Abstract. The education at a university is increasingly challenging in terms of student capacity development to adapt to the world globalization and modernization. Under this situation, one of the key natures of the capacity of a well-qualified graduate is the ability of problem solving based on information sampling and decision-making. The capacity should be cultivated in ordinary programme, especially in major subjects leaning and teaching procedure. Tunnel engineering is one of the subjects, in which complex problems should be solved in project execution and systems thinking is necessary in problem solving. This contribution presents the application of systems thinking in the teaching practice of tunnel engineering, in terms of content preparation, lecturing, interaction and learning efficiency evaluation.

Introduction

In a university, students acquire not only information in some specific fields, but also the skills of developing their knowledge, to think and solve problems in both course study and future profession. This means that a university is one of the areas, where knowledge and skills are transferred and developed in student’s minds. And therefore new ideas are produced in a continuous mode. However, it is always a great challenge to both teachers and students to make this procedure smoothly and effectively, especially under the present situation of the world globalization and modernization. A well-qualified graduate should have the capacity of problem solving based on information sampling and decision-making. It is clear that the capacity should be cultivated in ordinary course study, especially in main subjects leaning and teaching procedure, in which the application of systems thinking is beneficial [1], especially for the subject with complex problems involved.

Systems thinking is well used to tackle a wide variety of the subjects of being complex natures [2]. Tunnel engineering is one of the subjects, in which complex problems should be solved in project execution and systems thinking is necessary in problem solving. In this contribution, the application of system thinking in the teaching of tunnel engineering is presented in terms of content preparation, teaching and learning performances, as well as the evaluation of this project.

Necessary of Systems Thinking in the Teaching of Tunnel Engineering

General Features of College Student Learning

It is well accepted that a university plays one of her social roles through providing education and related environment. In a long run, the social reputation of a university is closely related to the quality of her students. In this term, it cannot be overemphasized to improve students learning quality in ordinary subject teaching process. To meet the requirement of modern society and the increasing tendency of globalization, the capacity development of problem solving is increasingly one of the focuses of the teaching and learning program at a university.

In general, a student’s learning performance at a university depends on: (1) what has been taught; (2) how the content is taught; (3) how to learn and response to the instruction or teaching activities and requirements; (4) what and how the skills of problem solving capacity are being developed. As
shown in Fig. 1, in a learning process, there need knowledge transferring from the open shared information to personal mind stored information, also called remembered information. However, it is noted that if these information is only simply stored in a student’s mind, the main usage of this kind of knowledge is to cope with relatively simple test and retelling them. It is not can be directly applied in problem solving, which need skills of reconstructing the information and developing personal ideas of coping with a specified situation, with complex features. For example, tunneling is of complex and nonlinear features and the situation of a tunneling project is always unique. The information we meet is not totally same as what we remembered in mind. What the situation is depended also on the dynamic features of tunneling. The information sequence and response time lasting will have strong influence on the result of the decision making and problem solving. There needs systems thinking in both learning process and practical problem solving (Fig. 1b) in tunnel engineering.

In other words, where the information is stored in a student’s mind in a pattern of simply remembered, it is almost same as the information stored in an open shared library, since the information is always at hand, such as through internet at present situation. So what is important and challengeable in the learning and teaching at present is how to make the knowledge transferring from a simply remembered mode to reconstructed pattern, such as through systems structure to mental models (Fig. 1a). Only is this way, the student’s skill of problem solving may be developed as what is expected in a highly supposed university. At the same time, there is an increasing leverage in learning provided that systems thinking is effectively applied in this process.

In a long run, the social evaluation results of the teaching quality at a university are mainly reflected in the problem solving capacity of her graduates. Students’ capacity development, in which systems thinking is indispensable, is vital to the learning and teaching style of a university and the quality of the capacity will have strong influence on the level of the university deserved reputation.

**Necessary of Systems Thinking in Tunnel Engineering**

In general, tunnel project is a complex system. There various factors (Fig. 2), including the features of the tunnel, requirement to tunnel construction and environment confinement, to be considered in the planning and design of a tunnel project. For each of the major factors under consideration, several parameters will have influence on the natures of the factors. On the other hand, the parameters are, at least conditionally, co-dependent in a project. For example, The features of a tunnel project is determined by the ground conditions, structural features of the tunnel, such as size, shape, structural dimensions and building materials.

Of the complex features of tunneling, the behavior or stability of a tunnel depends on the features of the tunnel project, construction procedure of the tunnel, environmental effect. For example, tunneling in soft ground is of dynamic feature. The magnitude of the excavation disturbance to the ground and environment is related to not only excavation method applied and supporting system installation followed, but also the building sequence and time spent. Time effect is always significant, especially
for a big tunnel in bad ground, in terms of the interaction between the surrounding rocks and the supporting system, the behavior or stability of a tunnel, as well as the magnitude of the disturbance to the environment.

As the above-mentioned, systems thinking is necessary to cope with the tunnel engineering of being complex natures [2] and is beneficial to develop students’ problem-solving capacity in the field, with complex problems involved [1].

Application of Systems Thinking in Tunnel Engineering Teaching Practice

The efficiency of students’ capacity developing is related to both how to learn and how to teach, as well as to the interaction between the learning and teaching. In general, the efficiency of a student’s learning is not simply a personal affair. Indeed, it is also heavily depended upon the performance of the teaching, and the interaction between the learning and teaching. Considering the capacity developing is a complex and dynamic process, the learning and teaching, as well as their interaction, should be considered with the help of systems thinking [1].

The four rules of thinking [2] including distinctions, organizing ideas into parts and wholes of systems, identifying relationships, and taking perspectives are well recognized guide for building working knowledge using information, i.e., how we should think. As an educator we need integrate systems thinking into what we are teaching. Considering thinking is a process that people build knowledge from information, such as using systems thinking skills guidelines [2], a teacher can help students to build their thinking skills, provided that our thinking and knowledge of issues are well mapped in the teaching and learning interaction. Here is the application of systems thinking in tunnel engineering teaching at Chang’an University presented briefly, with key points shown in Fig. 3.

Systems Thinking Cultivating in Teaching and Learning Interaction

Performance of Teaching. Course execution at a university should be a learner-centric instructional procedure, in which the role of a teacher is not only to explain some facts, but also help student to develop their capacity of information sampling, analyzing and knowledge constructing, rather than to reproduce a series of facts.

To make the tunnel engineering teaching procedure efficient, the teaching motivation should be positive, active, and full of enthusiasm. The teaching performance generally includes content preparing, lecturing and interacting with students in classroom, and evaluating students’ performance in time (Fig. 3). In course execution, there are technical affairs, which need problem-solving and decision making in each of the stages, in which a specified subject is executed. There need systems
thinking in content preparation, execution and evaluation. The preparation of the information and knowledge points, major topics and principles, typical case histories for the teaching should be fulfilled ahead of schedule and be executed in a planned process. For example, the content preparation should consider the complex features of a tunnel project (Fig. 2) and the execution procedure of a project in stages, including planning, survey and design, construction and operation, which generally determine the major topics and their execution sequence in teaching. The project execution process is not in a linear mode. There often need feed loops to revise and modify the original planning, design and construction scheme to improve the design and adapt to the project practical situation. This feature should be presented in major principles and case histories choosing.

Figure 3. Application of Systems Thinking in Learning and Teaching Interaction Process.

**Performance of Learning.** Teaching is a student-centered process, in which effective learning is mainly founded on students’ good performance. Good learning needs constructing meaning, which is based on both the newly-learned and stored information, technical skills and principles of the related subjects, to fulfill knowledge and capacity developing perspective.

Effective learning is based on students' active participation in problem-solving and critical thinking, which is a process of knowledge constructing by testing ideas and approaches based on their prior knowledge and experience. In this process, the information accumulation and thinking skill development are intertwined, such as through the related task accomplishing (Fig. 3).

A student can not effectively develop her or his knowledge in a problem solving process, unless he or she has a solid grasp of both the basic information, such as the basic concept and principle, and the associated thinking skills. In this process, the thinking should be considered as a complex adaptive system. In simplicity, this is also a process of problem solving. In practice, effective learning is a self reinforcing system including three processes: thinking, communicating and learning, which is indeed in a feed loop and a spiral up procedure. Unless a mental model changes, learning does not occur [3].

**Teaching and Learning Interaction.** Personal knowledge construction is based on what is mastered and the capacity of dealing with new information. The both the information presented and how to be mastered in a teaching and learning procedure need a well planned system thinking. In terms of teaching, the means, such as good content preparation and well designed execution, well organized classroom activities, well chosen assessment modes, proper feedback to students’ task accomplishing in time, will trigger students’ learning and improve the quality of teaching [4]. Teacher’s good performance will increase students’ learning motivation (Fig. 3). On the other hand, a well prepared and performed lecturing is not only an effective mean of information and knowledge presenting, but also a way of leading students to devote their time or even life to the subject.

Active interaction between teacher and students will improve classroom environment. Similarly, well-organized presentation by students in classroom is also an effective and practical way to encourage and actively develop students’ learning skills. As the speaker is presenting, the classmates
are parts of the environment. The presenter expresses the capacity of playing a social role in a group. This is similar to that a person needs to be admitted and respected where and when hard working is performed. On the other hand, who plan to present some topic or idea before others, should prepare related information and materials for it, which is a knowledge constructing and skill developing process. The presentation is a powerful way to deepen students’ understanding. Presentation and discussion make our thinking transparent and is a way of building shared mental models of an issue. These skills are vital to a qualified professional engineer to cope with complex situation in practice.

On the other hand, the students’ actively responses to a teacher’s question and assigned tasks are extremely important in the execution of a course. An active response implies that the responder is not only actively involved in the process, but also skillfully constructs personal knowledge.

Evaluating Timely and Properly

Timely Evaluating is Necessary in Learning and Teaching. As the above discussed, the one of the focuses in teaching at a university is to improve student’s problem-solving capacity. Considering the features of the learning and teaching at a university, such as to accomplish a course in a semester, timely evaluating students’ task accomplishing, including quiz and test, assignments, presentation and instant response to instructor question (Fig. 3) is necessary for both learning and teaching. A feedback of the evaluation to students is beneficial to trigger students’ learning [4], such as in terms of strengthening learning motivation and interactions between learner and instructor (Fig. 3). Timely evaluating is one of the well-organized course environments, which strengthens the commitment and involvement of self-motivated learners. On the other hand, the results of the evaluation also act as indicator of teaching quality. The students’ good performance will also strengthen the teaching motivation (Fig. 3) and the teaching plan should be implemented in a dynamic style.

There Need Well-designed Evaluation Modes. As the above mentioned, it is necessary to apply systems thinking in tunnel engineering learning and teaching. Systems thinking is also beneficial in program evaluation design [5]. In general, a well-designed evaluation mode is of the features: (1) the key points of assessment should match the teaching content; (2) the modes of evaluation are flexible, diverse and incentive; (3) the execution of assessment is planned in the teaching time schedule. For example, the style of the questions testing the application of the principles with systems thinking needed should not be in standardization form. The presentation style of the evaluation results of students’ performance should serve the capacity-developing plan. To encourage student’s positive and active response to the assigned tasks, relatively high score is timely recorded to well-performed presentations. Volunteer is praised, such as with 25% plus in score, to make it an example.

Summary

Problem-solving capacity development is indispensable for a college student to adapt to the world globalization and modernization. The capacity should be cultivated in ordinary programme, especially in subjects leaning and teaching procedure, with systems thinking being involved. Considering the complex features of tunnel engineering, systems thinking is necessary and beneficial in course execution. The application of systems thinking in the tunnel engineering teaching practice is presented, in terms of content preparation, lecturing, learning and teaching interaction, and learning efficiency evaluation. The experience implies that the teaching should be implemented in a dynamic style, in which learning efficiency evaluation should be timely and properly.

References


