Promoting active and deep learning in my classroom

Chai Zhiming
Department of Mathematics and Physics
University of Petroleum
Beijing 102249
People's Republic of China

Introduction

In my university, we teach Advanced Mathematics, Linear Algebra, Probability and Statistics, Complex Functions, Mathematical Modeling, Computing Methods, Mathematical and Physical Equations, Optimization, and some other mathematical courses. Among them, Advanced Mathematics holds a fundamental position, so I will use it as an example in this article.

Advanced Mathematics consists of Calculus of Functions of Single Variable and Application, Calculus of Functions of Several Variables and Application, 3-D Analytic Geometry and Vector Algebra, Sequences and Series, and Ordinary Differential Equations. We have six lecture hours per week, totaling 196 hours through two semesters among the first year students.

The results of the final examination in 2003 are given (Table 1). In that year, there were 1257 students enrolled in this course.

Table 1. Results in Advanced Mathematics, UPC (2003)

Department	No. of students	≥90	89-80	79-70	69-60	59-0	Average mark	Rate of HD	Rate of F
Petroleum Engineering	152	17	53	49	26	7	76.9①	11.2①	4.6①
Chemical Engineering	337	15	65	119	100	38	71	4.4	11.2
Economy	154	15	43	48	37	11	71.8	9.7	7.1
Geology	151	0	17	46	71	17	67.0②	0.0②	11.3
Mechanism Engineering	156	5	31	53	50	17	69.8	3.2	10.9
Electronics and Automation	151	16	45	50	24	16	74.1	11	10.5
Business Administration	156	11	32	45	43	25	68.6	7.1	16②
Total No.	1257	79 6.3	286 22.8	410 32.6	351 27.9	131 10.4	71.2③	6.3③	10.4③

Mark= 30% (assignments + mid examination) + 70% (final examination).
①best results across all departments, ②worst results, and ③the average,

After an analysis of examination papers, we found:
1. the effect of the lecture was disappointing;
2. there was not enough understanding of the materials, some students mechanically copied examples in disregard of specific conditions; and
3. most students found it hard to apply what they had been taught to solve problems.

I agree that it's students who should take responsibility for their own learning. However, as a facilitator of the learning, what should we do so that we can promote students' learning? Let's consider the following aspects.

Course design
All of the students who have different majors, different interests and different abilities learn the same content, in the same way, at the same time, and are given the same assessment.

Content
More stress is put on foundation and abstract theories. It's hard for students to perceive their applications.

Teaching
Teaching methods are the traditional teacher-centred, lecture spoon-fed style. Most class time is spent with the professor lecturing and the students listening and taking notes.

Assessment
Assessment methods place too high a premium on memory and recall.

As a consequence, students felt bored, without interest or motivation. Passive and surface learning were involved.

So, I feel we do need some improvement in the teaching method. How should we improve? To answer this question, first of all, we should make clear:

What kind of graduate do we need in the 21st century?
Science and technology change with each passing day. New disciplines occur and intersection among different disciplines becomes more and more extensive. Information technology is developing rapidly. The times call for a graduate in the 21st century who should:

- be able to transfer the knowledge to solve a real problem;
- be able to make a judgment individually;
- have a broad perspective and insights into his/her field;
- have imaginative and creative powers;
- be able to communicate and cooperate with others;
- be able to utilize new technology; and
- continue to learn all of his/her life.

Mathematical education must meet with the demands of the times. Mathematicians say that mathematics is the language of nature, and the behaviour of human beings.

So, fostering the development of generic thinking skills in students should be a mission of mathematical education. We should put emphasis on ‘Mathematics for all’. After all, not all mathematics students become mathematicians!

Having looked at the demands of society, let’s consider…

Contemporary theories of teaching and learning
Based on the objectives of modern education stated above and research outcomes, contemporary educators have raised many new theories, such as constructivism, interactive learning, student-centred learning, collaborative learning, project based learning, problem based learning, case study, and so on.

In my opinion, one of the main ideas behind them is that students must be active participants in the learning process wherever possible in order to promote deep level processing of knowledge.

Here is a psychological report on what students retain:

- 10% of what they read
- 26% of what they hear
- 30% of what they see
- 50% of what they see and hear
- 70% of what they say
- 90% of something they say as they do something. (Lagowski 1990)

This demonstrates that students must do more than just listen. Firstly, students must be active participants. They receive information from multiple sources: listening; reading; watching; and feeling. They process information in multiple ways: thinking; discussing; debating; testing; and acting. They output information by: writing; answering questions; and solving problems.

Secondly, learning should occur on a deep rather than surface level. After learning, students should be able to: gain an overview of a topic; grasp the main ideas on the subject; develop logical arguments in an essay; produce a response or some evidence; make a decision; or solve real problems.

In active and deep learning, learning occurs through teacher-to-student, student-to-teacher, and student-to-student interactions. Motivation comes intrinsically rather than extrinsically. As a result, students increasingly take responsibility for their own education.

To promote the active participation and deep understanding of the learner in the learning process, we should move from a ‘teacher-centred approach’ to a much more ‘student-centred approach’ by adopting as many teaching strategies as we can.

Several strategies in my classroom

Speech techniques
A well-organized lecture is the most important. You should use a clear voice and legible writing. Gestures and body language can be used to assist students in understanding what you are saying. Good discipline is important. Some students show their discontent for the teacher who doesn’t take measures to control discipline. Of course, the teacher should keep the atmosphere of the classroom friendly and amiable, for example, by smiling, so students will feel relaxed. If they have questions, they should feel comfortable asking them.

Besides, the facts have shown that if you show enthusiasm for your subject and interest in your students, students will find it easier to follow you.

Outline
First, we found that younger students find it difficult to distinguish between what’s important and what’s trivial; or between generalizations and specific data. So, the use of an outline can help them to organize the knowledge. Second, the use of an outline may help students to build up a whole image of the course in order to make it easier for them to follow the development of the lecture. Third, it’s important that students know what the aim of the learning is and how they should learn. We can make use of the overhead projector or board on the very first day of class or at the beginning of each lecture.

Pace
Students’ attention wanes quickly, within 15-25 minutes. So, it’s a good idea to pause two or three times during a lecture and do something else, for example, let students review what you’ve just said or let students consolidate their notes, or tell a mathematical story.

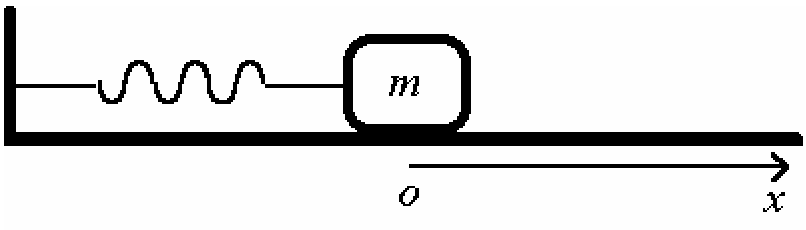
Interpretation
Mathematics is full of difficult and abstract concepts. So lecturers should try their best to interpret some important concepts or content from different angles, such as algebraic, geometrical, numerical, graphical, physical and economical. For example, when we introduce the derivative, we can interpret it geometrically (slope of curve); physically (instantaneous velocity); economically marginal (cost, revenue, profit); generally (instantaneous rate of change).

Visual quiz
Most students are a little too shy to ask questions. So, taking a short quiz is good not only for the teacher but also for students to know how well they understand the content. Quiz questions are usually based on basic concepts or common mistakes which students easily make. The answers can be multiple choice (A, B, C, or D) or True (T) and False (F) and typically displayed on an overhead screen. After students answer it, make a quick survey and then give an immediate feedback.

Problem based learning
Problem based learning (PBL) begins with the introduction of a problem on which all learning centres. Teachers assume the role of cognitive and metacognitive coach rather than knowledge holder and disseminator. Students assume the role of active problem-solvers, decision-makers, and meaning makers rather than passive listeners.

Here is an example. Before we give a lecture on second order differential equations, we can ask students to deal with the problem below.

Problem: Damped Vibration



A metal block of mass is attached to a spring having a stiffness, *k*.

When the block is displaced from the equilibrium position o to a position *x*, it will experience a restoring force that is proportional to the displacement *x* and the spring constant *k*. i. e.

$$f_{restoring} = -kx$$

When the system vibrates in a medium, the block will experience a resistance. Provided the block moves slowly, the damping force is proportional to the block's velocity:

$$f_{damping} = -c\frac{dx}{dt}$$

where *c* is called the coefficient of viscous damping.

Students are asked to set up a mathematical model to find the functional relationship between the displacement and time. This is a second-order ordinary differential equation.

PBL is a powerful strategy of teaching. However, I'd like to say it is not very easy to find many suitable examples for mathematics and use them in the lecture.

Cooperative learning
Learning should be cooperative in nature rather than competitive because people do not learn things best at the expense of others. By this strategy, students work together to learn and are responsible for one another's learning as well as their own. Developing positive race relations as well as collaborative work are very important in the future.

The methods we can take include:

1. Pair: The teacher gives a lecture and raises a question. Students think about the question individually at first. Then, individuals pair up and exchange thoughts. After that, the pairs share their responses with other pairs, other teams, or the entire class.
2. Discussion: Discussion in class is one of the most common strategies promoting active learning. We encourage students to discuss, debate and ultimately to teach one another.
3. Presentation: We assign students to study a topic in the textbook within a group. Then, ask representatives from some groups to give presentations on their findings. During the presentation, the students in the same group can add comments and other groups can raise questions.
4. The group members explain concepts to one another and make sure that everyone in the group is ready for a quiz or other assessment that they will take without teammate help. Students' quiz scores are then summed to form a group score and the best group earns a reward.

Question and answer
Using questions can put students in a position where they can make a decision, and can stimulate them to respond actively to the lecture. Questions are used to check students' comprehension on concepts and content. These can help ascertain whether the students can recall or recognize basic information. For example, what conditions must be met to apply L'Hopital's rule? Other questions require students to apply formulas to new problems, or to relate theoretical abstractions to real situations. These can help both students and teachers determine how well students are grasping concepts. For example, after having learned the Dot Product and Cross Product, we can ask students to give a geometric interpretation of the Triple

Product. Questions can also require students to make evaluative decisions, explore new approaches to familiar material or solve problems.

For example, after the Rolle's theorem (Diagram 1) and before the Mean Value Theorem (Diagram 2), we can ask students to think for themselves how the conditions have changed and what kind of conclusion they can draw from the second diagram.

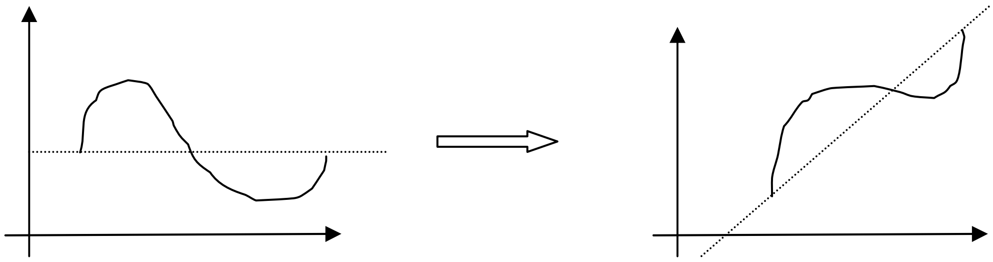


Diagram 1

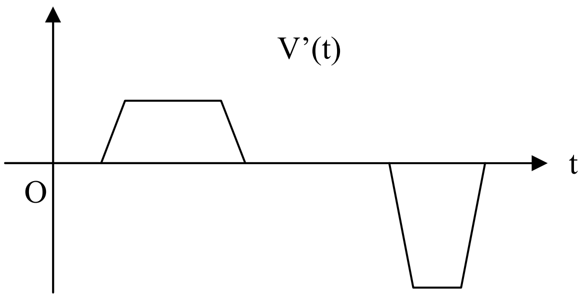
Diagram 2

Reading and writing
In-class reading and writing exercises can help students realize any problems they might have, as well as learn to express their thoughts more clearly and focus their attention on important elements of the course.

For example,

1. In proving a corollary to a theorem, a similar process is used, but some steps are omitted. So, the teacher first explains the proof of the theorem while the students follow in their books. After this explanation, individual students may be called upon to write a similar proof for the corollary.
2. We can ask students to write the interpretation of a curve or a graph in the textbook or notes in their own words.

Here is an example.
A child inflates a balloon, admires it for a while and then lets the air out at a constant rate. If *V(t)* gives the volume of the balloon at time *t*, then figure shows *V'(t)* as a function of *t*.



Ask students to read the graph, and annotate each segment on the graph. Students will then be asked to determine what each segment represents.

Multimedia assisted teaching
Consider again the problem used in the strategy of PBL above.

After students have set up the equation,

$$-kx - c\frac{dx}{dt} = m\frac{d^2x}{dt^2}$$

we can get the general solution by using a computer.

$$x(t) = \_C1\, e^{\left(\frac{1}{2}\frac{(-c+\sqrt{c^2-4mk})t}{m}\right)} + \_C2\, e^{\left(-\frac{1}{2}\frac{(-c+\sqrt{c^2-4mk})t}{m}\right)}$$

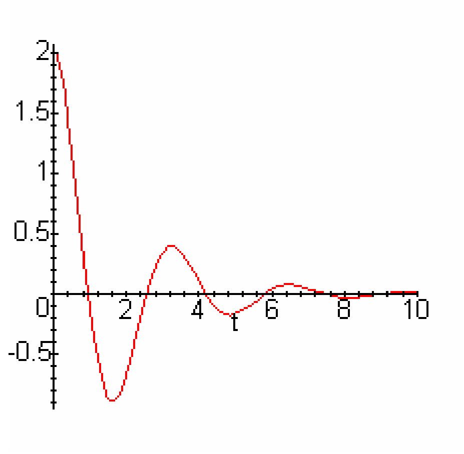
Given the initial conditions,

$$\begin{cases} x = A & \text{initial position} \\ \dfrac{dx}{dt} = 0 & \text{initial velocity} \end{cases}$$

we get the particular solution.

$$s62 := x(t) = \frac{A(c+\sqrt{c^2-4mk})\,e^{\left(-\frac{1}{2}\frac{(c-\sqrt{c^2-4mk})t}{m}\right)}}{2\sqrt{c^2-4mk}} - \frac{A(c-\sqrt{c^2-4mk})\,e^{\left(-\frac{1}{2}\frac{(c+\sqrt{c^2-4mk})t}{m}\right)}}{2\sqrt{c^2-4mk}}$$

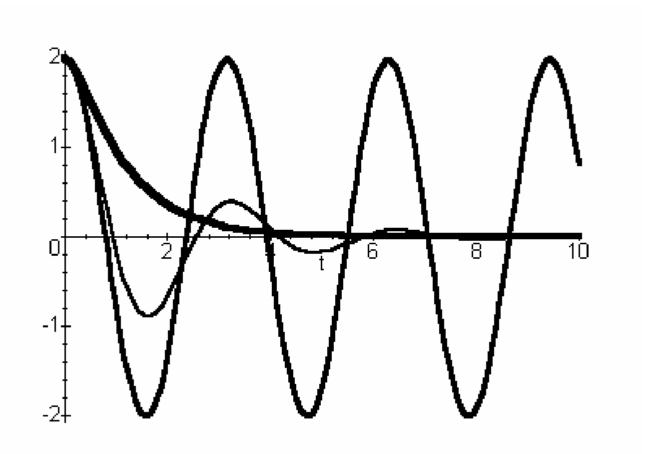
Now let us substitute the specific values of *m*, *k*, *c* and *A* into the solution and plot it out:
m=1, k=4, A= 2, c=1,



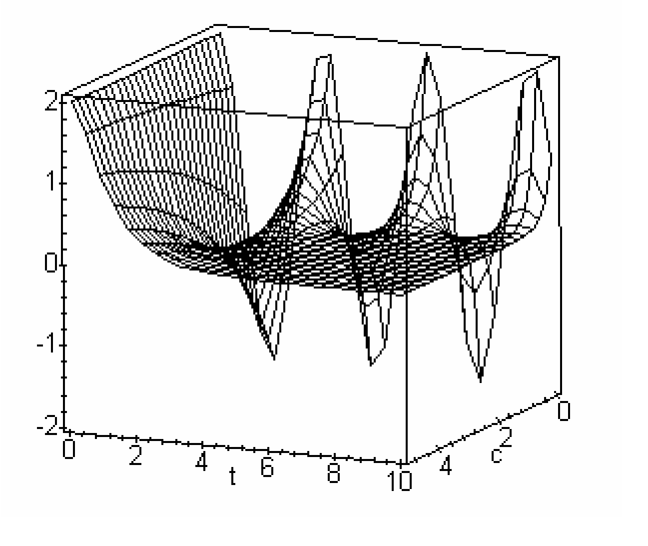
Students can interpret the meanings of the solution.

In particular, we can substitute the value of the parameters and investigate the meaning of the damping constant c by plotting the solution with different c values.

[C=1, 0, 5, separately]



Also, we can use the computer to have a complete view of the displacement x as a function of time t and the damping constant c.



By using the computer, students can save time on tedious numerical calculations and concentrate on understanding the mathematical problems and exploring mathematical structures. The complex concepts or theorems become vivid and easy to understand through graphics, animation or other audiovisual products. It is helpful for students to link theoretical knowledge to realistic applications.

Relevant issues

Of course, to achieve these aims, there are still a lot of difficulties. Firstly, promoting active and deep learning can't be achieved solely through making changes to lectures. We also have to consider things such as course design, textbook reform and the assessment system. Secondly, teachers need to have a rich understanding of the subject knowledge they teach and appreciate how the knowledge of their subject is created, organised, linked to other disciplines and to real-world settings. Also, teachers need to know how to apply these strategies properly and effectively. This requires experience. Thirdly, there are many common barriers to change. For example, the powerful influence of educational tradition; the use of active learning within limited class time; a possible increase in preparation time; the potential difficulty of using active learning in large classes; and a lack of necessary materials, equipment, or resources; and the risks that students will not participate, use higher-order thinking, or learn sufficient content.

However, I believe all these kinds of difficulties or barriers will be overcome gradually.

Conclusion

We live in a changing world. Facilitating active and deep learning is absolutely valuable. It is the learner who should be responsible for the learning. However, the teacher should become a good facilitator or instructor. We believe that each obstacle or barrier and each type of risk can be successfully overcome through careful, thoughtful planning by the instructor, and adequate preparation by students. The reform of instructional practice in higher education must begin with faculty members' efforts.

Acknowledgements

I would like to express my sincere thanks to the China Scholarship Council and the University of Sydney, who organized the program *Teaching Science in English*. I would also like to thank the Centre for English Teaching, Faculty of Science, Faculty of Education and the School of Mathematics and Statistics for carrying out the program successfully. I also want to say thanks to Cecilia, Mike, Mary, Tony, Lloyd and Lindsay for their excellent and useful seminars; to Jim and Caroline for improving my English level; to Bob, Jenny, Adrian, Andrew, Hugh and Choo for allowing me to sit in on their classes; to Daniel, Charlie, Hugh, Peter and Jenny for giving us wonderful presentations; and especially to Sandra Britton for her generous help and circumspect support and all the people who supported us all the time.

Reference

Bonwell, C. *The Active Learning Site* [Online] http://www.active-learning-site.com/

British Columbia Institute of Technology (1996) *Exactly How Is Math Used In Technology?* [Online] http://www.math.bcit.ca/examples/.

Lagowski, J.J. (1990) Retention rates for Student Learning. *Journal of Chemical Engineering*, **67**, 811.

Rosenthal, J.S. (1995) Active Learning Strategies in Advanced Mathematics Class. *Studies in Higher Education*, **20**(2), 223-228.

Slavin, R.E. (1995/96) Synthesis of Research on Cooperative Learning. *Educational Psychology*, 131-138.

Woods, D.R. (1994) *Problem-based Learning: How to Gain the Most from PBL*. Ontario: D. Woods.