A shift from traditional teacher-centred strategy to student-centred strategy in genetics teaching

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Abstract

Genetics is an important basic subject in biological sciences. During their studies, students need to master the skills of learning and communicating, and develop self-reliance and lifelong learning techniques, although the traditional teaching strategies are generally teacher-centred. The present paper introduces general categories of teaching styles, reconsiders the current teaching strategies, and indicates that a major transformation should be made in the concepts of teaching: a) from teacher-centred to student-centred teaching and learning; b) from lecture-based to problem based teaching and learning; c) from teaching-focused approach to learning-focused approach; and d) addressing problem-solving skills and lifelong learning competence. Effective contemporary teaching strategies are urgently needed in the shift to student-centred approaches and active learning. Teaching should be constructivist and systematic, and it is important for us to build a Virtual Learning Environment (VLE).

Introduction

In biological sciences, genetics is an important basic subject. It includes the properties and functions of genetic materials, the rules and the processes of heredity and variation, genetic operation, and the relevant practical application. All activities of life take place on the basis of the genetic background of the organisms. Many diseases and deficiencies are caused by abnormal changes in genetic material. So, after several basic courses in biology, genetics is included in the schedule of basic courses for third year students in the College of Life Sciences, Beijing Normal University (BNU), Beijing, China.

By third year, undergraduates have completed many assessments for primary basic courses, and are faced with the choice of either preparing to join society or getting a promotion into graduate studies. They need to foster the skills of learning and communicating, and the abilities of self-reliance and lifelong learning to achieve either goal.

In China, the current framework of teaching in higher education has been the subject of much attention, with respect to the reform of teaching styles and strategies. There are three general teaching styles: discipline-, teacher-, and student-centred (Dressel and Marcus 1982; Woods 1994). In the former two styles, students passively receive information, because they are forced into special teaching moulds or materials. The latter style, however, requires the students to participate in the process of teaching and learning (Billett 2002). Since the students are the receptors of teaching, teaching should focus on the students, especially on the development of their cognition, generic skills and ability to apply knowledge in practical situations.

As a teacher, one should know the philosophy and practice of effective ways to teach. The points at issue are:

1. the content which is taught;
2. the instructional strategies and approaches which may be beneficial;
3. the styles and methods by which the students learn; and
4. the prediction and assessment of the effect of teaching and learning.

A definition given by the Curtin University of Technology Human Ethics Review Committee states 'An innovative teacher is more than just one who uses a new or significantly improved technique for teaching and learning, but rather s/he is committed to the goals or philosophy of improving the quality of student learning through innovation'.

Since 12 February 2004, I have taken part in the project *Teaching Science in English* as a member of the fellow academics from China, hosted by the Faculties

of Science, Education and Social Work, the University of Sydney (USyd). This training at the University of Sydney is a favourable event in my teaching career, and it is absolutely necessary to conceive some framework for improving teaching in our own university when I return to my professional post in China.

In this report, the generic contents of the genetics course in BNU will be briefly described, and the objectives of this curriculum will be stated. The report will provide contemporary ideas about how students should learn and how the teacher should teach. This paper will consider how we can adopt these strategies and approaches in China.

Description of the course and teaching approaches

Genetics is a branch of biology for the study of genetic material, the way heredity and variation happen, and the impacts they have on the development, reproduction and evolution of organisms.

Curriculum outline

The main content of the genetics curriculum include basic concepts, the structure and function of genetic materials, the laws of heredity and variation, gene expression and its effects, genetic operations and their applications (Figure 1).

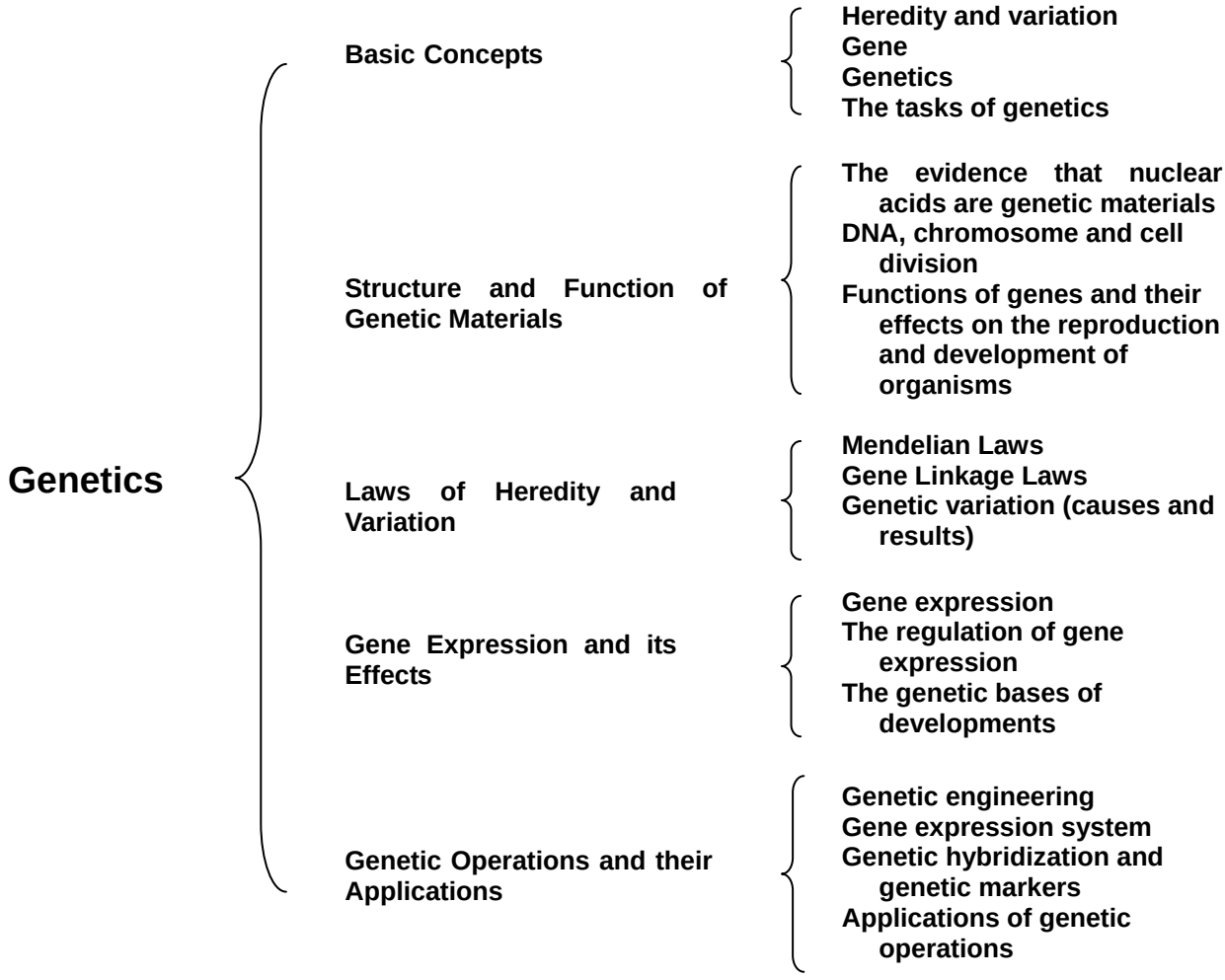

Figure 1. Outline of the genetics curriculum

The main objectives of the current course

The main objectives of genetics course are to teach the students:

1. to understand the properties, structure and function of genetic material;
2. to grasp the laws of heredity and variation;
3. to grasp the concepts of modern genetics, especially molecular genetics; and
4. to be able to use genetic operations to solve or try to solve practical problems (such as genetic modification, gene therapy).

The current teaching styles

The style of the teaching is closely related to the number of student, the number of teachers, the contents and the facilities for teaching and learning. Figure 2 shows the related data.

In recent years, the number of students has stabilized at 110, but the number of teachers has decreased (from 4 to 2), and so has the number of teaching hours (from 72 hours to 51hours). These changes strongly affect the style of teaching.

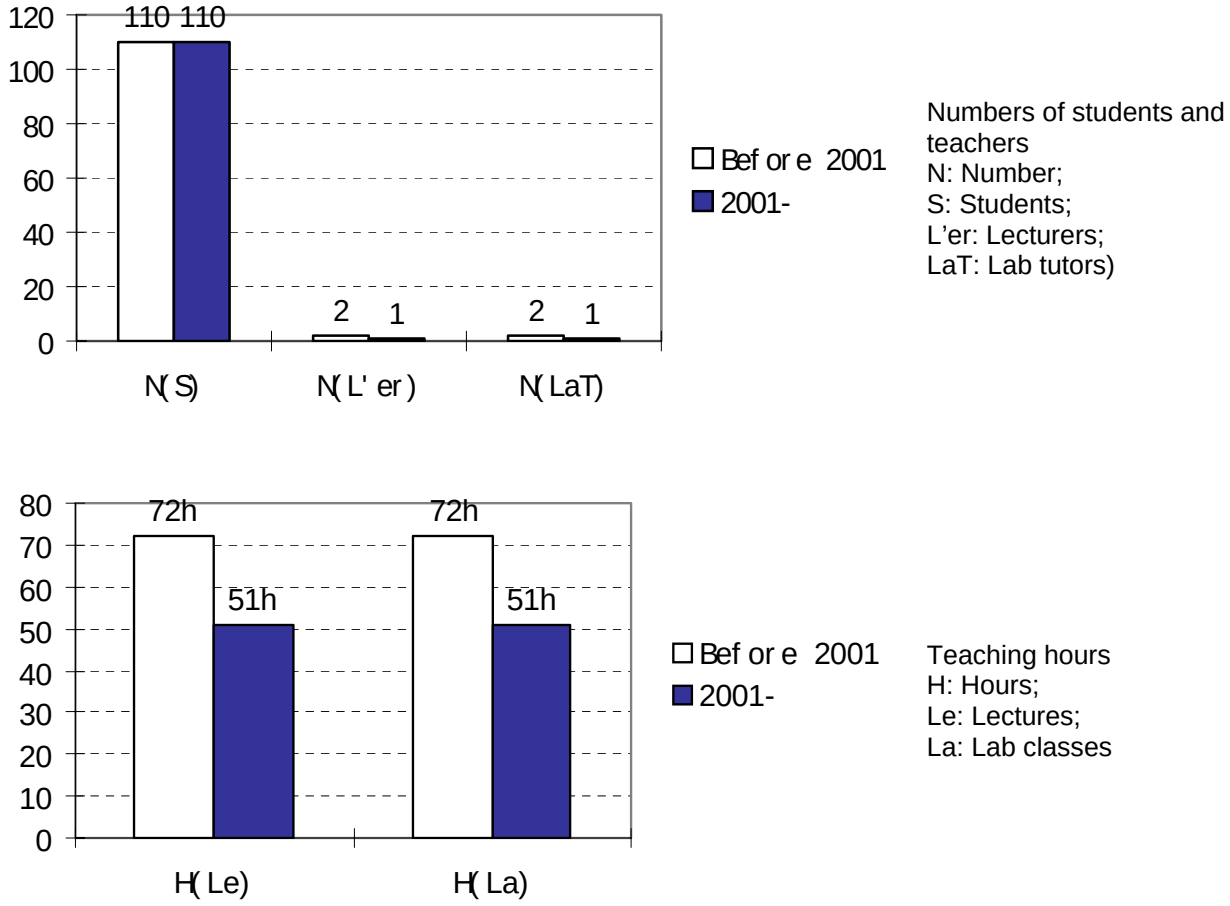

Figure 2. A comparison of the number of students, staff and teaching hours before, and after 2001

Generally,the following teaching processes are employed in the genetics course:

Lectures

The number of students has remained constant, but the number of lecturers and the amount of teaching time have decreased, especially when considering the growth of modern research in genetics. Although the lectures have been taught by means of modern multimedia devices, the wide disparity between the numbers of student and teachers, and the limited number of teaching hours, make it difficult to escape from a teacher-centred strategy.

Laboratory classes

As with the lectures, only one tutor has been employed to supervise the laboratory courses. The lab classes are arranged into 20 or more students in each session, with 5 laboratory sessions per week. The tutor must work in the laboratory with the student groups every weekday. The fundamental strategy of laboratory teaching is a teacher-centred one.

Additionally, sometimes video or audio aided teaching is provided to the students. We use the intervals between experimental steps to introduce new discoveries or complementary knowledge of genetics or relevant disciplines. Occasionally, we acquire progress reports from research projects, for example, the breakthrough in the Human Genome Project. In cases of unforeseen epidemic diseases or natural calamities, we use video / audio aided teaching to meet the needs of the discipline, the practical situation and the desire of the students. Of course, the video/audio aided teaching is more interesting and lively. Steps need to be adopted to take advantage of it more in the future.

Reconsideration of the current teaching strategies

Generally speaking, our teaching strategy is teacher-centred, discipline-centred and lecture-based. In a teacher-centred approach, the teacher transmits information to students and tries to help students acquire the concepts of the discipline. In this situation, the students do understand the discipline to a considerable degree (Trigwell, Prosser and Taylor 1994), but they don't have sufficient opportunities to engage in self-directed learning. Their concepts are rote-learned and they have only a superficial level of understanding of the subject.

Our current teaching strategy is also discipline-centred, due to limited preparation time and teaching materials, and most of the content is derived from the textbook. Students have little prior experience of the topics covered. They passively hear the concepts once and try to memorise them without knowing where they belong in the overall conceptual framework.

The current teaching approaches are also lecture-based. Typically of this teaching style, the lecturer delivers his speech from a stage, and a large number of students pay close attention to him, trying their best to hear what is said. The organisation of lectures makes it unnecessary for the students to consider the material deeply.

In summary, teacher-centred learning and the related teaching approaches mould the student into a passive recipient for information already acquired by the teacher. The learning task is to reproduce the subject matter at a later date (Chin and Brown 2000). Therefore, reform is required to develop student-centred learning experiences that lead to lifelong learning outcomes.

Consideration of modifications

Concepts to be changed

Students are supposed to become independent, lifelong and active learners. Consequently, the teaching program needs to include materials, strategies and approaches which are interesting, motivating and require the learners to be involved not only in individual tasks but also in cooperative tasks (team tasks) (King 1997). To improve our teaching quality with respect to these outcomes, the changes will need to be made.

From teacher-centred to student-centred teaching and learning

Student-centred teaching focuses on the student and, in particular, on the cognitive development of the student. The teacher's goal is to help students grasp the development of knowledge as a process rather than a product. In the student-centred approach, teachers adopt a student-focused strategy to help the learners change their world view or concept of the phenomena they are studying (Trigwell, Prosser and Waterhouse 1999). Since it is the learners who need to re-construct knowledge and build up a new world view or constructive system, student-centred learning is assumed to be indispensable.

From lecture based to problem based teaching and learning

In problem based learning, students tackle design problems in order to generate a need to find out. The approaches of problem based learning provide a learning environment that embodies most of the principles mentioned above. It renders the students active in learning through the process of solving a problem. With this strategy, students get an opportunity to practice processing skills (Wood,1994).

Meaningful real world problems are provided in problem based strategy, and they enhanced the epistemic motivation of the learners (Woods 1994, 1996; De Grave, Boshuizen and Schmidt 1996). This strategy reconstructs and integrates the knowledge the learner has acquired by various pathways.

From a teacher focused approach to a learner focused approach

Learning starts from an understanding of one's prior knowledge and how new information fits into this schema. Ongoing learning occurs with the process of constructing new meaning. If no learning is accomplished, teaching is meaningless. Simply telling the students what is right or wrong does not necessarily mean that the students will grasp the concept. Efficient teaching requires an understanding of how the learner acquires knowledge and what existing misconceptions he or she holds.

Addressing problems – solving skills and lifelong learning competency

The world is real, concrete, and ever changing. No existing strategies can solve all problems. Nobody may become an omnipotent veteran by participating in a single combat.

The teacher should expose students to a 'real-world context' so that they can understand the significance and the relevance of the learning material they meet. The world is changing at every moment, so learning should be lifelong experience. Learning skills will benefit students throughout their life.

Contemporary teaching strategies to be used

Moving to a student-centred approach

In order to realize student-centred learning, many effective approaches such as peer group activities (Tao 1999), discussion assignments and occasional mini-reports can be used in the course of teaching.

In April 2003, a severe pandemic, SARS (severe acute respiratory syndrome, or atypical pneumonia) occurred in Beijing. Because of the quarantine, I was not able to leave the campus easily for more than a month. During that period, 24 students in my class were quarantined in their homes. However, we could not deprive the students of learning. The challenge was to revise our usual teaching methods to reach two different groups of learners. One group was sitting in the lecture theatre or laboratory room with masks and could not interact with the teachers, and moreover, they were sub-divided into small groups to decrease the population density and prevent inter-infecting. The other group consisted of students confined to their homes and the only means of communication were telephones and the Internet. We could not see each other or communicate frequently, but the teaching continued after a break of only a day. First, we made sure that every telephone was working. Then we gave outlines and real problems over the phone. After this, we occasionally checked the study progress of the students. In the meantime, small class lectures of shortened length were given to students who were willing to attend them. We constructed a mini-environment online, an electronic space called FTP (File Transfer Protocol), for providing lecture notes, discussion, assignments and asking questions/giving

answers. I arranged the students into peer groups, with 5-7 persons per group, naturally formed or mixed among the nearest dormitories. I opened a special email address for the course. As not all students had access to the Internet, I sent materials to them and arranged for someone to correspond with them during the course. Both the helpers and the students benefited, as retention rate in learning depends on the level of activity during study (Lagowski 1990).

A summary of the modifications in teaching approaches can be shown as in Figure 3.

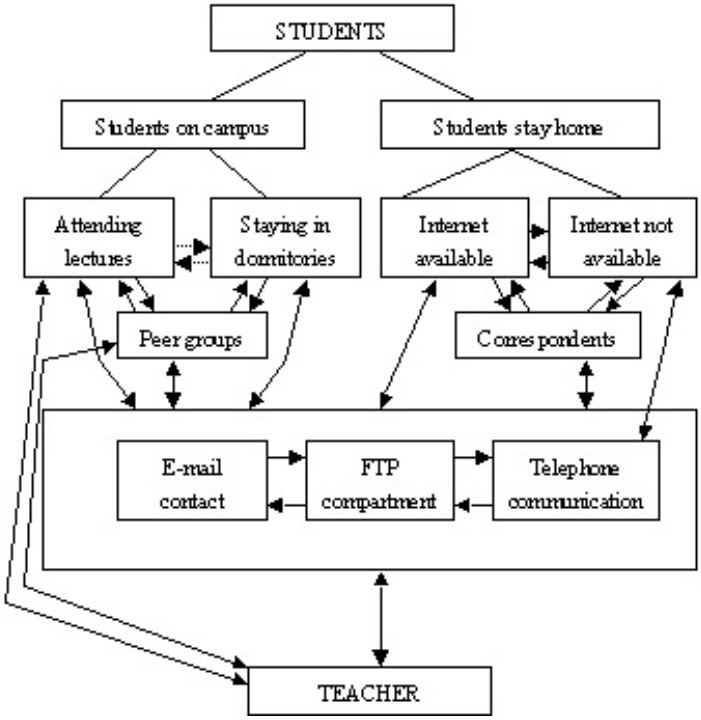

Figure 3. The modification in teaching strategies used during the SARS outbreak

These reforms were in response to the pandemic disease, but it heightened the deeper consideration of the progress in teaching strategies. The relevant means and their functions are shown in Table 1. This was a successful trial, not forgetting any of the students. Although the teacher had to give the same task several times, resulting in extra work, the teaching was very student focused. Student learning became active and cooperative.

In my teaching, I will develop and enhance the approaches developed during the SARS pandemic. To reach this goal, the many improvements will be considered. For example:

a. For certain topics, such as the discovery of genetic material in which there were many historic experiments, the peer group discussion-presentation strategy will be used.

Table 1. The relevant teaching methods and their functions used during the SARS quarantine

Method	**Functions**	**Situation in which it was used**
Lecture	Main content, basic concepts	To those willing to attend lectures
Peer group	Real problems, cooperation skills, active learning	Amongst students who were able to meet
Telephone communication	Outline, simple assignments, oral interaction between the teacher and the students	For individual contact between teachers and students
Email contact	Assignments, individual tutorial online, ideas exchange (privately), problem-solving, private questionnaires	For individual contact between the teacher and the students, and quickly, briefly or informally transferring massages
Correspondent	Bridge between teacher and students, providing students with access to the teaching, pathway for discussion amongst students	For those without internet access
Questioning/answering	Providing/solving real world problems, developing deep learning, extracting and digesting detailed points	In classroom/laboratory, online, or via telephone
FTP compartment	Publishing lecture notes/laboratory work information, providing references and complementary materials, plenary tutorials, answers to assignments, results of lab work, public discussion, summary of texts	For all teachers and students (directly linking them together to the core content of teaching/learning)

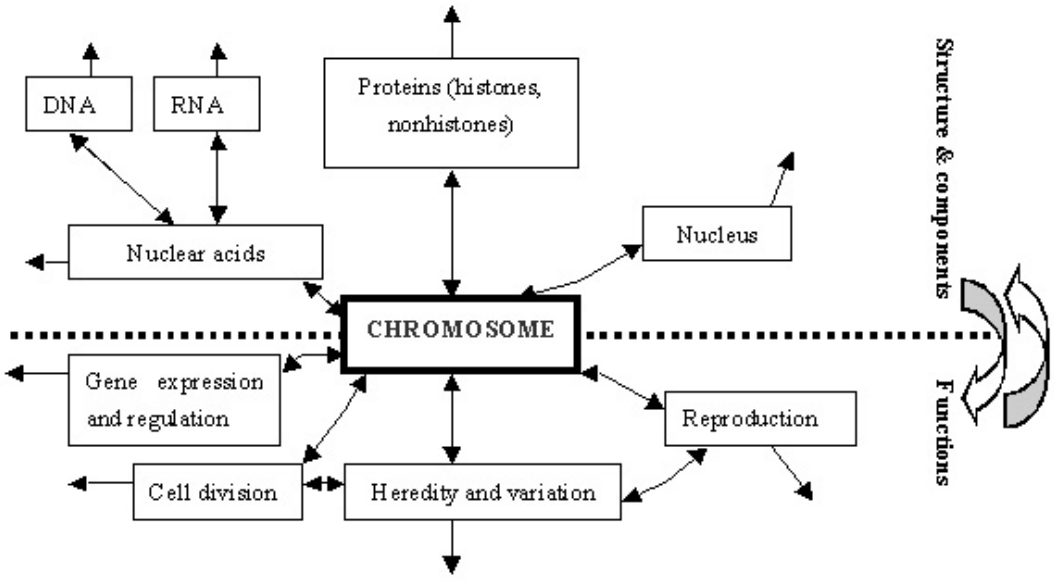

Figure 4. The relevant learning materials for chromosomes assumed to be linked through *WebCT* or the like (The open arrows means the corresponding items are associated with other online or Web resources)

b. Online teaching-learning methods will continue, and, on the basis of FTP, local network and internet linkage, will gradually develop the electronic information system to play a similar role to the *WebCT* (Web Course Tool) environment in Australian Universities. For example, when the content of the chromosome structure and function is taught, the relevant materials can be linked through *WebCT* or the like (Figure 4).
c. Public lecture notes and concise handouts will be used to allow students to pay attention to the classroom teaching without having to write notes, and preview and review the concepts constructively.

Moving to various resources to accommodate learning

According to the observation of the Chinese scholars in our group, the following efficient teaching resources are used at the University of Sydney.

a. Alternative teaching materials instead of one single assigned textbook. The curriculum includes all that should be taught and nothing unnecessary, over-explained or out-of-date.
b. High quality of the course content. The teacher uses a variety of supplementary materials from sources. The students can receive and digest more concepts or ideas in the same unit of time.
c. Efficient classroom aids. For example, there are usually two sets of multimedia or over-head projector devices. The teacher can show lists of the main points or outlines through one set, and project movies, *PowerPoint* slides or other types of writing/drawing materials by the other set.
d. Detailed timetables of courses with the titles, outlines or selected introduction of the contents. The students attend lectures or seminars with pre-prepared.

In our current genetics course, the contents are defined by the chosen textbook (He 2002). In order to activate the learning process and make the students understand the contents at a deeper level, I will select several new books or other resources. Table 2 shows some examples of these teaching aided books (online information) and the reasons for their selection.

Table 2. Examples of teaching aided books and the reasons for selection

Titles of the Books	Editors	Publishers	Reasons for selection
Genetics	Liu, Z.D.	Higher Education Press (1991)	Concise in expressing the fundamental laws of Heredity, Variation and Evolution
An Introduction to Genetic Analysis (7th Ed)	Suzuki, D.T., Griffiths, A.J.F. and Lewontin, R.C.	W.H. Freeman and Company (2002)	Explicit in explaining concepts, logic and laws in traditional and modern genetics
Genetics—from Gene to Genome	Hartwell, L.H., Hood, L., Goldberg, M.L., Lee, M., Silver, R. and Veres, A.	McGraw-Hill Co. (2000)	Informative in introducing genetic operation and application
http://www.genetics.ac.cn/	Institute of Genetics and Developmental Biology, China Academy of Sciences	Institute of Genetics and Developmental Biology, China Academy of Sciences	Endlessly beneficial in reporting research and applying technology

By means of these alternative learning materials as well as the textbook, which is required to be the blueprint, a full view of the genetic framework will be rebuilt by the students (Figure 5). At the same time, using peer group work (Peat, Dalziel and Grant 2001), discussion, mini-reports and so on, I believe that taking advantage of these resources will be promising.

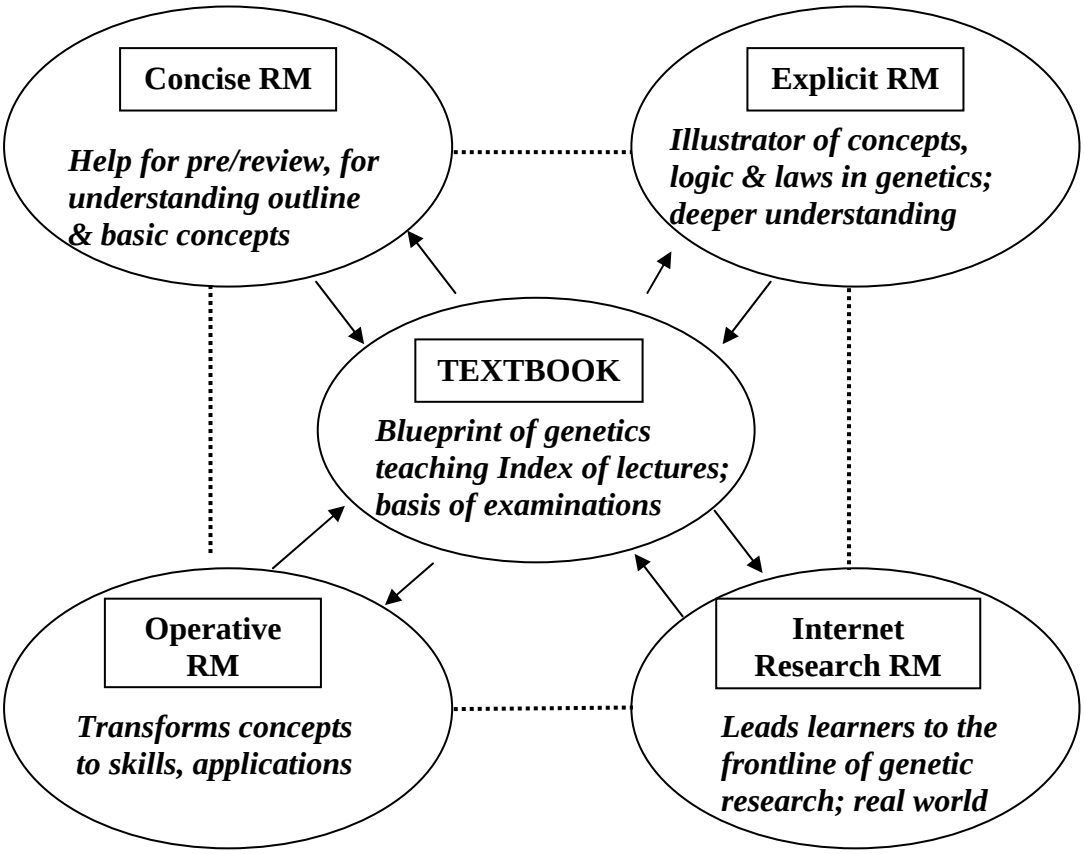

Figure 5. Textbook and the alternative learning materials
(RM: Reading materials)

Moving to active learning

The core issue in teaching is facilitating the learning of the students. Many approaches can be used to accommodate active learning.

Problem based learning (PBL)

The learners play a role as a practitioner in solving problems by using academic knowledge bases and skills. It is not reserved for activities and interactions intentionally organized for learning (Billett 2002).

To sum up, an effective problem has the following characteristics:

i. it is a real world problem so that it must be solved;
ii. it is complex enough so that epistemic motivation and enthusiasm for learning can be created;
iii. it trains thinking and cooperative skills; and
iv. it integrates knowledge and concepts.

During March to May, 2003, I trained three fourth year students in their Undergraduate Research Project. When the students came to my office, I told them I would like them to solve a chromosome problem. Then we talked about this topic by discussing selected questions (Figure 6).

The talking was gradually focused to the issue I wanted to train the students in: function of a chromosome → behaviour of chromosomes in cell division → effective factors / structures in chromosome function → centromeres →centromere protein (worth studying).

After the discussion, we proposed a topic for the research: the expression of a new centromere protein in the fruit fly. Then the students went online and to the library looking up the protocol for the analysis and discussed the related problems. Using indirect immunofluorescent, electrophoretic and immune blotting techniques, they found that this centromere protein is conserved between humans and fruit flies (Figure 7), and the molecular weight is around 65 kd. The open-ended mini-project brought about a meaningful result.

Undoubtedly, PBL is a type of active learning. I will keep continue to use this strategy in genetics teaching, by:

- placing students onto the active role of problem solvers;
- confronting students with a situation which is probably an ill-structured problem and reflects the real world;
- aiming at developing students' decision making and critical thinking skills; and
- encouraging self-directed learning and peer-group cooperation.

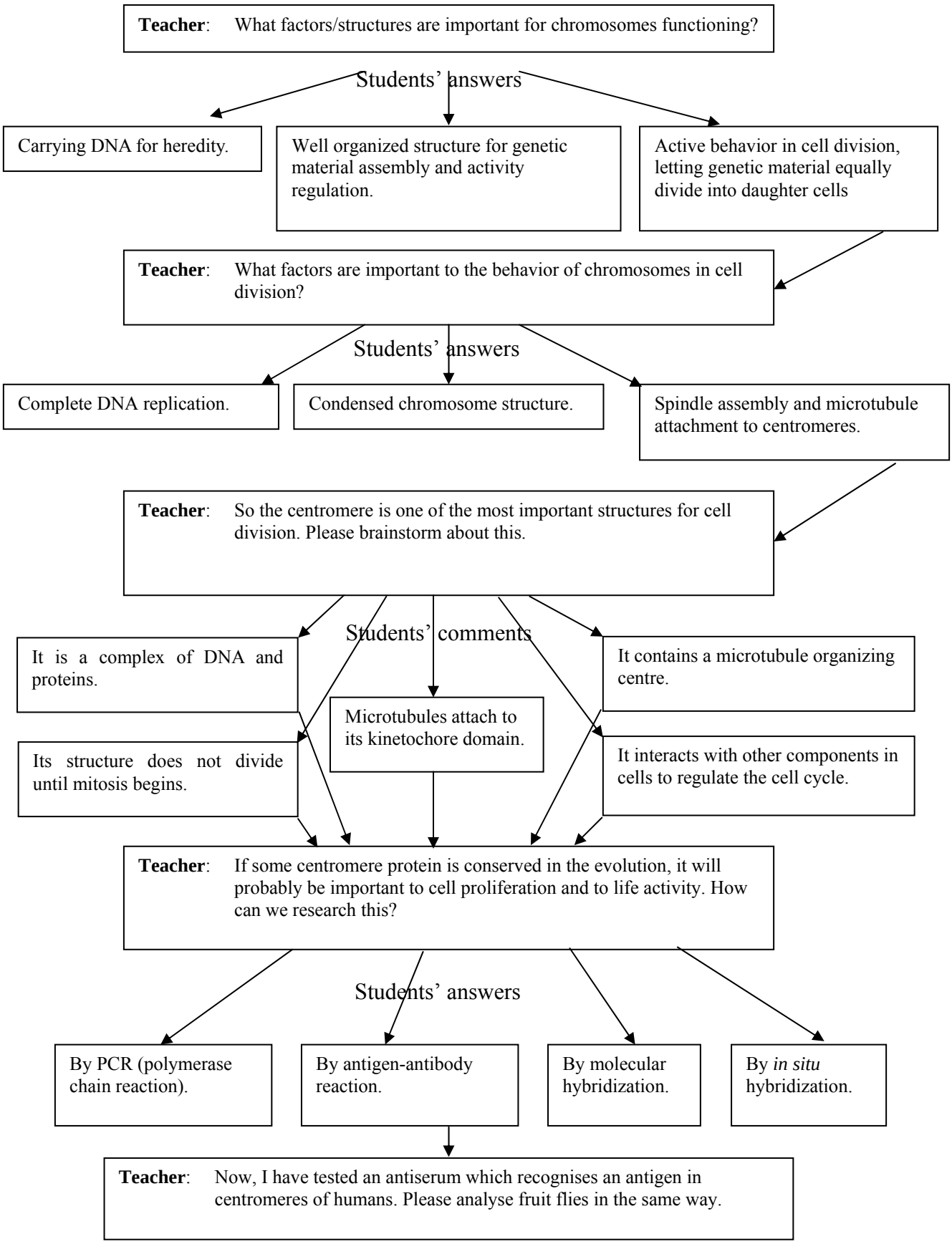

Figure 6. Chromosome problems for topic selection by students in research training

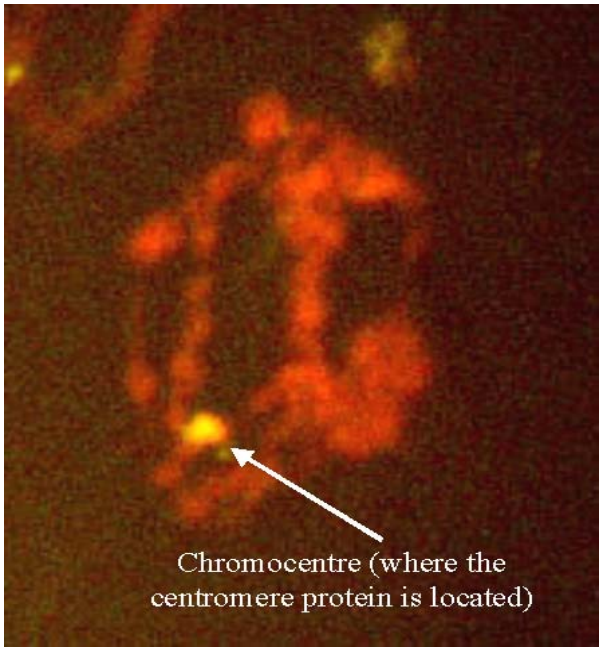

Figure 7. The centromere protein detected in the chromocentre of a fruit fly
(Chromosomes are fluorescently stained red, and the centromere protein is fluorescently stained green, showing a yellow signal overlapping by two colors)

Case studies

Case studies have academic and professional significance. The selected cases are always set in real world contexts and have social implications (Wilson 1996; Baird and White 1982; Buckley 2003). A famous example in genetic research history is the discovery that DNA is the genetic material. A kind of bacteria called *Diplococcus pneumoniae* can cause human pneumonia and mouse septicemia. But the pathogen is its S-type (smooth type) instead of R-type (rough type). In 1928, F. Griffish discovered that nontoxic R bacteria can also induce the death of mice if they are mixed with dead S bacteria and injected into mice. He focused his research on this accidental discovery:

i. Analysing the mice, he found living S bacteria in their blood.
ii. Injected with live R bacteria or dead S bacteria, the mice did not die.

He came to this conclusion: S-type bacteria released a transforming factor. The R-type bacteria took in this factor, and consequently R-type turned into S-type. This discovery must be exciting, because it means some factor determines genetic patterns!

In the next 10 years, he and his colleague, O. Avery, adhered to this significant research. They tried many important biological molecules as the focus of study. They extracted DNA, RNA, proteins, lipids and polysaccharoses from S-type bacteria and mixed them with live R bacteria respectively. Then injected the mixture into mice. They also used enzymes to break down these molecules and observed the results.

The result was absolutely exciting: it is the DNA from S bacteria that can transform R bacteria to S bacteria, because when R bacteria mixed with this kind of DNA are injected into mice, they will be killed, and if the DNA is digested by enzyme, the effect will be lost. Any other molecule does not have this function. Griffith and Avery testified that DNA was the transforming factor, i.e., genetic material.

Case studies have distinct characteristics. They are: real; simple at the first sight; hiding significant phenomenon but usually neglected by ordinary people; and able to lead to new concepts, even the forefront of the relevant research.

Concept maps

In the classroom or a discussion panel, one of the most active tasks is concept mapping (Kankkunen 2001). Concept mapping is a teaching approach for representing knowledge graphically: it provides an interconnected network of concepts. A concept map generally consists of 3 elements (Figure 8): Topic—the focused issue or main concept; Nodes—the joints that represent related concepts within the topic; and Links—the connecting parts which represent the relationship between concepts.

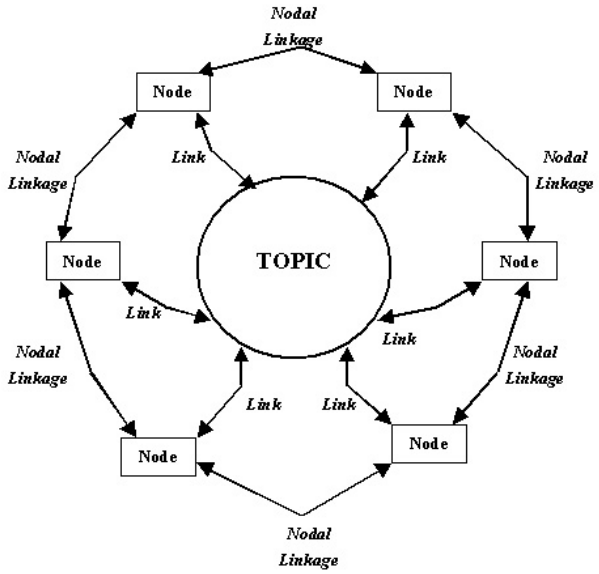

Figure 8. Concept map and its elements

Concept mapping can be used to brainstorm general ideas, design complex concept structures, communicate complex ideas, and assess the concept understanding of the learners. As an example, we can map the concepts related to genes, (Figure 9).

Concept mapping often requires building up gradually, firstly a few basic nodes and links, then leading to more concepts and crossover thinking moulds. For example, in Figure 9, it is obvious that 'Diseases and abnormality' node is closely related to 'Gene therapy and genetic engineering' node. It can be linked during the discussion after the concise basic map has been drawn. The students will be excited when they get the first new linkage at a glance.

As a developing country, China needs more constructive people, although our teaching resources are very limited. In addition to the introduction of international teaching methods, the strategies or approaches mentioned above may save teaching resources and produce the talented and well-trained individuals China requires faster.

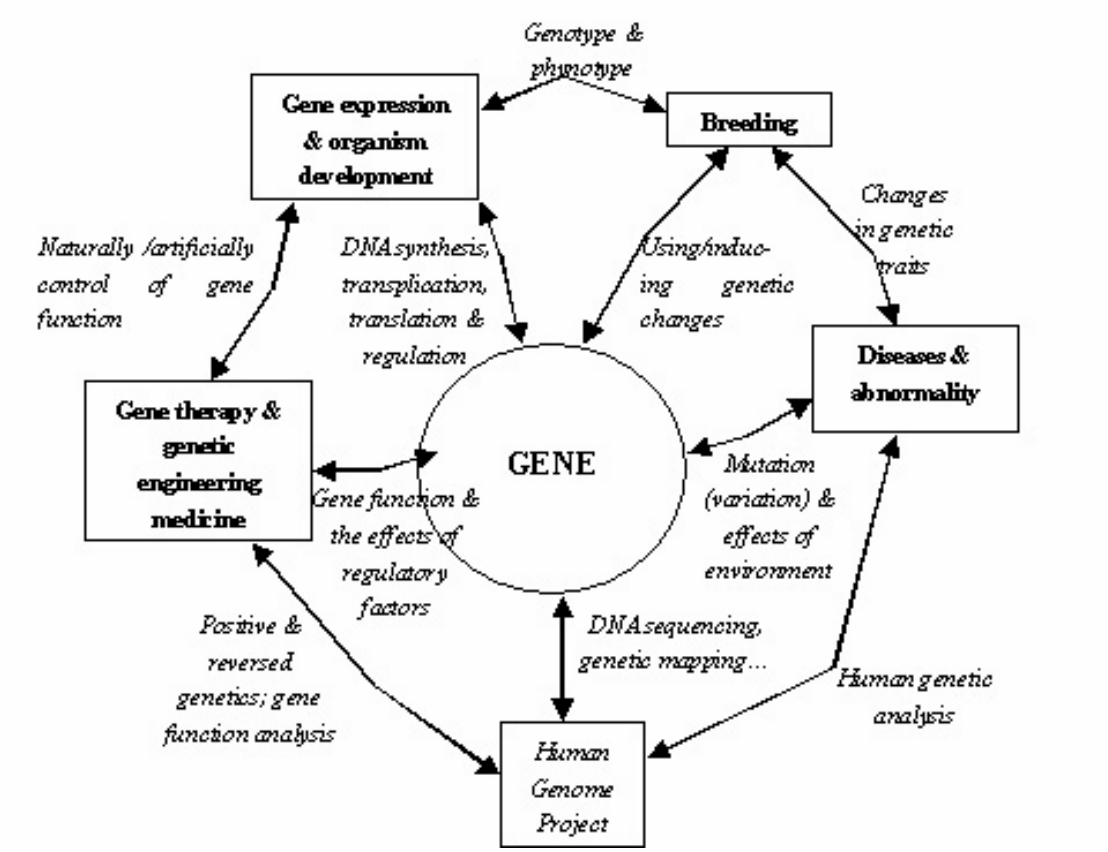

Figure 9. Concept map of the gene

Discussion

In the last class of Teaching Science in English at the University of Sydney, I expressed two points about the particular ideas I have obtained during the past 10 weeks in this program:

1. Changing is usually difficult, but we have to change from a teacher-centred to a student-focused style, fostering self-oriented and life-long learning skills.
2. Teaching is constructivist and systematic (von Glasersfeld 1991; Fosnot 1996; Dougiamas 1998; Funderstanding 2001). Even if we are not able to do more, we can at least begin with a breakthrough in one approach or a couple of approaches, for example, making modifications in teaching by using teamwork, concept mapping or case study.

This is my opinion, and will be the starting point of changes in my teaching when I return from Australia to China. To aid in this reform, and on the basis of the gradual improvement in the hardware and software of our computer systems and Web-work, it is important for us to build a Virtual Learning Environment (VLE) (Peat 2000). It includes several functional sections (Figure 10):

- realworld problems;
- concepts, theories and quizzes;
- electronic library;
- administration; and
- student discussion forum

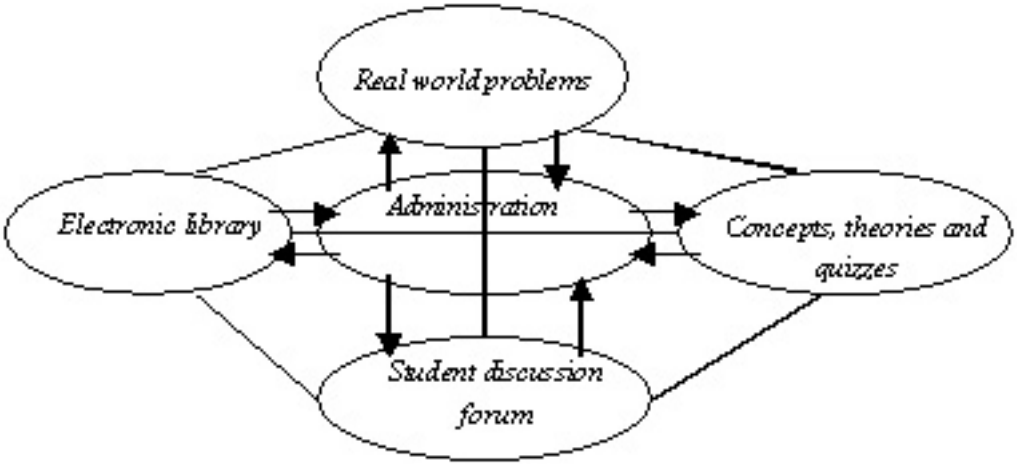

Figure 10. A sketch map of Virtual Learning Environment (VLE)

Learning is an active process, and subject material is constantly changing, so there is no reason to set teaching strategies in stone. Sometimes a remarkable change can happen overnight, and effective changes are usually gradual. So at a particular moment, introduction of one or two innovative approaches to a course is often more effective.

In the knowledge-exploding era, the cause of education is a cooperative cause. If we are going to challenge traditional or out-of-date ideas by improved strategy, we must win the hearts and minds of our colleagues. On the other hand, new should not mean losing the best from the past; if an existing approach has been confirmed to be correct or suitable, we have reason to insist on it.

In conclusion, I would like to declare some intentions according to the speech of Professor Mary Peat given in the last lecture of our *Teaching Science in English* program: Teaching and learning will lead China through the 21st century, whilst the audience will be taken from all parts of our universities. We must clarify our ideas and address them to the management as well as our teaching colleagues. Teaching requires new ways of thinking about constructivism, new curricula not bound by the age old traditions of textbooks, and changing assessment to encourage students to develop skills for lifelong learning. Furthermore, these changes should be developed collaboratively within discipline groups.

Since I have been brought into the bilingual teaching track, I plan to keep up my English skills as these are a key to this teaching stage. Here is my chance to try it myself. No muss! No fuss! Well begun is half done!

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