Using constructivism as a teaching model for computer science

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Abstract

Contemporary teaching models are more student-centred and are based on the constructivist learning theory. This article discusses how to adopt a constructivist-teaching model in computer science disciplines. The problem based learning (PBL) practice and teaching experience in China is first discussed. Based on the constructivist learning theory and nature of computer science, the author discusses how to improve teaching in three aspects. The first is a possible modifiication of the conventional PBL model; the second considers how to provide multi-entries for students to learn knowledge; and the third is to suggest some measures to help students to become lifelong learners.

Introduction

Constructivist learning theory is based on educational psychology. Jean Piaget (1896-1980) was the first theorist who regarded children as 'builders of their intellectual structures'. Another Soviet psychologist Lev Semanovich Vygotsky (1896-1934) studied how children learn through communication with others (such as parents and peers). These educational psychology theories have been further developed by a number of constructivists (Wilson, 1996; Duffy, Lowyck and Jonassen, 1993; Papert, 1980) in recent years. With the rapid development of information and communication technology (ICT), especially computer-based teaching and learning, several teaching models based on the constructivist theory, such as PBL (problem based learning) and CBL (case based learning), have been widely adopted.

In comparison with other teaching methodologies, approaches based on constructivism have certain unique characteristics. These include:
1. student-centred learning, students have more control on their study;
2. group work, students are divided into groups when they are learning which in turn can help them improve their communication skills; and
3. during the process of learning knowledge, the ability to learn is also developed, with tasks such as: seeking meaning; forming opinions; evaluating information; and thinking critically.

Constructivists believe that learning is a mind constructing procedure. Each learner constructs meaning as he or she learns. Our teaching should concentrate on the learner. Since learning is personal and social, several principles of learning are proposed:
1. motivation is a key factor in learning;
2. learning is contextual, it relates to learner's mental status, such as knowing, unknowing, belief, and prejudice;
3. people learn to learn when they learn;
4. learning is an active process in which the learner constructs meaning out of sensory input;
5. construction of meaning is mental and experience is important in learning;
6. learning is a social activity, our learning is associated with environment and interaction with others;
7. learning involves language;
8. it takes time to learn; and
9. to learn something, certain basic knowledge is needed.
The most adopted teaching models based on these principles are PBL and CBL.

PBL requires elaborate problems to help students to process information deeply. In certain circumstances, however, to design problems that fully meet the criteria of PBL is difficult. Furthermore, if we do believe the constructivist principle, that 'each learner individually constructs meaning, as he or she learns', we should provide multi-entries for learners to access knowledge, then PBL would not,

necessarily be the only way to teach in a real educational environment. The constructivism approach is beneficial for the learner to develop the ability to learn, such as to seeking meaning, forming opinion and evaluating information. However, the question is whether it is enough for the learner to become a lifelong learner. What else should we do when considering students as lifelong learners? The purpose of this paper is to discuss these issues and propose possible solutions for teaching and learning in computer science.

PBL problem

The PBL teaching procedure starts from an ill-structured problem. Students solve the problem through self-learning and group activities, such as discussion, analysis, and sharing information with each other. The typical PBL framework is as follows (where step 5 is optional):
1. an ill-structured problem;
2. stating the problem;
3. problem analysis (to generate sub-problems) and sub-problem classification;
4. self-study and team work;
5. solution generation; and
6. solution implementation.

In computer science, many courses require students to develop real systems.

In order to stimulate and challenge students, the problem in step 1 should be ill-structured, collaborative and authentic. It is better if the problem has several possible solutions. In computer science, however, designing such problems is difficult. In certain cases we need to use a well-known method to solve problems and then the instructor cannot design problems which have more than one solution. If students get a problem that only has a unique solution, some of students may not stay on track, and many important objectives may be ignored (Dolmans, Gijselaers and Schmidt, 1992). To address these issues, we need to ensure that students are working in the right direction before step 4, and a possible plan of action might be solution hints, problem guides and milestones. Thus we need to modify the first four steps as illustrated below.
1. Ill-structured problem and solution hints: students are confronted with the problem accompanied by hints. The hints give students ideas about a possible solution. Particularly, in computer science, the instructor can give students a similar solution that can show the 'magic', or give students a partial solution as a starting point.
2. Concept clarification and restating the problem: the instructor outlines fundamental concepts according to the hints. Students elaborate on the problem with these concepts.
3. Problem analysis (to generate sub-problems) and problem guide: students list 'knowns and unknowns', and divide the original problem into manageable sub-problems. The instructor gives the problem guide, which outlines the key problems that students have to take into account. While using the problem guide, student do not miss important objectives.
4. Milestones and sub-problem classification: milestones are set up under the guidance of the instructor. With milestones, students can divide the procedure of

problem solving into several stages, and with each milestone, they can focus on certain particular problems. Students classify sub-problems into groups so that each team member can study a group of sub-problems.

The remaining steps could be self-study and team work; solution generation and implementation.

As the key concepts and important requirements are checked and confirmed, the students should be able to remain on track. The milestones could also help students solve those sub-problems in turn. For example, in step 1, the following problem may be given to students in a second-year undergraduate database fundamental course:
Luckydog Book Store's business has been developing rapidly in recent years. This company now wants to sell movies on the Internet. You are responsible for designing and implementing the system. You have checked other web sites that sell movies, and found that their customers often complain because it is hard to find the movie they want unless they can provided the exact name of the movie. Therefore, your object is to provide your customers with a user-friendly search engine for looking for movies.

The instructor then demonstratess a database system that could help passengers select their tickets according to different features, such as ticket name, valid time, destination etc. This system is similar to the one that student have been asked to design.

In step 2, the instructor gives a brief introduction of related concepts (entity, relation, table, query, user interface). After discussion, students may set up their problem:
We are trying to design a system that stores data in a database table that allows customers to search for their favourite movies.

In step 3, students analyse the problem, and each student group gets a list of questions generated from Step 2. The instructor then emphasises those problems and student groups modify the problem list according to the instructor's guide. One of the problems may be:
- what types of information should be stored?
- how many tables do we need?
- how can we store the relationship between different things, such as actors and movies?
- how many queries should we design?
- what kind of user interface is preferable?

May we present the entity and relation in a diagram? (Instructor emphasises)
Can we convert the diagram into tables if we have one, and how to do it? (Instructor emphasises)

In step 4, the instructor gives three milestones: Entity-Relation Diagrams and tables design; tables and queries implantation; and web-based user interface implementation. According to the milestones, students classify the problems and each student in a group works on a sub-group of problems.

Access knowledge through multi-entries

Learning is contextual – the learning process varies according to learner's knowledge, values and beliefs. This construction of knowledge is different from person to person. Whilst one way of teaching is powerful for one group of students, it may not necessarily be powerful for another group of students. One object of a constructivist-teaching approach is to provide multi-entries of knowledge through which students can construct their knowledge in different ways. PBL and CBL are both possible ways for students to start learning about what they are most interested in. The construction of knowledge from concept to concept is different from student to student. Secondly, teamwork asks students to take different tasks, sharing and discussing information with each other. This implies that students in the same group access knowledge differently. On the other hand, multi-entries also mean students might use different learning approaches to assimilate knowledge. As the constructivist method is just one example of an approach to learning and teaching, if we really want to cater to students who have different learning styles, this approach may not be sufficient.

Preparing teaching materials and allowing students to cover course content through constructivist approaches is seen to be time-consuming (Delafuente, Munyer, Angaran, and Doering, 1994; Vernon, 1995). Although students are more likely to adopt deep processing of the content of the course, it is still hard for instructors to control. Generally, students stop at different depths, and so with a specific concept, some students may reach a very deep level of understanding, whilst others do not. In a team or group the tasks may not be equally distributed among the students and some may not adopt deep learning, but focus on shallow learning.

From my experience in teaching in China, female students prefer lectures, and they often get a higher score in the examinations than male students. On the other hand, male students prefer activities rather than attending lectures. Males are good at programming. Students are inclined to avoid those things that are 'hard' to them. In a teamwork learning approach such as PBL and CBL, some students may try to avoid certain activities because they can rely on the work of other team members. In computer science courses, basic concepts and programming experience are equally important, sometimes, team work provides student with a way to pick one and drop the other. Furthermore, because of cultural difference, Chinese students are more used to passively receiving information given by the teacher than by actively looking for information. The transition from this traditional model to a constructivist model should be smooth and gradual.

This implies that a better approach to teaching and learning would be to combine traditional models and constructivist models. In fact, these blended approaches have been designed and are successfully used in different universities.

Professor Geoff Kennedy (School of Information Technologies, The University of Sydney) uses a blended mode in teaching *organisational database* systems course.

In this course, lectures are still the backbone of the course, and weekly laboratories focus mostly on individual skills of database design and implementation tools and platforms. A realworld problem is also presented in a lecture, and students are required to solve it in 10 weeks (Week 2 to Week 11). Furthermore, the procedure of solving the problem is staged – the first milestone focuses on design, the second milestone focuses on implementation. Another course at The University of Sydney that uses blending techniques is *Software Development* which is a first year undergraduate students course. The framework of this course is PBL. There are also other approaches used to support the main problem solving project. This includes a period of two hours for practical activities designed to facilitate the development of certain skills important to success in the main problem based activities and a one-hour seminar each week (Greening, Kay, Kingston and Crawford, 1996)

In China, there has been a strong emphasis on quality education in recent years. In information technology education, Professor Wu Wenhu (Tsinghua University) has introduced innovations in teaching *Program Design Fundamental*, and this course was regarded as a national exemplary course in 2003. The teaching approach of his course is lecture based, with the lectures are focused on tasks or problems, while the laboratories are more problem-oriented.

In summary there are no teaching and learning approaches that can satisfy all teachers and students. However, instructors use the principles of constructivism to design different blended models that are compatible with different disciplines and cultures.

Lifelong learning support

Two fundamental motivations drive contemporary education reform. One is how to cultivate the learners' thinking ability and creativity. Another is how to encourage lifelong learning. Both motivations relate to the learner's ability and quality, not knowledge itself. It is believed that constructivist approaches can help deep processing of information, and abilities that involved in this procedure will be cultivated and improved. Constructivist teaching approaches can cultivate the learner's abilities of independent learning, communication, critical thinking and problem solving. However, it is still necessary to consider how much the constructivist approaches support lifelong learning and to consider how to improve this support when we are employing a constructivist teaching approach.

Lifelong learning implies that learning occurs throughout the life span (of which schooling is just one significant stage) (Knapper and Cropley, 1991). Candy, Crebert and O'Leary (1994) profile lifelong learners in higher education as individuals who have:
1. inquiring minds (a love of learning, curiosity, a critical spirit);
2. 'helicopter vision' (a breadth of vision and sense of inter-connectedness of fields of knowledge);
3. information literacy (an ability to locate, decode, evaluate and use information);

4. a sense of personal agency (a positive self-concept, good organisational skills); and
5. a 'repertoire of learning skills' (knowledge of learning styles and a range of learning strategies).

Constructivist teaching approaches offer more support to lifelong learning than traditional approaches (i.e., steps 1-3 support lifelong learning, but steps 4-5 do not fully support it). Furthermore, the lifelong learning usually offers more flexibility for learners to choose time, place, and situations for learning, especially for informal learning.

When learners set study goals and choose a proper learning strategy, the sense of personal activity is important. From my experience in China, students often think that their learning ability is innate and fixed. Some of them think they are too smart while some think they are incapable of learning. At the same time, it seems they do not have much understanding with the idea 'People learn to learn when they are learning'. In order to make students have a clearer sense of their abilities (strengths and weaknesses) it is necessary to introduce self-assessment during the teaching process. Based on these assessments, learners can have an objective view of their learning ability and can see the improvement in their learning ability in a tangible way. These self-assessments could contain questions from several skill areas: surface learning skills; deep learning skills; strategic learning abilities; meta-learning abilities; time management skills; and communication skills.

Since lifelong learning is more flexible and contextual, it requires the learner to have the ability to change the learning strategy according to different environments. In the traditional teaching approach, students have to use certain learning strategies, such as surface learning strategy, to acquire knowledge. To some extent, under the constructivist teaching approach, students could learn in different ways but with an emphasis on deep learning strategy. If learners could develop several learning strategies, it will help them to be a lifelong learner. Unfortunately, it seems most students like their own established learning habits, and are reluctant to change them. In addition, they tend to look down on the learning strategies of others. For example, a deep learner may think that spending time memorising concepts is a waste of time. To address this issue, students should be aware of learning skills. Instructors should explicitly teach the strategies of how to learn. Together with analysing different learning approaches and their applications, instructors should inspire students to undertake different tasks in the learning teams. In PBL and CBL, instructors could setup a mechanism that each student would have to take a different task each time and that this is determined by what tasks they have previously done. Moreover, instructors could discuss learning strategies with students after they experience different learning skills.

Finally, learning from experience is vital in lifelong learning. More than 90% knowledge is acquired through experience. In addition, there is no substitute for some experience, and this experience is compulsory to some extent. For example, in computer science, the only way to learn programming is to experience programming. In constructivist teaching approaches, learners could construct their knowledge from their previous experience and interest. It is necessary to provide activities that are more practical to them and to introduce new experiences for them. As to my experience, most students feel programming is extremely difficult at the beginning, but after having some programming experience, they feel it is not so difficult after all.

Conclusions

The constructivist learning theory and teaching approaches have many advantages in comparison with traditional learning theories and approaches. Based on constructivism, instructors are responsible for designing a concrete teaching model in the context of the discipline, whilst students are encouraged to work through the problem using collaborative group strategies.

Acknowledgements

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