Reforms of an operating system course at a local university

Xuemin Zhang, Zenggang Xiong, Yaomin Ding & Guangwei Wang

Hubei Engineering University
Xiaogan City, People's Republic of China

ABSTRACT: An operating system course is one of the most important professional and basic modules taught in computer science. But, such a course can be abstract, hard to teach and to learn. The aim of this article is to discuss the characteristics of the operating system course run at a Chinese university, and to discuss reforms of course content and methods. Through reforming course content and teaching methods, as well as strengthening the experimental teaching and examination methods, an improvement can be made to attract students to this course and to improve the quality of teaching.

INTRODUCTION

An operating system is the most crucial and basic system software in a computer. An operating system course is one of the most important professional and basis courses in computer science. It is a module in degree courses in computer science and technology, and a compulsory course for entrance examinations for postgraduate students. The course discussed in this article introduces the basic principles and implementation techniques of an operating system, which is important for understanding how a computer system actually works.

The user interacts with the computer system, during the design and development of the computer applications. As a fundamental and professional course, this module on a computer operating system is important overall in the computing curriculum. The content of the course includes theory, algorithms, technology and applications. It is difficult for students to understand all this knowledge sufficiently well. Therefore, the extent of mastering and understanding of the course impacts directly on the professional standards and development of the learner.

As far as educational activities are concerned, the learning and teaching of operating systems has always been a significant and difficult task in computer science. Because an operating system course includes an abstract set of principles, the course can be very hard to teach and to learn. In various types and levels of college and university, there are large differences in course contents for operating systems. For a local university, full of undergraduate students who wish to learn a practical subject, the focus should be on linking theory with practice, so as to improve system programming capabilities.

Through comparative studies, as well as communications and discussions with other teachers at colleges and universities, it was found that at comprehensive institutions, such as Tsinghua University and Zhejiang University, where reforms already have been carried out, there are many qualified teachers and improved teaching conditions. These institutions use English teaching materials and also teach in the English language or in both languages, which students accept. A variety of flexible teaching methods have been introduced across lectures and discussion groups. The experiments are more difficult, such as the analysis of source code or designing their own operating system, because network resources are utilised almost to the capacity. Hence, the examination mode is flexible. The current status of operating system teaching in local universities is that trials of some reform are being carried out, but the outcome is not very clear. Also, there is a lack of sufficiently qualified teachers.

Most textbooks are written in Chinese, with versions updated rather slowly. Because there are different levels of student knowledge and use of English, bilingual education is minimal. Course content covers either just the basic principles only or experiments, or both basic principles and experiments, but the content on experiments varies. Most institutions use multimedia teaching methods combined with blackboard teaching; and teaching methods are simple. Traditional

classroom teaching methods are most often used. Rarely used are heuristic or discussion based methods. Hence, students conduct less research or exploratory learning; use of animation technology is inadequate. In traditional classroom teaching, students feel bored and it is difficult for them to participate in the classroom. The network resource library of the operating system curriculum also is not complete and practical. As a result network resources are not fully utilised for the coaching of students or answering questions. Assessment methods are fixed and teachers do not freely change their scope [1].

Reform of course content and methods of an operating system course at local universities cannot be mechanically derived from a comprehensive university model, as it should have its own distinctive characteristics. With the support of Hubei Engineering University, the reforms of course content and methods of the operating system course have been carried out for a few years now. Practice has proved that, after the reforms, although the workload of teachers has risen, the students study well, and there is a closer combined knowledge of theory and practice. The quality of teaching has improved significantly.

REFORMS OF COURSE CONTENT AND METHODS OF AN OPERATING SYSTEM COURSE

Improve Teachers' Knowledge

In computer operating system courses, there are many concepts and applications requiring frequent course content updates. This means the teaching of operating system courses in many universities is seriously out of date. While some knowledge should be eliminated over the years, it is still repeatedly used in teaching case studies. Therefore, many graduates before taking a job must undergo prior training.

It was found, therefore, that teaching reform must focus on research activities and academic exchanges to keep up with the pace of development of operating systems. Hence, students will better understand the relationship of curriculum to practice. This requires that teachers must study and improve their knowledge every year or even every day. There are some specific measures that can be introduced: for example, holding teaching seminars regularly or irregularly; inviting foreign experts to carry out academic exchanges; organising teachers and students in such a way that they actively participate in various teaching and research activities. For example, each year, every teacher of an operating system course should attend at least once, a teaching and research activity in other universities. Hubei Engineering University holds teaching seminars each month to exchange new ideas or methods. The University also adheres to teaching and research activities that promote computer science teaching.

Select Appropriate Teaching Content on Theory

First, select the appropriate teaching materials for the course taught. There is a wide variety of textbooks on operating systems to choose from. It is important to select appropriate materials for teaching a course. Students at local universities are required to have an appropriate textbook, but purely English teaching materials are inappropriate taking into account the level of students' proficiency in English. Teaching staff at Hubei Engineering University use the classic textbook, *Computer Operating Systems*, compiled by Tang Ziying, and recommend the *Operating System Concepts* (English version) for students to read. Also, students are encouraged to read English textbooks and view open class videos from well-known foreign universities. It is recommended that important concepts are expressed in English in courseware, so that students find it easier to understand English concepts that may be encountered later.

Second, select reasonable teaching content that matches students' knowledge and expectations. Rapid development of computer systems means that the structure and function of an operating system evolves continually. Therefore, older teaching content may not be suited for cutting-edge computer technology. According to the institution's teaching objectives, it will be necessary to add and replace teaching content in a scientific and rational way. So, as to offer a complete teaching system, at Hubei Engineering University, the out-of-date course content is removed, and new content is added appropriately. The continuous development of computer network technology, for example, network operating systems, distributed operating systems, multi-core operating systems, and so on, require that the teaching content for these must be increased. The many concepts, ideas, methods and techniques that are easy to understand, and secondary, non-essential content do not need to be covered in too much detail. Teaching methods should not be constrained by the content of the material being taught, and teaching staff should ensure that the knowledge is restructured and refined.

Concrete Proposals for the Reform of Teaching Methods

Problem-Driven Classroom Teaching of Operating Systems

The term, *problem-driven*, refers to using a problem as being a means of carrying a student through a series of steps or *problem chain* by which to guide students' autonomous learning. In the process of teaching, teachers will make the knowledge inherent in the problem dealt with, and the students then master the knowledge. Overall quality improves in the process of answering questions and solving problems. In this way, teacher-student interaction is helpful in improving the effectiveness of the teaching.

Ask Guiding Questions while Teaching the Main Content to Prompt Students to Use their Initiative

In the teaching process at Hubei Engineering University, guiding questions are used related to the content of each section. Questions are asked to guide students' thinking and to help them understand both the purpose of the teaching and to help them learn. This can promote their thinking and learning by acting on their own initiative [2]. Each part of the course material starts by introducing the *what*, *why*, *how* in learning the operating system from the perspective of system design. Each chapter of the course material describes how to deal with problems by asking questions first; then, put forward the possible solution to the problem and, then lastly, analyse the problem to see if the correct solution has been identified. For example, course material in the chapter on process management includes the basic concepts of process, state, process synchronisation, and process communication. Teachers ask questions focused on process management to guide students to think actively. Teachers ask such questions as *Why is a process introduced? What is a process?* and *How do processes resolve the concurrency problem?* Figure 1 shows the reasoning behind the question, *Why is a process introduced?*

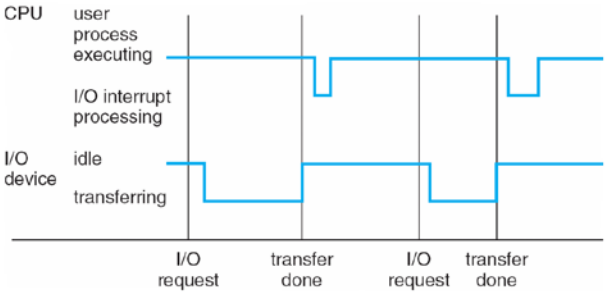

Figure 1: Interrupt timeline for a single process doing I/O.

The program execution environment changes in a multiprogramming system leading to the question: *In a concurrent system, with many programs in memory, how does the operating system decide how to finely manage the activity of each program?* Students will learn from this why the process mechanism exists and will come to understand the concept of a *process*. Then, the teacher puts forward the questions: *What is in the process?*; *What status does the process have?*; *How do you convert between states?* Students study the textbook to learn and understand the *process state* and *transition conditions*. Afterwards, the teacher asks appropriate questions, such as: *The process can solve what kind of problem? If interacting processes are executed, how can the correctness and efficiency of process execution be ensured?* Guidance is, then, given to the students to learn about process synchronisation and communication.

When the students understand these questions, they can read the book themselves and enjoy studying the operating system. Figure 2 is a map starting with the Process Control Block (PCB), and constructing a PCB tree in Linux, which corresponds to the question: *How does the process resolve the concurrency problem? Pid* refers to the unique process *id* for each process.

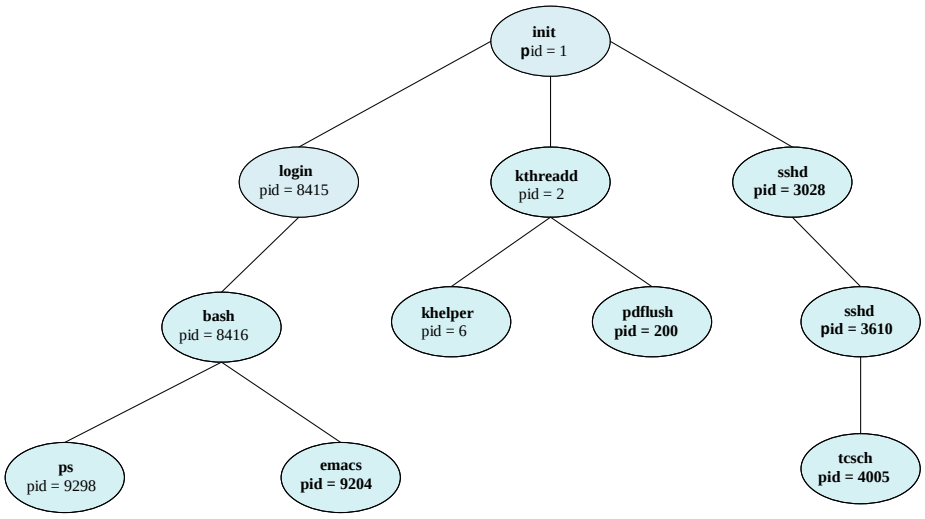

Figure 2: A tree of processes in Linux.

Build Instructive Questions by Analogy, so as to Stimulate Students' Interest

Developing and maintaining students' interest in studying the operating systems course is also critical to the effectiveness of classroom teaching. Some of the content is too abstract and difficult to rely entirely on students' self-

learning. Teachers should express common phenomena found in daily life by analogy with operating systems concepts. This should inspire students to better understand the reality of the abstract principles; thus, making the operating system a more interesting element of the course. While students are capable of digesting the interesting facts through their own initiative, they should actively explore the subject for themselves. This requires the cultivation of students' ability to think logically. For instance, with the processor scheduling algorithm, teachers can use analogies to build heuristic questions to help students' awareness and understanding; for example, using an analogy, such as queuing at a bank to explain queuing within an operating system. When explaining the solution to deadlock within an operating system, teachers can guide students to use their initiative to think about such things as the work principle, merits and costs. Using this approach to teaching, it is easy for them to link up the knowledge. Table 1 gives examples of teaching by analogy.

Table 1: Examples of teaching by analogy.

Concepts in operating system	Analogy description
Program and process	Tablature and the process of playing the piano
Process mutex (mutual exclusion)	Using a public telephone or ATM
Deadlock	Traffic jam
Algorithm	Queuing rules in real life
Paging memory management	Book page

Holding Lectures and Increasing Interactivity

Combine Principles and Implementation when Teaching Operating Systems - Put forward specific questions; arrange comprehensive lectures and seminar topics or discussions related to new technologies and new ways of using the operating system. Therefore, stimulate students' thinking and sustain their interest and motivation. Through communication between teachers and students, such as: asking questions, discussions and reviewing, guide students toward autonomous learning by inquiry and train them to acquire a deeper understanding and an ability to conduct analyses and make comparisons. Students are very willing to achieve this in an interactive way.

Teach with Multimedia and Through a Dynamic Teaching Web Site - Compared with the rigid features of the traditional chalk and blackboard, multimedia teaching can make abstract, indigestible knowledge better through organisation and visualisation [3]. Elaborate preparation is required for the courseware and should be included with the courseware, such as text, pictures, tables, sound, video and animation. For example, to display the process of communication in the human-computer interface, animation can be used to great effect, making the process easy to understand and lively. The authors do some of these animations, and students are allowed to practise their programming ability and operating system knowledge on others.

In addition, teachers can build a dynamic teaching Web site that incorporates network courseware, on-line jobs, on-line questions and answers, email, blogging, as well as other means by which to increase student interaction. At Hubei Engineering University students always access the operating system Web sites; they ask questions and give suggestions; and the teachers are able to give answers immediately, which they prefer to do.

Rational Design in Experiment Content

The operating system module is a part of the computer science curriculum that blends theory and practice. It not only contains a considerable number of scientific ingredients, but can be considered an engineering technology. The basic concepts, principles and algorithms introduced in the theory must be understood and absorbed through practice. The course not only allows students to learn in-depth the principles of the operating system, but also, by practice, allows them to grasp effectively the application of this knowledge. Students also can develop awareness of combining theory and practice. This enhances the students' practical ability, innovative ability and scientific literacy. Introducing the operating system in the experimental practice classes, can expand students' theoretical knowledge, while they gain a deeper understanding of the nature of operating systems. This ability to use learned knowledge to solve practical problems enhances employability.

Research was carried out on the experiment content of the operating system module. The teaching was divided into three levels of difficulty: user-level, the primary kernel and the senior kernel. The experiment teaching was divided into four grades: use and management, observation and experience, programming and modification, design and implementation [4]. Multi-level operating system experiment classes were introduced. This caters for different levels of student and enables them to understand the principles and practice and to master the design of operating systems. This enhances the students' practical ability, innovation ability and scientific literacy.

The abstract principles related to specific system implementations help students to move from *knowing it's so, but don't know why it's so*; to go from the *abstract understanding* to *emotional understanding* of the basic principles and ultimately to *rational understanding*. Experiments enable students to understand and master the practical skills and knowledge [5].

When designing experimental content, consider it from the perspective of relevance of daily life. For example, take a banking system or train ticketing system as a concurrent process. This can imply a process scheduling algorithm, page replacement algorithm or disk scheduling algorithm. Good students can be asked to improve an algorithm. For file management, students can be required to design a small operating system which includes basic file management. This develops the students' ability to think independently, analyse problems and find solutions.

Reform of Assessment and Appraisal

Aassessment and appraisal are an important means by which to test the quality of classroom and practice teaching. The evaluation of a traditional operating system course is by a final examination paper with an emphasis on theoretical knowledge. It is necessary to reform the evaluation criteria by combining results based on different criteria to establish a better evaluation system. The overall score for this course is based on 50% for non-examination tasks and 50% for a final examination. The non-examination tasks takes into account student attendance, classroom questions, course experiments, homework, project design and completion. These incorporate independent learning into the appraisal system [6]. The students' ability in practice-oriented tasks and participation can be promoted by reforming content and the methods of assessment and appraisal. This strengthens the foundations of professional learning. Table 2 gives an example of the breakdown of evaluation criteria.

Table 2: Example of evaluation criteria.

Evaluation criteria	Classroom	Homework	Discussion	Experiment	Final examination
Proportion	10%	12%	20%	18%	50%

Concrete Methods to Improve Participation

Questioning in classrooms. Teachers best exchange communication with students through question and answer sessions. Asking questions is actually a form of student feedback on teaching content and a way for students to participate in the teaching process. It is also a record of the course success. Question and answer sessions are the equivalent of an oral test for the students which also reflects teaching effectiveness. In traditional education, students are not the main focus as it is in interactive teaching. Academic democracy should also be reflected in the classroom. Students should be encouraged to express their opinions [7].

Write short papers. Simply copying or downloading from the Internet is wrong. The title of a paper should be on a subject that is leading edge and worthy of study and the topic should be provided early or mid-term, rather than late in the teaching schedule. This promotes students' knowledge and investigation. Moreover, acknowledgement of authorship is mandatory.

Participate in research. Universities promote research projects. Students formed into voluntary groups for data collection and research can participate in a spirit of collaboration and, thus, promote teaching and learning [8].

CONCLUSIONS

Operating system courses in computer science and technology are extremely important professional and foundation courses. Students who have mastered the basic principles of operating systems can better learn about other software systems. In addition, an operating system course is an important way to train students in carrying out hands-on tasks, while developing their creative thinking and preparing them for future employment. Therefore, encouraging quality in education and innovation should be the goal of teaching. It is essential that research on teaching content and methods is carried out and that teaching systems are reformed.

Through reforming course content and teaching, strengthening experimental teaching and methods of examination, interest in studying the course and teaching quality can be advanced. But reforming operating system course teaching is a lengthy process that requires classroom teachers to continue to accumulate teaching experience by which to improve the existing education system. There is still a lot of work that can be done in this area.

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REFERENCES

1. Zhang, X.M. and Xiong, Z.G., Research on teaching methods of operating system in local university. *Proc. 2012 Inter. Conf. on Cybernetics and Informatics*, 1763-1768 (2012).

2. Zhang, Q.Y., Question-driven teaching methods in university operating system. *J. of Lvliang Educ. Institute*, 29, **4**, 95-96 (2012).
3. Yan, H.W, Wang, Y.H. and Hou, L.J., Teaching reform of operating system based on *Excellence Program*. *J. of Chinese Electric Power Educ.*, 273, **14**, 87-88 (2013).
4. Ma, X.H. and Chen J., Research and practice of experimental teaching of operating system course. *Modern Computer*, 2013, **2**, 40-42 (2013).
5. Liang, B.H., Zheng, S.Y. and Wang, S.Y., Discuss on operating system experiment teaching. *J. of Chaohu College*, 6, **14**, 144-146 (2012).
6. Chan, Q. and Wei, D., Explore and application of CDIO in Linux operating system. *J. of Jilin Business and Technol. College*, 27, **3**, 120-122 (2010).
7. Xiong, Z.G., Zhang, X.M., Xia X.W., Xie Y. and Chen J.X., Research on experiment teaching of *Computer Network* in local university. *Proc. IEEE 2010 2nd Inter. Conf. on Educ. Technol. and Computer*, 308-310 (2010).
8. Zhang, X.M. and Xiong, Z.G., Teaching reform of discrete mathematics in local university. *Proc. 2012 Inter. Conf. on Cybernetics and Informatics*, 2253-2259 (2013).