Critical Thinking Strategies in Teaching Advanced Timing Analysis Course

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Abstract - Due to the increasing design complexity and time-to-market pressure for digital integrated circuit design, the efficient static timing analysis method based circuit analysis becomes essential in circuit design nowadays. In this paper, we propose using critical thinking strategies to teach advanced timing analysis to electrical engineering and computer engineering graduate students. Traditionally, graduate students only passively receive information inside classroom without developing critical thinking skills for problem solving. Critical thinking occurs when students formulate hypothesis, synthesize information from thorough analysis of problems, articulate their thoughts and finally draw logical conclusions. In addition, interaction with team members in class engages students in course materials, foster critical thinking, and enhance their learning process. This paper is to present the importance of critical thinking for graduate student education, and describe multiple critical thinking strategies to innovate teaching, to engage and motivate students for better learning.

Keywords: Critical thinking, computer engineering education, electrical engineering education, static timing analysis, team based learning

1 Introduction

Traditionally, instructors play dominant roles in engineering education and students receive knowledge inside classroom passively. Most of the time, students acquire ideas through memorizing facts. During such passive learning process, students are not given enough time or they may not feel comfortable for raising questions, promoting class discussion, analyzing and evaluating information.

Passive learning is the result of instructor-centered one-way communication in teaching. Without getting verbal feedback from students, the instructors usually need much more time and greater effort to find out strength and weakness of students in studying course materials. Moreover, because students only absorb information without much effort for comprehension or understanding, such routinely memorizing activity does not sharp their brain for questioning, thinking and analyzing. Consequently, students do not acquire critical thinking skills and they are not prepared to solve complex problem in their future career.

In recent years, with an increasing market demand for graduate students to develop reasoning and critical thinking skills through academic studies [1], teaching methodologies in engineering education have trends of integrating lectures with active participation of students through critical thinking and collaborative learning [2][3][4][5].

Critical thinking changes instructor-centered learning into actively involving students in learning. To develop critical thinking skills, students are encouraged to improve attention and observation of the problems from multiple angles. They are motivated to enhance their understanding of information through their own questioning, analysis and evaluation process. In general, critical thinking has direct impact on effective and logical decision making for students. In addition, such practice allows students to come up with solutions to new scenarios and also complex problems in their future career. It facilitates life-long learning and personal growth.

Although surveys show that above 90\% faculty agree that critical thinking is one of the primary goals of higher education, development of critical thinking skills is generally considered important and emphasized in undergraduate education [6]. More effort for critical thinking in the graduate study especially in the engineering field needs to be conducted and the results need to be distributed.

With the increasing design complexity and time-to-market pressure for digital integrated circuit design, using efficient static timing analysis method to verify and optimize the performance of the digital circuit is emerging as a critical approach for the success of the application-specific integrated circuit (ASIC) design [7][8][9]. In addition, the explosive growth of the digital circuit design and rapid technological changes require graduate students in the computer engineering field and the electrical engineering field to be able to analyze and evaluate information, and also think critically to solve complex problems in their future career.

In this paper, critical thinking strategies in teaching advanced timing analysis course to graduate students in Electrical Engineering and Computer Engineering at California State University, Sacramento (CSUS) are discussed in detail. Part 2 discusses how to provide design
problems to stimulate critical thinking among students. Part 3 presents team based learning strategy to engage students on critical thinking. Part 4 covers the usage of computer tools for critical thinking. Part 5 describes the strategy of using writing assignment of technical paper review to motivate students for critical thinking. Finally, part 6 draws conclusions of this work.

2 Problem design for critical thinking

In order to change instructor-centered learning into active learning requiring critical thinking, graduate students should be provided with opportunity to reason course contents, conduct student-centered learning and derive logic conclusions by themselves. Proper design of questions for students to practice critical thinking is critical. The questions should arouse intellectual curiosity and also encourage deeper investigation from students. Meanwhile, the questions should be mapped into course learning outcomes.

In student-centered learning, proper guidance is still required from instructors to prepare students to enter critical thinking stage, to evaluate student study results and help students improve learning.

Before working on more complicated critical thinking assignment, students need to first participate in some warm-up activities. For example, the first exercise is for students to follow a tutorial developed by instructor to learn how to use Synopsys static timing analysis tool of Design Vision. The second exercise is for students to study one set of example design constraints provided by textbook [8] using Design Vision online help tool. Students are required to summarize the usage of the following clock design constraints in a table after completing the second exercise: create_clock, set_clock_uncertainty, set_clock_latency, set_input_delay, set_output_delay, and set_clock_transition.

4).Thoroughly analyze the assumptions of timing constraints, and carefully evaluate the relevance among gate level circuit timing, setup condition and hold condition.

5).Formulate a specific hypothesis of circuit timing equations which accounts for the complexities of the setup and hold violation issues. Use Design Vision tool to verify the hypothesis. Four or five students form a group for discussion. Acknowledge the limits of the position and synthesize others’ points of view in each group.

6). Draw logical conclusions and related outcomes of the assignment.

After graduate students finish their work, the feedback discussion with instructor allows students to confirm their ideas, to correct errors, and also to go back to work on the assignment again to fix errors. The feedback loop makes critical thinking work of students more conductive.

Instead of providing solutions as lecture materials directly to students in the traditional instructor-centered teaching, the instructor created this assignment to engage students in critical thinking, active learning and also achieve major student learning outcomes. By working on such assignment, students benefit from improving critical thinking skills to analyze and synthesize course materials with practice.

3 Team based learning

Developing critical thinking skills require time from graduate students to practice and also require courage from them to face complex problems. Usually graduate students with different academic background have different learning styles, some are slower learners and some are faster learners. To help graduate student retention in the classroom, to help graduate student better manage their time for study, and also to balance learning environment inside the classroom, team based learning is very useful.

In advanced timing analysis course, usually four or five students form one team for practice. The instructor’s primary role is to design and manage the overall instruction process. In addition, the instructor needs to monitor the study behavior of graduate student teams and provide feedback to student team work through face-to-face

![Figure 1. A sequential circuit with multiple gates](image)
discussions. Each team is allowed to distribute work among students.

In advanced timing analysis graduate course, the instructor developed unique model of tutorial-critical thinking practice-feedback loop to organize team assignments and discussions. Tutorial exercises are usually designed by instructor to get each team of students familiar with general concepts related to course materials and also the critical thinking practice problems.

The tutorials are straight-forward exercises for students to follow. They are used to warm up students. Generally speaking, the completion of tutorial work introduces the sense of academic success in students, and also motivates them to try harder assignments for the next step.

The critical thinking practice problems are designed to emphasize student learning outcomes outlined in course syllabus. Each problem is of sufficient difficulty for a team of four or five students to work together, conduct experiments, collect data, evaluate results, derive reasonable conclusions and enable significant learning.

During the team work, graduate students learn from each other, argue with each other, evaluate views of others in the same team, solve problems through critical thinking and team discussions, and finally make logical decision to reach a consensus. Such practice is not only good for graduate students to cultivate critical thinking skill, but also improve their oral communication skill. Both are highly desirable employee characteristics in the future industry working environment.

Finally, each team is also required to articulate their work in a written report which allows students to document design work, review technical design details, analyze and evaluate the whole design process, make the thinking of team members visible, and also draw the final logical conclusions. The instructor needs to provide report feedback through face-to-face discussion. Such practice enhances critical thinking skills of students and also helps improve their writing skills.

4 Usage of computer tools

The usage of computer tools is extremely beneficial for promoting critical thinking among graduate students in the engineering field. Computer tools allow graduate students to model different scenarios for a problem and visualize tangible results. In addition, computer based visualization help students organize information in brain for useful future retrieval. Computer tools make study more interesting for graduate students. As a result, the usage of computer tools can bring strong sense of accomplishment to graduate students, stimulate them to participate in the critical thinking process, allow them to evaluate ideas more objectively, and speed up their problem-solving process.

The activities of using computer tools for teaching need to be well planned to ensure quality instruction, to engage students in course materials, and to facilitate student learning outcomes.

For example, the advanced timing analysis course at CSUS is majorly related to ASIC design. Students are expected to learn industry tools for static timing analysis. The usage of computer tools in this course is based on the simplified ASIC design flow chart shown in Figure 2.

![Figure 2. Simplified ASIC design flow chart](image)

Since the course is about static timing analysis of the ASIC design, physical floor planning, place and route in Figure 2 are not covered by this course.

Typical assignments in this graduate course include following.

1). HDL simulation using Perl and Synopsys VCS simulator tools in step 2 of the above flow chart.

2). Pre-layout and post-layout static timing analysis assignments based on step 7 and step 10 of the above flow chart using Synopsys Design Vision and PrimeTime tools. Students also need to learn how to use TCL tool to write design constraints for static timing analysis.

All of above computer tools are widely used by industry for ASIC design. Consequently, most graduate students feel strongly motivated for study and stimulated to apply critical thinking for design assignments using computer tools.

5 Writing technical paper review

Engineer learning is a life-long process due to the fast development of technology. Although reading technical papers is quite challenging, it is essential for graduate students to develop critical thinking and problem-solving skills in their future career and also their life-long learning.
In advanced timing analysis graduate course, each individual student is required to write a technical paper review regarding digital circuit static timing issues. One IEEE paper titled “Type-Matching Clock Tree for Zero Skew Clock Gating”[10] provided by the instructor is available for graduate students to review. Moreover, each graduate student is also allowed to choose a different technical paper related to the static timing analysis issues based on personal interest.

The writing instruction provided by the instructor is designed to ensure the review writing to serve as a product communicating the result of critical thinking. It requires graduate students to include five parts shown below in their technical paper review.

Part 1 of the technical review writing is instruction part. In this part, graduate students need to clearly identify the major findings of the technical article including major methodology, major concerns, major data collection, major results and so on.

Part 2 is for students to clarify the hypothesis. In this part, graduate students summarize the problem and the proposed solution employed in the technical paper.

Part 3 requires students to collect engineering data by presenting the main figures, schematics, tables, logic diagrams, truth tables, Boolean algebra, logic equations, waveform and state diagram used in the technical paper.

Part 4 asks students to explain the functionality of the engineering data, analyze whether the methods used in the technical paper can apply the engineering data to achieve the design purpose or solve particular problems. Moreover, students are required to evaluate if the technical paper makes any interesting points or controversial points, and also evaluate if the technical paper makes major contributions to new ideas, new experimental methods, new survey and so on.

In Part 5, students need to draw a conclusion about what they have learnt from their reading.

The above technical paper review assignments require graduate students to evaluate other people’s view, provide reasoning to support their thought, and make their ideas explicit. Such exercises motivate graduate students, stimulate their interests in the subject and improve their critical thinking skills. The technical paper review is no longer team based learning, instead it is individual work.

6 Conclusions

Critical thinking strategies in teaching advanced timing analysis course to graduate students in electrical engineering and computer engineering at CSUS are proposed in this paper.

First of all, the proper design of problems to encourage critical thinking among graduate students allows transfer from instructor-centered teaching to student-centered active learning.

Second, team based learning strategy helps organizing critical thinking activities and facilitates achieving conductive student outcomes. This paper presents one unique tutorial-critical thinking practice-feedback loop model applied to team based learning in the engineering education field for critical thinking.

In addition, this paper discusses the usage of computer tools for critical thinking based on course objectives, student learning outcomes, and industry application trend.

Finally, this paper presents how to use writing assignment for technical paper review to enhance critical thinking skill in the engineering field.

In conclusion, critical thinking strategies help engage students in active learning inside classroom, and also prepare students for complex problem solving in their future career as well as in their life-long learning.

7 References


