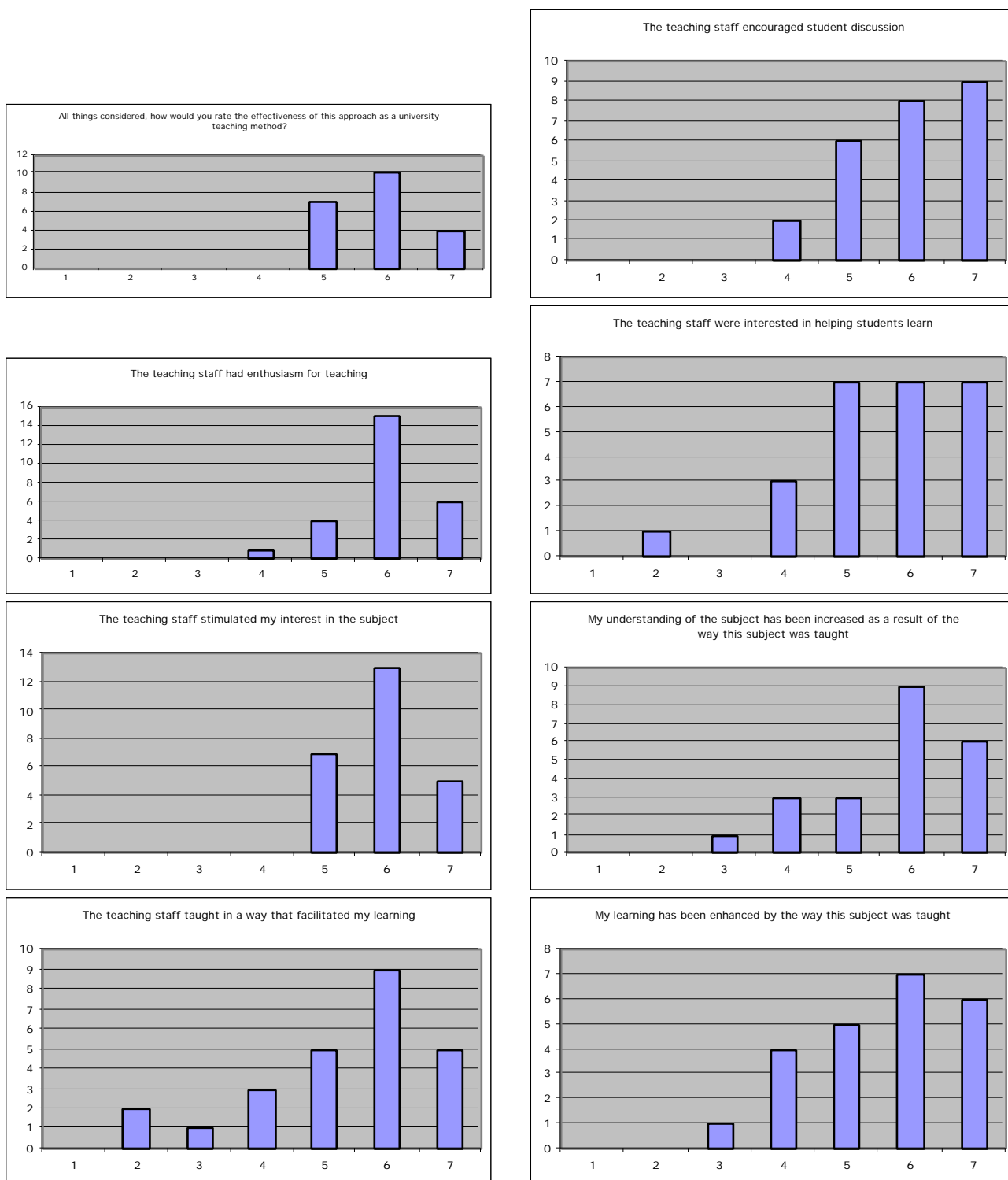
Figure 1. Bar graphs of the distribution of student responses for a sample of the questions from the summative/ratings questionnaire (1 = strongly disagree; 7 = strongly agree)

The most common responses to the first question (best aspects of the teaching) related to the value of the fieldwork and the process of developing questions. The other aspect of the teaching approach that was frequently commented on was the opportunity for the students to pursue their own research question.

Suggestions for improvement were particularly useful in the context of adapting the teaching methodology for the following year. Several responses suggested that more help was required in refining the research question and one student suggested that we resume the former practice of lectures and set questions for assignments.

The student focus group interviews

The primary purpose of the interview was to gather feedback about the students' perceptions of their learning outcomes and their views about the potential benefits of this different approach to their, and others' learning. Conducting an interview with each member of the student cohort was considered time consuming and unnecessary because the questionnaire data represented a response from the cohort. It was decided to group interview a random selection of students. The strength of using a 'focus group' interview at which all interviewees attended, was that it allowed answers to be responded to on the spot by the rest of the group thus providing the opportunity to probe the responses more deeply (Laurillard, 1993).

Twenty-nine of the thirty-three students agreed to participate in the focus group. From these, seven were randomly selected. An academic staff member who had not been involved in teaching the students led the focus group interview. A non-participant recorder supported him. Five questions were used to guide the focus group interview. The questions that were used to guide the discussion and a summary of the responses are contained in Table 2.

Focus Group Questions	Summary of Focus Group Responses
Question 1 – Do you think the emphasis on recording (in your notebooks) your questions for later discussion and clarification helped your learning?	All students agreed. Several thought more time should have been spent addressing the questions. It was considered especially helpful when completing the research project. There was strong agreement that the process aided learning.
Question 2 – Did the process of framing your own research question make a difference to the way you approached the assignment?	The response was mixed (No = 4, Yes = 3). Those who did not like the process wanted more direction such as a set of questions to choose from. Others liked the freedom to pursue a topic of interest. There was also some concern about conflicting ideas in the literature.
Question 3 – Did you perceive the workload for this subject to be any different to that of other subjects you are doing or have done?	The consensus was no difference, but some students spent more time researching their question than they would normally have done for a set question.
Question 4 – Do you think this approach to teaching helped your learning?	All agreed that it was better than 'lecture, classroom' approach; it encouraged thinking; students gained better understanding. It was suggested that it suited some students more than others.
Question 5 – In what ways do you think this approach to teaching affected your learning?	No consistent theme in answers to this question.

Table 2. A summary of the questions used to guide the focus interview

Discussion

The research was undertaken to determine whether this teaching method was suited to a geoscience course, and whether students believed it provided opportunities to improve their learning outcomes. The analysis of the questionnaire and interview data showed there was a consistently positive response to the teaching method used. Two key points emerged from the analysis of the student feedback. The first related to the generation of questions. A major focus of this teaching approach was the emphasis on student-generated questions. The students' responses indicated that they found this a difficult aspect of the subject. This response was confirmed by many of the logbook entries that indicated the students had difficulty framing their questions. Some of the interview comments

indicated they wanted to 'be told' what question to research. Such a response is symptomatic of students who have developed a dependency approach to their learning. Encouraging students to ask questions promotes deep learning. It requires students to reflect on what they know, and make links between what is being studied and their existing conceptions.

The second issue to emerge was that of supporting students to become independent learners. The students did not know what they wanted to know, and were a little resistant to having to think about what they might research. This became apparent to us during the field trip when the group demonstrated a reluctance to select a question for their research project and is reflected by the wider spread of responses to Question 12 'The teaching staff taught in a way that facilitated my learning' (see Figure 1). We believe that if the approach to teaching and learning that we have used was introduced at an earlier stage of the course, by third year the students ought to be able to handle the process of selecting and then researching their own question without as much support. This being their first experience, it was perhaps too much to expect acceptance of the approach and an easy transition to this new style of learning.

Summary

The outcome of this evaluation has encouraged us to continue with this modified approach to teaching. Being the first phase of our action research cycle it has raised a number of issues that will be addressed in the second phase of the research, for example we will make more of an effort in the first few sessions to help the students become comfortable with this approach to teaching. We shall also allow more time for the development and refining of their research questions. While we think that the questionnaire and the focus group interviews were good methods of evaluating the process, we think that the use of a reflective journal may provide useful additional information and so we intend to add that to the evaluation process in the next phase of this project. As Ramsden (1988) points out, improving learning is about the relations between the learner and the subject matter and an essential aspect of teaching and learning is to understand the students' perspectives, their perceptions of learning and their previous experiences. However we need to be aware that students' perspectives of what supports their learning is not necessarily the same for each student, nor the same as that of the teacher.

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