Incorporating contemporary education theories into *Physics of Semiconductor Devices*

Yao Li
Physical Department
University of Science and Technology of China
Hefei 230026
People's Republic of China
yli@ustc.edu.cn

Abstract

Incorporation of contemporary education theories into *Physics of Semiconductor Devices* is suggested. According to the analysis of my course and link of theories of the old and new, I point out the importance of student-centred strategies such as workshop tutorial, problem based learning and concept mapping, web-based learning etc. Detailed realisations of them are discussed.

Introduction to *Physics of Semiconductor Devices*

Most of the teachers in China who are teaching *Physics of Semiconductor Devices* use teacher-centred strategies – they are unaware of student-centred teaching methods or neglect them, so most are using lectures, and just writing on the blackboard, which produces passive learning.

In my university, University of Science and Technology of China (USTC), some model courses are being reformed towards using virtual experiments, multimedia, and the Web. New teaching modes and methods are also being advocated. However, my course, *Physics of Semiconductor Devices,* is still traditional. It is a compulsory course for fourth year students majoring in microelectronics and it has in total 40 hours. Students have four hours lecture time per week in two-hour sessions. Experiments (very few) are separated, that is to say, experiments are not closely combined with this course. Students reflect that the course is hard.

Contemporary education theory

This year there is a collaborative project supported by China Scholarship Council, which is *Teaching Science in English* and I'm involved in it. At the University of Sydney, I have learned some contemporary education theories. The following is a summary.

Quality teaching should be aimed at promoting deep level processing of information in the mind of the learner (Gibbs 1992). A surface approach to learning is disastrous. We are looking for strategies to develop lifelong learning skills of students (King 2004). So there are two aspects: how do students become active learners? how do teachers motivate them? Two theories, which are related, give the answer:

Student-centred strategies: We have included some of the strategies: independent learning; field trips; problem based learning; case studies; independent group work; web-based learning; etc. All of them can make students active. Because students are all different, they learn in different ways. Quality teaching is most likely to happen when it is student-centred, because that's where the responsibility lies (King 2004).

Constructivism: Different from 'behaviourist' and 'developmentalist' views (King 2004), The constructivist view describes a wholly new understanding of how students learn. It includes: knowledge is a product of a learner's activities, i.e., individual activities decide his acquisition of knowledge; knowledge is constructed by the learner once his/her present knowledge structure is related to a new one; Social context is important; 'truth is in the making', therefore knowledge is created by doing, researching and linking the real world, teaching is not necessary to be in one direction; teacher's role is to stimulate and coach (Roelofs and Terwel 1999).

From above, we think four key elements are important in students' learning: a motivation context; learner activity; interactions with each other; and a well structured knowledge base. Four techniques made me think a lot. They indicate both theoretical and practical development (listed below) of how students learn consistent with the advancement of our society:

- Problem based learning (PBL) (Woods 1994): Problem-solving skills require students to do and be active;
- Concept maps (King 2004): link and accommodate scientific conceptions graphically;
- Web-based learning (Mattheos and Attström 2002): new information technology helps staff to improve their teaching and produce a relaxed learning enviroment.
- Cooperative learning: group work means higher learning efficiency.

Phenomenon analysis

Figure 1 is the cross-section of a basic MOS device. It is widely used in modern VLSI industry, however, its size is only several microns or even nanometres. Understanding it requires the following knowledge: semiconductor physics (energy band, carrier transport, etc.); material physics; semiconductor technology (how to fabricate?); device characteristics (through derivation); and application. All of them are difficult for students who have no experience in semiconductors, i.e., microscopic and complicated device theories block students' learning.

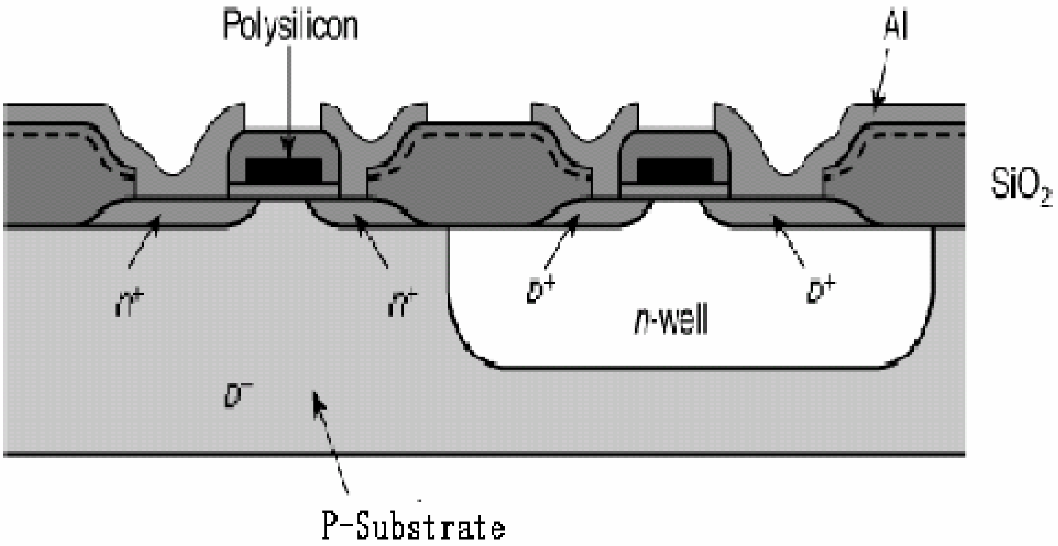

Figure 1. Cross-section of a basic MOS device

Table 1. Some of the phenomena related to my teaching experience

Issue	Phenomena
What's the proportion of lectures in whole course?	>95%
Which concept is the most difficult?	1. energy band 2. procedure derivation(they are too abstract)
What do students want?	More applicable knowledge for them in future society (such as to earn money)
Have students achieved deep-learning?	Most of them forget theory of device after one year
Have I trained their related skills for lifelong learning?	I don't know

It's time to reconsider what the most effective teaching methods are!

Linking ideas

With the development of modern society, the teacher-centred style may give rise to a surface learning approach for students (King 2004). How can students endure just listening to their teachers' constant talking about invisible theory? Students should develop lifelong learning skills such as problem-solving skills, independent-learning skills, communication skills, etc. Figure 2 lists some linking ideas.

Aiming at key problems students face, we may then create suitable methodology. Orientation of education in China should be shifted to mainly achieve lifelong learning skills of students. Specifically, as educators, we should consider/combine course characteristic when we are teaching. Table 2 lists some learning amounts that students retain by different routes (Lagowski 1990).

Table 2. Learning amounts students retain by different routes

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 what they say as they do something

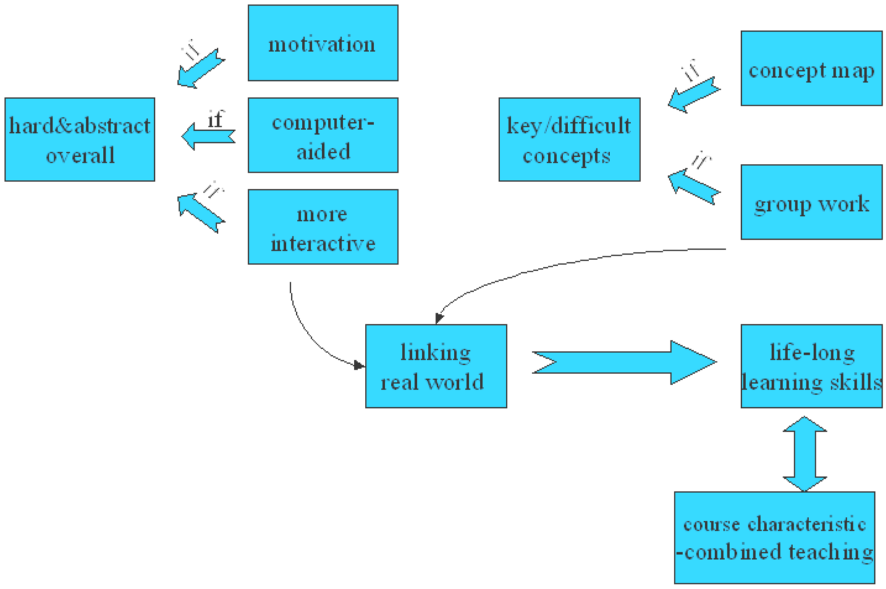

Figure 2. Linking ideas

Solutions

General ideas

Moving from teacher-centred to student-centred overall is a necessary step. We may transform pure lectures to four parts: lecture or mini-lecture (lecture should not be too long, based on research data, a common 2 hours lecture will be likely to make listeners lose concentration (King 2004)); PBL; workshop tutorial; and web-based learning. In the assessment discussion below, I will give approximate percentages of each activity for evaluation. During all the processes, we should notice the development of students' lifelong learning skills.

Subtlety, the impact of visual aids on teaching is tremendous. *PowerPoint*, slides and handouts are the basic choices. Demonstration is the most interactive in the lecture, reported results show that students achieve a very impressive improvement in 'understanding' through demonstrations (Stewart 2004). Interaction must be improved in the lecture. Besides demonstrations, asking questions and encouraging students to ask questions are also effective. Finally, trying to reduce abstract material and link to the real world should be suggested. Using diagrams (which is linking the real world) when explaining mathematics is a good approach. Computer simulation must be done in my course, which is a cheap, convenient way and a visible reality, although virtual.

Workshop tutorials

It is possible to make the groupwork more interactive. The workshop tutorial I will use has the following steps:

- set up the environment before the class begins:
  - instruments for demonstrations/experiment, such as HP parameter analyzer (I-V measurement), microscope (observing device structure), MOS circuit PCB (MOS device as a switch), etc.;
  - computers for simulation, and *Matlab* software (designed for process); and
  - problems worksheets which are related to experiments and designed specifically (pre-class);
- students come in, sit in groups of four and read the questions;
- they start to discuss, do demonstrations/experiments, use computers and maybe discuss some questions to tutors (perhaps Honours students or postgraduate students); and
- write group report.

This kind of workshop will be helpful to train learners' problem-solving skills (Sharma, Millar and Seth 1999). The whole process is like a game. Healthy functioning of the group is at the core of the learning process. Students can obtain peer assessment and cooperative work visions are kept in their minds. It is based on social context and meeting social needs. In industry, a new device product is created by hundreds of engineers. This is key.

PBL and concept map

Problem based learning is a context-based activity using 'real-life' situations. 'Real-life' situations make it easier to interest students or drive them to think. We design a 'real-life problem solving task' which we could give to a group of our students on the course and require them to fully understand the major concepts in order to solve the problem. It's convenient to use concept maps. This kind of concept map is regarded as part of 'concept change teaching' and it introduces new to old systematically.

Now I give an example of PBL and concept map method:

Demands

Develop a problem. The problem should be one I could give to a group of 4 or 5 students to work on collaboratively over a period of say 8 weeks and should be placed in the context of a real or potentially real situation. The concepts, ideas or issues that I want the students to understand should be central to the problem I pose.

Problem:

Do you think common electron devices can endure a sudden high temperature environment when the spaceship is traveling in the outer space?

We have done following experiment: Put a MOS device into a 200°C oven, after a while, it didn't work properly. We change the package and weld material of this MOS device and try again, it still can't work properly. Why?

If we carry these devices in the spaceship, how do we redesign them?

Process:
In order to solve this problem, if MOS device is chosen, Figure 3 is a concept map.

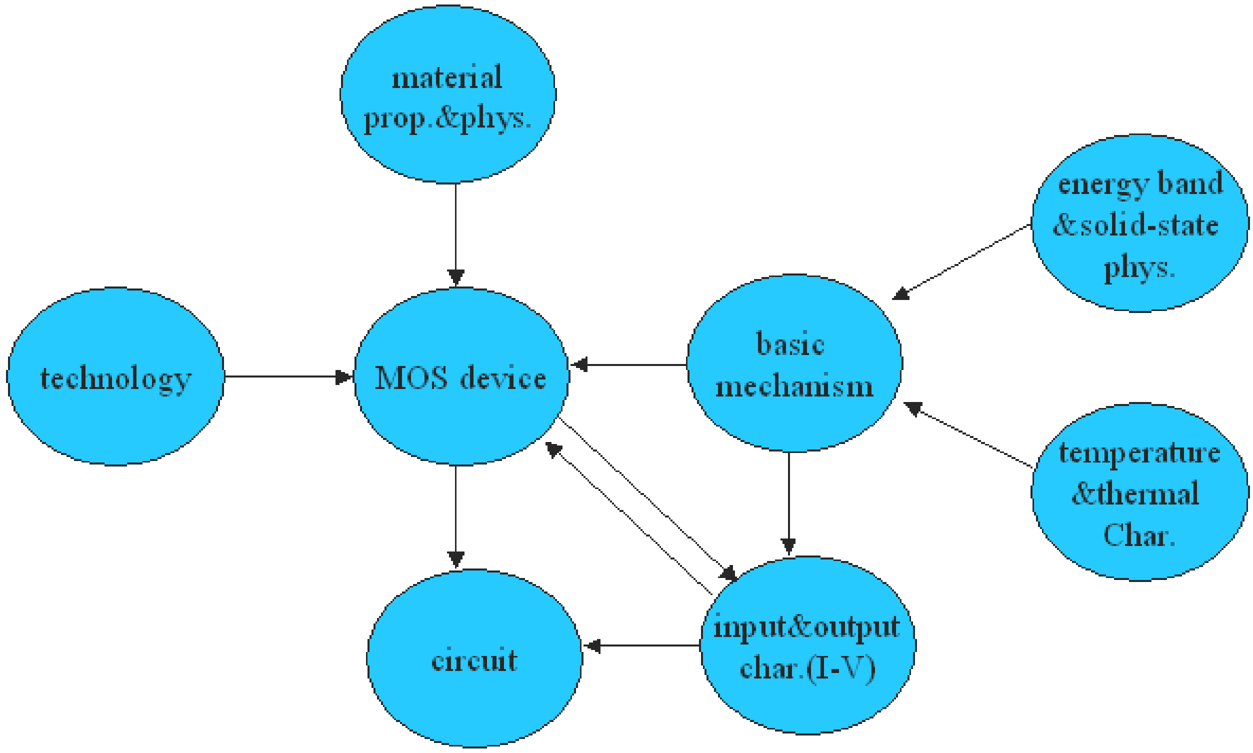

Figure 3. A concept map of MOS device

In fact it's a hard problem and needs group work, each person in the group has his/her responsibility. the MOS basic mechanism, technology and material properties and physics are the basic elements for designing a MOS device when constructing a circuit, and solid-state physics, energy band, temperature and thermal characteristics (which should be considered for this specific problem) are the roots of the basic mechanism. Input and output characteristics (i.e. I-V characteristic) are the keys of measurement. The concept which will probably cause most trouble is the concept of energy bands. To use the concept map, we can start with the parameters' characteristics analysis of solid-state physics.

In solving the problem I will focus on training students' skills of group cooperation, computer simulation and a practical field trip. Learning events involved are in the following order: first, give a video outlining a MOS device and how it works, then bring students to a factory to learn how a MOS device is fabricated. After that, they start to solve the problem, and simultaneously, we have mini lectures (including background introduction, orientation and method, cutting edge knowledge, concept map and so on) and workshop tutorials (described above) regularly. Students can do experiments or design using computer (we supply *Matlab*, device simulation tools, etc.) and finally, they should hand in both individual and group written reports and give computer demonstration of results or practical samples. During the process, they should search for information from the library or Internet and exchange it with each other.

Web-based learning
Web-based learning is a convenient and necessary supplement for teaching in the classroom. The virtual learning environments promote sustainable development in higher education for constructivist teaching. Some of them can be regarded as an assessment tool. Students can go into deeper understanding and keep interested. I have considered three types of learning which can improve the learning effect.

- Online exercise.
- Communication: we can put some visual information on the Web to support class, and we can communicate with students instantly by email and grasp opinions. Also, communication between students is important. Online chat offers the opportunity for students and academics to question, clarify, and re-clarify issues within a very short period of time.
- Cooperation via the Web: this is an issue especially for students who have a special interest in this course. We attach a question which arises in a real project and request answers. Students need not strictly give the answer and can freely participate in the online discussion. Outstanding students will be awarded.

Figure 4 gives an example which I will place on the web site.

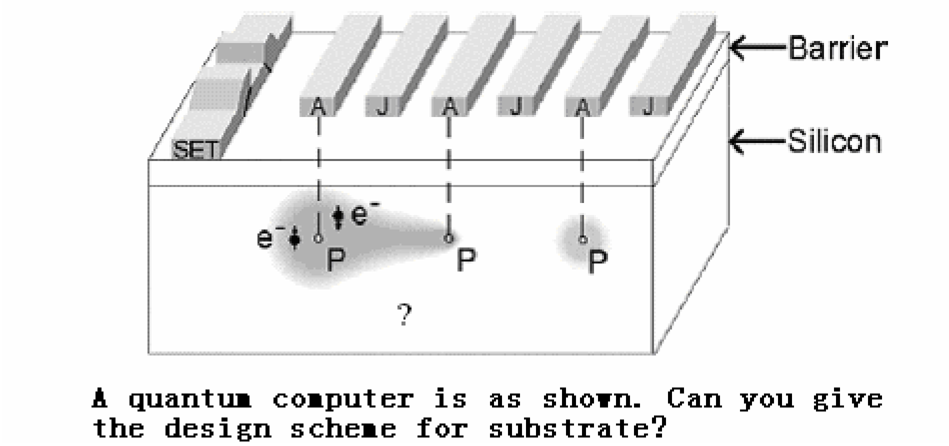

Figure 4. An example for web cooperation

Discussion

Money
Money is important when designing courses. The realisation of such an environment needs a lot of work, for example, the instrument HP parameter analyzer is expensive. Funds from the government are limited.

Assessment
Improving assessment promotes quality of teaching and learning. Different activities in the learning process should be involved in the assessment, which should be instant. There is a possible solution: final examination 40%; field work 25%; in-class little assignments 5%; online exercises 10%; peer and self assessment 10%; and oral, written and computer ability 10%.

Awareness
Changing is a gradual process, because few people have the awareness of changing even though sometimes they fail. Incorporating new strategies is a challenge to me. The learners themselves are responsible for their learning.

Conclusions

We have pointed out that teacher-centred teaching should be shifted to student-centred in order to promote deep level learning and lifelong learning skills of students should be developed, so we obtain following conclusions:

- we can achieve our teaching goals by many means, which should be student-centred;
- alternatives to hard, abstract teaching contents require a link to the real world; and
- we discuss a realisation scheme of contemporary education theories for the topic, *Physics of Semiconductor Devices.*

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