

Choosing and Using Appropriate Strategies to Improve Teaching and Learning in Sedimentology Courses at Peking University (Beida)

Chaodong Wu*

Peking University
Beijing 100871
People's Republic of China
cdwu@pku.edu.cn

Tom Hubble

School of Geosciences
The University of Sydney
NSW 2006
Australia

Xiancai Lu

Nanjing University
Nanjing 210093
People's Republic of China

Fanglin Li

China University of Geosciences
Wuhan 430074
People's Republic of China

Changhou Zhang

China University of Geosciences
Beijing 100083
People's Republic of China

* Corresponding author

Abstract

Tertiary education is experiencing profound reform in developed and developing countries. This reform focuses on making learning more efficient and improving educational practice. This is a challenge for university educators around the world. It seems to us that effective tertiary education in developed countries mainly employs a variety of student-centred approaches while teaching in Asia generally, and China in particular, is dominated by 'education by examination'. This article discusses aspects of these two different approaches, and describes proposed changes in teaching style that will be introduced to improve student learning in the sedimentology courses offered by the Department of Geology at Peking University. We address a variety of issues including student motivation, teaching styles, assessment and examination, computer access, student support and the involvement of industry and professionals in the curriculum. The practicalities of introducing a wider range of teaching and learning experience (projects, workshops, seminars, group critiques, performance, tutorials, field trips, student exchanges and work experience) are considered from our perspective as teachers and from the point of view of students. Teaching practice in the geological sciences at our institutions requires change in order to improve teaching and learning. This may require a rethink of our approach to education. The most pressing need is an increased emphasis on practical laboratory work and field classes and the involvement of students in course evaluation.

Introduction

The earth sciences provide many specific examples of the application of the scientific method as well as good examples of the practice of science. In the past two or three decades the earth sciences have been transformed from a field in which basic description of earth materials dominated into a field where descriptive data is examined to rigorously test hypotheses and improve our theoretical understanding of the whole range of earth processes. Despite this major change within the discipline as a whole, the approach to geoscience teaching has barely changed at Peking University (Beida). Over the last decade, campus-wide timetable reform has also resulted in a reduction in the time allotted for the teaching of sedimentology to one quarter of the previously allotted time. As a consequence of these two events there is a strong need to plan a new sedimentology syllabus and use this process to implement new approaches in teaching.

What is sedimentology?

Almost three quarters of the rocks exposed on the Earth's surface are sedimentary rocks and sedimentology involves the description, formation, and distribution of these materials. Much of the detail we know about the Earth's history is derived from the study of sedimentary rocks and their contained fossils. Many primary economic resources, such as coal, oil and natural gas, are of sedimentary origin. Therefore the goals of a sedimentology course are to understand how sedimentary rocks are formed and learn what types of stratigraphic, paleo-environmental, and tectonic information can be recovered from them. Consequently, students should be able to identify and interpret any sedimentary rock specimen. At the end of a course in this subject they should be able to communicate their understanding of these materials in a variety of ways.

The discipline of sedimentology is divided into three main parts: a) sedimentary petrology, which aims to describe the mineralogy and composition of sedimentary rocks; b) sedimentary processes, which deals with the mechanisms of erosion, transportation and deposition of sediments; and c) diagenesis, which is the study of the process by which soft, unconsolidated sediments are converted into hard rocks.

In general, the current approach employed in teaching sedimentology at Peking University is lecturing with very few practical laboratory sessions. For want of a better description, we use a fairly traditional Chinese educational approach at Beida. Lectures dominate the teaching schedule, with the lecturer carefully delivering highly detailed material, while students carefully record the lectures in their note books before comprehensively committing their class notes to memory. Assessment is entirely by examinations in which students 'dump' the memorized material back onto paper. Questions tend to be simple and usually require a brief factual response. Consequently, the majority of students are only learning at the surface of the subject.

Contemporary approaches to teaching and learning

There are several reasons why methods of teaching the geosciences at Beida would benefit from review and revision. Firstly, there is vastly more information available to students and teachers today than twenty years ago. Secondly, new developments, especially the acceptance of plate tectonics by Chinese scholars, have improved our understanding of the geosciences in the general sense and in many specific ways. Thirdly, study and research into educational techniques have led to a better understanding of how students learn.

The majority of changes we need to implement result from this third point. We need to apply many contemporary developments in the theory of 'how people learn'. For example, our lecturers should use contemporary teaching and learning strategies that focus on 'how best to teach them', that is, we should apply more student-centred teaching approaches.

Examples of methods that might achieve this aim include:

- workshop-based, problem-orientated approaches such as those described by Simm and David (2002), Healey and Jenkins (2000), and Gardiner and Hughes (2000). This method would equip students with the research skills and methodology necessary for independent project work, which is an important part of the training of geosciences students; and
- research-led teaching (Prosser and Trigwell 1999) in which an academic facilitates 'information transmission' or 'conceptual change' in a teacher-focused setting. The 'information transmission' style of teaching involves the academic telling students about the academic's own research, for example, in lectures, perhaps using anecdotes from laboratory experiences. Alternatively the 'conceptual change' approach is more 'student-focused' and aims to engage students in the research in some way.

The relationship between teaching and research is an important issue for the university teacher. Indeed, in research-intensive universities, teachers generally care much more about their research, than they do about their teaching. Research-led teaching can be involving and interesting for the teacher and could be easily utilized in the teaching of the geosciences. Research builds on the natural

curiosity of the human beings. A philosophical approach to education that is based on the processes of inquiry, could effectively harness the curiosity of both the teacher and the student.

We feel that it is necessary for the teacher to take a step back and become a support role to the student as suggested by the constructivist theory of teaching. The teacher instructs, but then also support, while students use this active-based learning technique. In the past decade, many university educators have begun to move away from traditional didactic instruction to a more student-centred approach to learning. An increasing number of academic institutions throughout the world have recognized that Problem Based Learning (PBL) is an instructional method that challenges students to develop the ability to think critically, analyze problems, find and use appropriate learning resources. In fact, we feel that PBL could lead us down a path to better learning, and will enable us to help students to learn how to learn (<http://www.udel.edu/ce/pbl2002/>). Many authors (Bradbeer 1996; Lee 2001) have researched the use of problem based learning in geosciences teaching and indicate that PBL can be used effectively in the geosciences. This is because the geosciences often deal with real problems, real data sets and because of the cross-disciplinary nature of the geosciences.

Using contemporary technologies in teaching and learning

Many of the better-supported Chinese universities have been equipped with multimedia classrooms recently. We now face the twin tasks of using these facilities effectively and integrating computers and Information Technology (IT) into the curriculum? We feel that the innovative use of IT should be compulsory for young and developing teachers. To this end we wish to introduce a competition for the best multimedia teaching developed by academics at Peking University and reward the innovators each semester. We feel that our teachers should set up electronic learning environments where this is appropriate. An electronic learning environment is an integrated solution to manage online learning and enhance student learning (Watson and Donoghue 2002). Examples of good electronic learning environments are *WebMCQ* and *WebCT*, which provide facilities that can structure learning and course content, as well as empowering students with their management, communication and self-assessment tools. A learning environment usually consists of module details and objectives, and resources such as lecture notes, *PowerPoint* presentations, images, audio and video. It also provides online assessment with a variety of question types that can be used to provide formal assessment, interactive feedback and questionnaires such as student course evaluation surveys (Boardman 2001). Tutors can give different levels of feedback for their assessments and the software can be configured to allow students to monitor their own progress.

In common with the other natural and physical sciences, the geosciences are information rich. The Internet allows students to access this information easily, which should enable them to learn from the wide variety of Internet

sources. The Internet can enrich student learning experiences, and generally facilitate their learning. We should encourage students to search in e-libraries, e-newspapers, and other resources. These Internet resources provide learning opportunities that are not necessarily limited by space, time, and the presence of a teacher. Of course, similar research practices exist already in paper-based format and the e-versions utilize the same intellectual skills. Students are able to access resources in libraries/institutions apart from their own and potentially contact experts in distant lands.

Teachers should probably set up web pages for their courses to assist students. These should include the syllabus and course notes for use by the class and any other interested students or geologists. Virtual field trips can be used as a supplementary activity for classes. If these are properly designed they can help students understand abstract concepts and assist them to develop a schema for geological phenomena that will help them understand the natural world. For students who have difficulties developing their spatial perception, such material can be invaluable. Nevertheless, virtual field trips cannot substitute for the real thing. Geological students need the ability to work in the field, and this skill is best developed in the field.

Computers and IT can also be useful during field trips. The use of these tools enables the teacher to deal simultaneously with the real-time data collected by the students, and then analyze the data at the field site. So, students have the opportunity to better understand the processes and phenomena that they observe in the field. The use of computers in the field has an additional benefit from the teacher's point of view – many students in China wish to become computer literate, so the application of computer technology in the field setting provides a strong motivation for them to participate conscientiously in the course. Computer simulation is also a useful tool that can assist students to understand the progress of geological processes. This is because many geological processes take a long time to occur and cannot be observed during a single human lifetime. Computer simulations can be used to demonstrate such processes.

Thus, the challenge for those of us who teach in the geosciences is to utilize the most appropriate techniques to stimulate student interest and motivate them to unlock nature's secrets.

Choosing strategies to be used in teaching sedimentology at Beida?

The traditional method of lecture-based teaching currently used in earth science lectures at Beida does not provide a good or effective teaching and learning experience. It may be difficult to change our teaching style and the necessary change will probably require an integration of new teaching methods with the older teaching methods. To begin with we need to replace the current emphasis on lectures with an emphasis on tutorials, laboratories and excursions. In addition we need to replace our current emphasis on the recall of facts with an emphasis on students being able to

analyze information and report their conclusions as well as develop their practical and laboratory skills. In addition to these fundamental changes we should try to develop problem based learning approaches and integrate e-learning into our teaching. Within this context, we will outline several specific, urgently required areas of reform which are dealt with individually in the subsections that follow.

Modification of the course curriculum

The search for better ways of teaching about sedimentology has led some teachers to experiment with supplementary materials such as videos, CD-ROM databases and simulations, challenging thinking exercises such as writing a mini-report, letter to the editor of a newspaper, travel-study programs, and various types of internships. We should attempt to update the course content, and reconsider teaching strategies in this context. The current course in sedimentology at Beida deals with three main topics: petrology, sedimentary processes and diagenesis. The content about rock genesis and sedimentary processes must be increased and integrated with the current content which emphasizes rock description and identification (which should be decreased). Currently the three main teacher-student contact components of this course are lectures, laboratories and a field trip. They are delivered as separate and completely distinct components. They must be combined and integrated in such a way that the major topics in sedimentology, (sedimentary processes, petrology and diagenesis) are delivered as coherent sets of content and concepts. The petrology section should also include material based on typical sedimentary sequences that occur in China. We should introduce these particular real-world settings to the senior students in particular as they are the people who will most likely become professional geologists and will need this knowledge.

As intellectuals in pursuit of knowledge and understanding, we tend to value both content and theory. Thus it is natural to feel that the most constructive method to convey these ideas is via both thematic and conceptual lectures. Yet, without the proper mix of thematic and conceptual focus, we run the risk of failing to convey the importance and excitement inherent in sedimentology. Consequently, we should improve the quality of the course instruction and, where applicable, laboratories and tutorials with the goals of making students more active, and more interactive and employ contemporary developments in education reform. We should also incorporate new technological developments, discipline news, etc., from the Internet, and introduce some of the unresolved problems of the discipline, which will encourage students to think about developments and make them active in the discipline.

Increase the amount of laboratory teaching (especially in petrology)

One of the main aims of any course in sedimentology is to train students to identify and describe the characteristics of a sedimentary rock. Students learn this skill best by doing it. Currently there is little laboratory time given to developing this skill – it is presented in lectures as a theoretical concept. Hence we need to introduce some laboratory classes that develop the methods and procedures used to analyze sedimentary rocks. These laboratory classes

should include experiments, rock identification (with hand specimens and thin-sections), and quantification of sedimentary rock features, stratigraphic correlation, and maybe an occasional local field trip. We can use the digital microscope and projector in the laboratory to help the teacher and students observe the same picture at the same time, which can keep the students in step with the teacher. To achieve this we must decrease the lecture time and correspondingly increase the practical program time. Let students have more time to experience.

Integrate IT and field trips properly into the course

During our time at The University of Sydney we observed the combination of a sedimentary processes field trip with practical classes that undertake computer simulations of the sedimentary processes that we and the students observed in the field. This approach offers an engaging classroom exercise that motivates and converts students with an interest in sedimentary process into active, rather than passive, learners.

In order to encourage the students' motivation, at the beginning of such sessions, the teacher will have an excursion, in which data is collected so that the students can analyse it for themselves. For example, when studying river sedimentary processes, we will have an excursion to a river. This will help educate students in the evaluation of hypothetical or actual responses of the physical environment. In other words, the excursion becomes a PBL exercise directly related to the student's world beyond the classroom.

Introduce a wider variety of learning experiences (especially more excursions, group work, regional geology case studies and PBL)

This part is very important for all of our courses. For example we could apply the students' knowledge of petrology by investigating a particular geological area. Focusing on the study of sediment process, students are empowered with their learning by means of group discussions and decision-making. With carefully staged guidance by tutors, students devise research questions and execute their project, analysing data collected on a field day. The students will be asked to describe, measure, sample, and interpret sedimentary rocks in the field. During the excursions, students will observe and analyze the outcrop and data, then give a final report. This should improve their abilities of self-direction and groupwork.

Problem based learning can be profitably employed during the preparation of students for field classes. PBL encourages active and deep learning in students and can readily be applied to fieldwork preparation. During fieldwork, we will organise the groups so that they include both shy students and active students, general students and talented students, in order to make everyone active. It is important to encourage all students to be actively involved.

Fieldwork could consist of four steps, first problem solving which summarise the ideas or identifies a geological problem or issue and outlines a plan to do fieldwork aimed

at resolving the issue. Secondly, ensure that the group works well together as a team; thirdly, analysis of the collected data; and finally, a report writing session, where the group prepares a scientific report.

During the groupwork, the teacher should use the brainstorming method, so that students can get some knowledge from others, and hopefully avoid making unnecessary mistakes. In order to share ideas, experience and the practical work, small groups of students should be set up. Small group work promotes situations in which students will work together to maximise their own and each other's learning. Students become actively involved in the learning process, it encourages creativity and initiative, more discussion and sharing of ideas, there is a beneficial sense of belonging and mutual support; and it introduces a wide range of transferable skills (Healey et al. 1996; Hindle 1993). Possible disadvantages, such as students 'hiding' within a group or from difficult tasks, need to be carefully monitored. A problem solving framework is adopted in which students are presented with realistic research situations. Experiential learning takes place through active participation in the research process, visualisation and reflection (Healey and Jenkins 2000). This encourages the use of previous knowledge and helps students to acquire and apply knowledge to new scenarios, and develops logical and critical thought (Bradbeer 1996).

Improve the link between the curriculum and its assessment

In general, much of geology teaching at Beida focuses on description and analysis yet there is no clear link between assessment criteria and learning objectives. Students rarely critically reflect, analyze or effectively communicate in their written work. There is little feedback to students about their work. Rectifying this situation would greatly improve the quality of their education.

Slowing down the classroom

There are many tasks in the sedimentology courses. For example, in-class quizzes, report, writing paper, etc. In most cases, we do not give students very much time to think before we ask them to respond to our questions. This can discourage some students from participating in discussion. We need to consciously increase our waiting-time before we require a response. Some people count for 3 to 5 seconds after they ask a question. Some give themselves physical reminders to wait (by putting their hands over their mouths, for example). The key is to find a strategy that will help you to increase reflection time for your students so that you give everyone a chance to come up with an answer.

Developing students' writing skills

Sedimentology should be redesigned as a 'writing intensive' course. Through writing their opinions, the students will benefit from the writing instruction in this course, especially analytical, scientific and popular science writing. Students should be expected to write papers on the core topics of the course sediment process and sedimentary petrology and to write other papers on optional topics in sedimentology and paleo-environments.

It is necessary to plan several writing assignments in this course, each of which is designed for as much writing instruction as evaluation. The most prominent will be a 10-15 page research paper on a sedimentological or stratigraphic topic, which goes beyond what we do in class or laboratory. A preliminary draft of this paper will be due three weeks before the final version so that the students have an opportunity to revise their work. There will be two essays, each 2-3 pages long, during the semester. One of them will be an analysis of a recent scientific paper, and the other will be about a recent geological news event. The paper and the news story will be chosen from what appears during the semester of interest to the class. Also there will be, twice weekly, written answers to the preparation questions. The report writing then offers the opportunity to demonstrate both the academic and transferable skills.

Reforming our approach to assessment

Assessment is an important aspect of both the student learning experience and the practicalities of providing fair and thorough feedback and, of course, 'assessment is the most powerful lever that teachers have to influence the way students respond to courses and behave as learners' (Gibbs 1999).

Assessments within the university setting are carried out through a wide range of methods appropriate to levels, including essays, dissertations, monographs, program reports, research notebooks (for example, studio notebooks and contextual journals), group critiques, performances, studio presentations as well as written examinations. External assessors comment favourably on the rigour of the Beida's assessment processes at final examination. In final assessments and dissertations there is clear evidence of moderation to help ensure parity between students. Currently however, the final assessment methodology is not uniform and requires consideration. In some courses, final assessment has changed from a weighted numerical scheme of examination assessments to a holistic assessment of the student's entire body of work, as a deliberate strategy to integrate theory and practice.

We must apply a new integrated method, which includes lecture tests and laboratory tests. The lecture tests will, naturally, be derived from lecture material, and the laboratory tests are from our laboratory work. Although, laboratory and lecture concepts are not easily separated – there may be ideas we introduce in lectures but cover in more detail in the laboratory, and vice versa. The final examination will include questions that require students to integrate material covered in laboratory sessions, lectures and excursions. These tests are a type of 'in-class' writing assignment, which are the best ways to craft written responses to scientific questions. And also there are unannounced quizzes in the laboratory and lecture. This system encourages students to review lecture notes and the readings before each lecture and laboratory.

A major positive feature of the teaching, learning and assessment strategy is the growing use of student self-evaluation and peer evaluation, focused through the use of tutorial groups, which meet regularly. This aspect makes a substantial contribution to the attainment of the stated

objectives; however, there is scope for improvement. The aims set by the subject provider are substantially met.

Haigh (2002) describes the use of classroom quizzes as a way of promoting student learning. Starting each class with a quiz on the previous session's work encourages students to review their course notes ahead of each session, removes the need for any spoken review of course progress, and abets attempts to help students convert surface memorization into deep learning through classroom discussion. Class quizzes are popular with most students, who mainly agree with the above analysis. Quiz scores correlate significantly with most other types of assessment, including those from formal essay-based examinations, so they may be considered valid as a mode of assessment. The exercise described in this paper will have transferability to other degree programs, including earth and environmental sciences.

It is hoped that the use of class quiz results will broadly reinforce the more traditional form of assessment, which is usually taken as the measure of student learning. In conventional terms, this suggests that the class quiz mechanism fosters student learning (Marco and Crone 1991). The introduction of regular class quizzes, that test student knowledge of the substance of previous sessions and required reading, has successfully encouraged students to review their course notes ahead of each class.

The significant difference between this application of class quizzes and their traditional use is that the main function of the tests is not assessment. Instead, it is to encourage class preparation, attendance and, hopefully, ensure that the students attending know enough to participate in class discussion designed to reinforce learning. However, the technique also contributes to assessment and this generates the question of whether or not the assessment generated supports other, more usual, modes of assessment. So the questions are, did the strategy work, and is the assessment generated useful?

Discussion and conclusion

Reflecting back on the undergraduate teaching we received, we believe that most of our teachers taught us by what we will call transmission. The teacher was active and transmitted information to us while we passively learnt by absorbing the teacher's lessons and lectures. While we were at The University of Sydney, we observed many teachers use a combination of both this transmission method and constructivist approaches. It was of great interest to us that students at The University of Sydney were generally not that attentive during classes based on transmission and did not appear to absorb much of the information delivered. However, the opposite occurred in the constructive learning environments where the students took a more active role. In these classes the students asked questions and appeared to actively adsorb the information. One thing that struck us was the fact that our own experiences as students seemed to be replicated during the transmission classes we observed at The University of Sydney. It seems to us that this response is not a culturally dependent one. Similarly, we expect that our classes' response to a constructive teaching approach will be culturally independent as well. If so, we can expect

this approach to generate a more involved and active learning response in the students at Beida.

It has been shown that the constructivist methods are more effective, especially in a geology class, where students can learn in a 'hands-on' way where they use the teacher for support. Nevertheless, and despite its drawbacks, we still consider the transmission technique useful because it is possible to deliver a large amount of information quickly. It is probably a matter of getting the balance right. Successful college teaching in geosciences demands that the teacher have available a variety of teaching methods. If they are all employed effectively and competently, students will have to adapt, which should aid them to become more self-directed, creative, adaptable, cooperative, and inductive in their thinking.

People learn differently to one another, and different sections of courses should be taught in different ways, such as lecturing to deliver theory, applied sessions using PBL, constructivist teaching in practical sessions, research-led learning, and work-based learning methods to develop curiosity and professionalism.

The new strategies should encourage deeper learning that suit the full range of individual learning styles. During the introduction of a new curriculum, we should aim to encourage critical thinking and improve questioning ability, encourage innovation and critical examination of existing practices, as well as self-reflection by the education in the context of student performance.

Problems might be encountered in implementing these proposed modifications. To minimize these a transition period will be required in which the New Curriculum is implemented. Reform is difficult and we should make the transitions at a sensible pace. Evolution will work better than revolution. Evolution has a lower risk. But reforms are needed. We should apply the results of successful experience to our own education, and probably stage their introduction in small jumps rather than in a single giant leap. It is predicted that within 10 to 20 years, the Chinese universities will have more freedom to develop education methods and establish independent management systems according to their specific needs.

Concluding statement

The use of different methods and teaching approaches will enable students to explore more deeply into the sedimentary world. Often students need encouragement to gain the confidence to develop their initiative and independent thinking. As students attain knowledge, understanding and experience of the research process and, through constructive self-evaluation, as they 'learn from their mistakes' they will be properly prepared for the large projects and fieldwork they will undertake later in their careers, particularly their dissertation projects. Adopting a learning and teaching strategy based around student-centred approaches, although challenging and demanding for students and teachers, will be an effective format for learning sedimentology and training students that are able to undertake research.

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