Abstract—Computer organization and design has played an important role in the field of computer science and technology. With the rapid progress in semi-conductor, there are also new relative advances in computer science and technology. How to design computer organization and design course becomes more challengeable than before. The traditional teaching contents and the new advances should be organized together and taught to the students through effective methods. Computer organization and design is designed as the fundamental course at Zhejiang University. In this paper, we describe the innovations and reformations in the teaching methods of the computer organization and design course based on our background of our many years’ teaching and research. During the teaching, we have designed different teaching innovations and reformations to improve teaching effect and cultivate students’ innovative concepts. We have also provided special support through the online course construction. It is indicated that using different teaching methods in class could inspire students’ learning interest and passion according to the different teaching scenarios, while the online support can extend the teaching in class further and provide a better learning platform to the students.

Keywords—computer organization; teaching method; case-driven teaching

I. INTRODUCTION

With the development of electronic industry, there are more and more transistors integrated on the single chip. The current situation is not that the scale and performance of the chips are not in line with Moore's Law, but that Moore's Law forces the vendors to produce more powerful chips which can be in line with the law. So the processor becomes more complex for higher frequency. But this also causes fatal side effect. The ceiling of the frequency and higher energy consumption impede the further improvements. Then CMP (Chip Multi-core Processor) and SoC (System on Chip) emerge as the inevitable solutions.

CMP integrates more than one core on the chip and such architecture can reduce the design complexity and power consumption. Current CMP bases on SMP (Symmetric Multi Processing), but communication on CMP is faster than SMP. When the scale of CMP is small, the bus can afford CMP communications. But when the number of the cores increases, the bus brings more conflicts, which will result in useless waiting. NoC (Network on Chip) is considered as a solution of CMP communication. SoC refers to integrating all components of a computer or other electronic system into a single chip. The fast development of computer architecture brings more challenges for computer hardware teaching. It is also a social and cultural encounter [4].

There are different proposed solutions for computer education including computer organization. Guido et al [1] proposed a computer science education system. In their opinions, computer science education is different with other science subjects, for the faster development of computer science than the other subjects. In [3], Thomas et al reported their exploration in the utilization of visualization and engagement in computer education.

Eitelman and Michael realized the similar problem like Guido [5, 7]. They suggested the problem-solving based education for computer science. Eitelman found that the teaching in class can not meet the requirements of the students and he suggested the question revolving tutoring in programming education. Similarly, Michael suggested the problem-solving education for computer science in real-world practice. Orit Hazzan et al summarized four key elements in computer science education including elements-teaching license, computer science curriculum & syllabus, teacher preparation programs and research in computer science education [2]. These elements have close relationship with each other. They also built a model based these elements. Martin [8] shared the computer science education in Japan. These practical experiences were good references to the other universities.

In this paper, we propose some teaching methodologies for computer organization and design course. Computer organization and design is the fundamental course of hardware curriculum of computer science major and related electric and information majors. It is also the core course for the students to master the basic principles of computer system design. The role of computer organization and design course is foundation of computer science. The fast development of computer hardware is the challenge to this course. The key goals of this course are how to instruct the students to learn the basic theories well and how to cultivate the students’ investigative spirit and how to awaken the
students’ innovative potential. Our teaching group tries to explore in this space. The paper is organized as follows. Section 2 describes the basic course design. Section 3 depicts the innovations and reformations in this course. Section 4 shows the teaching effects of these innovations and reformations of the course. Section 5 offers the conclusions and future work.

II. COURSE DESIGN

The emphasis of this course is on the basic issues of computer organization and computer design. Computer organization is concerned with the way the hardware components are organized and connected together to form a computer system. Computer design is concerned with the development of the hardware for the computer by taking into consideration of a given set of specifications. In this course, the students will learn the principles and hardware implementation of computer components, and how to completely design a correct single processor computer. According to the requirements to design a computer, the basic contents of this course include the following ones: the history and foreground of computers as the introduction content; computer arithmetic operation and hardware implementation; instruction set architecture; ALU design; register file design; single-cycle/multi-cycle processor data-path and control unit design and their hardware implementations; cache structure and memory design; the memory hierarchy; virtual memory; and input and output systems. At last, how to organize these components as a whole computer is also important in the course. The organization of the teaching contents is shown in Figure 1.

<table>
<thead>
<tr>
<th>Introduction: the History and Foreground of Computers</th>
<th>Control Unit Design and Hardware Implementation</th>
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<tbody>
<tr>
<td>Computer Arithmetic Operation and Hardware Implementation</td>
<td>Cache Structure and Memory Design</td>
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<tr>
<td>Instruction Set Architecture</td>
<td>the Memory Hierarchy</td>
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<td>ALU Design</td>
<td>Virtual Memory</td>
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<td>Register File Design</td>
<td>Input and Output Systems</td>
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<td>Data-path Design and Hardware Implementation</td>
<td>Performance Analysis</td>
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<tr>
<td>Complete Computer System Design</td>
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</table>

Figure 1. The matrix of the teaching contents

This course is aimed at teaching the fundamentals of the computer organization and design to the students. If we want to achieve this goal, the theory teaching and the hands-on labs are both needed when we design this course. The whole course can be divided into three parts including the theory teaching, the training of practice methods and the hands-on labs. This course has 60 lessons for theory teaching, eight lessons for practice and another 25 lessons for the hands-on labs. Except for the teaching in class, we also provide the supplementary resources for the students as the extended teaching out of class. The students will learn more practical knowledge and skills from these extra resources.

III. INNOVATION AND REFORMATION OF TEACHING METHODS

The development of computer technology is very fast, and it makes the teaching of computer organization and design more difficult. So we need the innovations and reformations in teaching methods to teach the knowledge points to the students with higher efficiency and make the students master the theories and practical skills. In this section, we will describe these innovations and reformations in detail.

A. Textbooks and Supplementary Materials

Textbooks are very important in the course. When we select the textbooks, the fast development of computer technology and the evaluation of the different textbooks are both taken into account. The guideline of our selecting is the quality of textbooks. We have selected two textbooks written in two different languages. One is a textbook written in English, which is titled as “computer organization and design: software and hardware interface”. This textbook has been modified four times for the new advances in computer technology and the revised versions can reflect these new advances in time. And at the same time, this textbook can train the students to master the professional ability in foreign language. This textbook is our main textbook.

At the same time, we also have the textbook written by ourselves in Chinese as the reference textbook. This textbook is written according to the background of the teaching and research in computer organization and related fields of Zhejiang University. Its authors are the teachers in our teaching group who have wealthy teaching experience in computer hardware. And the arrangement of the contents is derived from the past teaching in this course. It is useful complement to the above textbook.

The classical MIPS instruction set architecture (ISA) is the main ISA case in the course combing other instruction set system, such as X86, Core as the supplementary ISA. And the MIPS assembly language is also taught to the students. This is different from the traditional teaching method, which separate the computer organization and the assembly language. The combination of the two aspects can help the students learn this course.

Some other teaching materials are also provided to the students. The new ideas will always be in the academic papers and the new innovations will appear in the products. We provide some selected papers to the students. And at the same time, we also provide the new advances in the industry to the students. These resources are optional to the students. They can select these resources according to their interests.

B. Hands-on Lab Environment

Hands-on labs are very important in computer organization and design course. The students should also learn how to design and implement a whole computer
through practice based on the basic principles. We have
design the basic hands-on labs according to the teaching
contents. The main hands-on labs are: register file design,
cache design, ALU design, controller design, interrupt
controller design and CPU design. At the same time, we also
design a comprehensive hands-on lab for the students as the
final hands-on lab at the end of the course. The students have
to use almost all the knowledge and skills to complete this
hands-on lab. Besides the general development boards for
these hands-on labs, we also introduce FPGA as the hands-
on lab platform. The hardware description language (HDL)
is taught to the students. In our course, verilog language is
adopted as the HDL. The students can learn how to design
and implement the hardware component and the whole
computer through verilog language and FPGA.

Our teaching group updates the facilities according to the
development of the related technologies to catch up with the
advances in computer hardware. We have constructed hands-
on lab environment with the latest devices. In 2006, 69
FPGA development platforms are introduced into the
environment. And the teachers in our teaching group have
designed the corresponding hands-on lab package including
the detail of the hands-on labs. A special guidance titled
“practice of computer organization” is also published as the
hands-on lab guidance.

C. Reformation in Advanced Teaching Methods

Teaching methods which our group adopted focus on the
emerged problems both in teaching and feedbacks from the
students. The improved teaching effects rely on not only the
teaching but also the learning. The learning confidence and
inspired motivation of the students will play an important
role in the teaching and learning. We have tried to research
the following areas.

Heuristic teaching method. Based on the experience in
teaching computer organization and design, we use heuristic
teaching method in our course. Through such method, the
students will be inspired to think “why” and “how” in
computer organization and design. They will not only
receive the knowledge from the teachers and the textbooks
passively, but also try to understand the principles on their
own initiatives. The teachers will provide the questions and
try to lead the students in thinking. The students can have
their own designs even if some of these designs were wrong.
But the answers will correct the errors. And sometimes the
students will also have some interesting solutions.

Case-driven teaching method. Designing some operable
cases for the practice can inspire the students to learn in great
passions. It can also cultivate the students’ ability of
analyzing and solving the problems, and train the students’
skills in researching and practice. These cases provided to
the students will be divided into different levels according to
the difficulties. The different levels will help the students in
gradual progress.

Teaching method based on problems. The students are
organized as different groups according to their own wills.
Each group has two to four students. The teachers will
provide many topics. Each group can select one topic as their
problem or design their own topic. The main challenge for
each group is to analyze the topic, search and acquire the
correlative information around the problem need to solve.
Each group should have the sure technology route and
implementation schema and dispatch the detail tasks to each
member in this group to cooperate on this problem. And at
last they have to solve the problem and submit their solutions.
The whole process is finished by students completely while
the teachers only offer some necessary tutorship. Such
practice based on problems could increase the students’
interests to the course, cultivate their ability of exploration
and innovation and boost their cooperative consciousness
and spirit. It is good for their further learning and work in the
future.

Task-driven teaching method. The teachers could
organize teaching contents as some special tasks and
dispach them to the students. The main target of task-driven
teaching method is to train the self-learning ability. During
the process, the teachers would provide some examples to
the students to give them confidence that they can finish the
task after learning. This step is very important, for it may
eliminate the students’ feeling of fear to complete tasks in
time.

The keystone of task-driven teaching method is how to
implement the teaching goal during self-learning and
collaboration learning. Self-learning is around the students to
to complete the tasks by their own after their searching for
useful information. The students are required to exert
initiative during the learning. The students can obtain
different ideas and approaches from the others. Collaborative
learning is based on self-learning, and it may improve the
learning effects through the discussions.

Based on the above advanced teaching methods, an
architecture of teaching methods is proposed, which is
shown in details in the following figure.

![Architecture of teaching methods](image)

Figure 2. Architecture of teaching methods.
D. Online Resource

The website of computer organization and design course is designed, implemented and published. This website contains course introduce, teaching outline, teaching calendar, teacher introduction, teaching materials, reference books and papers, course information and discussion forum. These online resources are open to all the students in this course. The students can select the teachers, prepare for the learning, design a good learning schedule and obtain additional contents. And they can also discuss on different topics and obtain the help from the teachers online.

IV. TEACHING EFFECTS

In this section, we present the teaching effects after the innovations and reformations are adopted in our course. The teaching effects are mainly focus on the comments from the students. The students are the best judgments of the teaching effects. The evaluation from the students shows that the teaching effects are improved.

The students who have taken this course have an opportunity to submit their evaluations of this course through the website. The time spans from year 2005 to 2008. The students can evaluate our teaching with five ranks including very satisfied (5), satisfied (4), plain (3), unsatisfied (2) and very unsatisfied (1) respectively. In our evaluation system, 5 is the best rank. Calculation method of the scores is:

\[
\text{Weighted Average Score} = \frac{\sum \text{Score} \times \text{Number of Students}}{\text{Total Number of Students}}
\]

![Number of the students selecting this course](image1.png)

![Average course score](image2.png)

Figure 3. The changes of the students to take course and average course score from year 2005 to 2008.

Figure 3 presents the number of the students to take this course and the average course score in each year. From this figure, we can see that the weighted average score has increment in each year. There are more and more students to select computer organization and design as major course. It illustrates our course is attractive and our proposed teaching methods are successful.

V. CONCLUSIONS AND FUTURE WORK

Computer organization and design course has played an important role in computer science major and the related electronic and information majors as the fundamental course. The rapid progress in semi-conductor and the new advances in computer hardware make the teaching of computer organization and design course be more challenging than before. How to teach the knowledge of computer organization and design to the students is important for the universities. In this paper, we present our innovations and reformations in teaching methods of computer organization and design course at Zhejiang University. These innovations and reformations are based on the background of our teaching and research in related fields. The teaching effects show that the proposed innovations and reformations are effective in teaching.

During the teaching work, there are also some problems, which should be solved. And the evaluation of the innovations and reformations should also be more accurate to obtain better feedbacks to improve the teaching. These are our future work.

REFERENCES