Use Wrong Examples as a Tool for Teaching

J. Pang\textsuperscript{1}, K. Ah Yun\textsuperscript{2}, and M. Stoner\textsuperscript{2}

\textsuperscript{1}Department of Electrical and Electronic Engineering, California State University, Sacramento, CA, USA
\textsuperscript{2}Department of Communication Studies, California State University, Sacramento, CA, USA

Abstract - Active learning plays an important role for invigorating students in learning. Different active learning strategies have been discussed and implemented in many disciplines. In this paper, we propose using wrong examples as a tool on teaching computer engineering courses. Traditionally, an instructor only passes correct knowledge to students and students are busy with note-taking inside classroom which bounds them in the passive learning mode. Active learning occurs when students have chances to compare the correct solutions with the wrong ones. Looking at course materials from different perspectives allow students to clear the invisible learning barriers, and help them create better knowledge map for brain storage and retrieval. This paper addresses the need for organizing active learning inside class, presents two sources of creating wrong examples, and describes multiple approaches on planning and conducting effective class discussion by using wrong examples.

Keywords: active learning, computer engineering education, wrong examples

1 Introduction

Active learning is to find active learning activities on engaging students in the learning process [1]. How to organize active learning environment in class has been a passionate topic for many educators. Food science nutrition instructors explored active learning in food science teaching. The proposed methods included writing research report, giving presentation, student self-assessment, and so on [2]. In the mathematics field, active learning such as problem solving, small group work, and collaborative learning were encouraged [3]. Other methods such as small group activities “think-pair-share” and quizzes are used for active learning [4] [5]. Most of these methods need careful preparation of teaching materials. In addition, to be able to organize active learning, and at the same time, to be able to cover enough course materials inside classroom is challenging. In this paper, one new method of using wrong examples as a tool for teaching is proposed as an efficient supplement for active learning.

Active learning using wrong examples as a teaching tool has been used by author to teach digital design courses to computer engineering students. The author has observed that when students learn new materials, they may make different implicit assumptions, which are usually incorrect. Providing students with only correct examples is not sufficient for them to clarify their thoughts. Wrong examples provide students with different perspectives for learning new materials. When looking at wrong examples, students have to sharpen their brains and be more engaged in the course materials.

Wrong examples can be collected from two sources. One source is from the instructor who purposely creates some errors in the lecture examples to ask students to identify problems. Another source is from students who may be asked by the instructor to solve some problems in class and they usually make unexpected errors during this process.

This paper looks at the role of wrong examples for teaching engineering course and implementation details of this technique. Part 2 discusses the needs for organizing active learning in class. Part 3 discusses the wrong examples can be provided by instructor based on his or her past teaching experience. Part 4 discusses wrong example source comes from students. Part 5 presents how to plan and conduct an effective class discussion using wrong examples. Part 6 gives the conclusions of this work.

2 Need for organizing active learning

Engineering courses at upper division undergraduate level or graduate level usually require more problem solving and creative thinking skills. Inside classroom, students may feel intimated when facing new complicated information. In the instructor-centered lectures, students usually play passive roles. Sometimes, they are busy in writing down notes and passively accept the knowledge which instructors transfer to them. They may feel bored by memorizing large amount of new facts and become hesitated on thinking. After class, students may have troubles in applying the new knowledge to solve design problems or have to spend a lot of time to figure out solutions. Active learning is needed to motivate and engage students inside classroom.

Although active learning can take many different formats, the implementation approaches need to be designed properly so that it will ease lecture preparation for instructors, and also enable instructors to cover enough materials during class time.
The author of this paper found out many students didn’t learn very well if only correct examples were provided to them inside classroom. On the other hand, wrong examples evoked students’ curiosity to have a deeper understanding of tricky issues. After basic concepts were covered in detail in the beginning of the class, students were asked to use block diagrams, state tables, waveforms and other visualization tools to show solutions to more complicated problems. This approach saved the class time for involving students with more discussions.

Wrong examples may come from two sources: the instructor and students. While the instructor provides wrong examples based on past teaching experience, students add more wrong examples by problem-solving. Students are also asked to use computer tools and digital hardware in lab to work on assignments based on the materials they learn in class. They are required to discuss the problem solving process in their lab reports. Problem-solving in classroom and lab by students make it possible for instructor to identify students’ misunderstanding.

3 Wrong examples given by instructor

Instructors acquire extensive experience after teaching the engineering courses for several semesters. They can summarize the commonly made mistakes.

As one example, hardware description language (HDL) is now being taught and used in the digital design courses [6] [7] in many universities. In Verilog HDL, there are two data types called “reg” and “wire”. Students who have basic logic circuit background may consider “reg” as register by mistake, and “wire” as real physical wire in schematic. Although “wire” is really related to the physical wire, “reg” is not absolutely related to the register. When a signal is used on the left-hand side of any assignment inside the always block, it must be declared as “reg” data type. “reg” can represent either the output of combinational or sequential circuit.

wire a;
wire b;
wire d;
reg c;
assign d = a | b;
always@(a or b)
begin
  c = a & b;
end

The above example describes one AND gate and one OR gate. Students easily understand signal “d” needs to have a wire type because it is the output of the combinational circuit OR gate. But they can easily mistakenly declare signal “c” as “wire” type instead of “reg” type because they think signal “c” is only the output of the combinational circuit AND gate, not the register.

It is useful for instructor to provide wrong examples below to emphasize the difference between data types and real hardware.

Table 1: Wrong examples on using “reg” and “wire” data types

<table>
<thead>
<tr>
<th>Example 1:</th>
<th>Example 2:</th>
</tr>
</thead>
<tbody>
<tr>
<td>wire a;</td>
<td>wire a;</td>
</tr>
<tr>
<td>Wire b;</td>
<td>wire b;</td>
</tr>
<tr>
<td>wire c;</td>
<td>reg d;</td>
</tr>
<tr>
<td>always@(a or b)</td>
<td>assign d = a</td>
</tr>
<tr>
<td>c = a &amp; b;</td>
<td></td>
</tr>
</tbody>
</table>

In table 1, the signal c in example 1 should be declared as “reg” data type because its value is assigned inside the always block. The signal d in example 2 should be declared as “wire” data type.

Figure 1 shows another example of the algorithmic state machine (ASM) chart.

![ASM chart](image)

Table 1 shows the correct and wrong solutions to the above ASM chart problem.

Table 2: Wrong and correct examples of ASM design

<table>
<thead>
<tr>
<th>Example 3: // Correct design</th>
<th>Example 4: // Wrong design</th>
</tr>
</thead>
<tbody>
<tr>
<td>module asm_1 (reset, clk, w, y);</td>
<td>module asm_2 (reset, clk, w, y);</td>
</tr>
<tr>
<td>input reset;</td>
<td>input reset;</td>
</tr>
<tr>
<td>input clk;</td>
<td>input clk;</td>
</tr>
<tr>
<td>input w;</td>
<td>input w;</td>
</tr>
<tr>
<td>output y;</td>
<td>output y;</td>
</tr>
</tbody>
</table>
4 Wrong examples come from students’ problem solving

Sometimes, students have wrong understanding of the materials delivered inside classroom.

For example, in order to test a design module, the instructor first explained the definition and functionality of a testbench. Testbench is used to instantiate a design under test (DUT), create stimulus to the DUT, and observe the design outputs. The stimulus signals generated inside one initial block are applied sequentially to the DUT. After the instructor explained what the testbench was, students were asked to solve another design testbench problem using the given testing vector sequence.

Testing vectors:

<table>
<thead>
<tr>
<th>Time (ns)</th>
<th>a</th>
<th>b</th>
<th>ci</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>70</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3: Wrong testbench solution

```module wrong;
reg a;
reg b;
reg ci;
wire dout1;
wire dout2;
initial begin
    a = 0;
b = 0;
ci = 0;
#10 ci = 1;
#10 b = 1;
#10 b = 1; ci = 1;
#10 a = 1;
#10 a = 1; b = 1;
#10 a = 1; b = 1; ci = 1;
end
design g1 (dout1, dout2, a, b, ci);
endmodule```

Unexpectedly, some students thought they should only assign value 1s to signals, and those signals which didn’t get value assignments would automatically have logic value 0s. Actually this is wrong. If one signal does not get new value assignment, it will keep the previous value. After one student showed this wrong solution on board inside classroom, the instructor pointed out errors and provided the corrected testbench shown in table 4. This exercise helped students in the whole class clarify the main concepts of testbench.

In figure 1, the output signal y has logic value ‘1’ only in state C. The correct design is to make sure y=1 in state C, and y=0 in other states. The wrong design only assigns value 1 to the signal y in state C, but does not assign any value to signal y in other states. This is one common mistake students make. Missing output signal value assignment in any state will create harmful latch. The wrong example helps students to clarify this important concept.
Table 4: Corrected testbench

```verilog
module correct;
reg a;
reg b;
reg ci;
wire dout1;
wire dout2;
initial begin
a = 0;
b = 0;
ci = 0;
#10 ci = 1;
#10 b = 1; ci = 0;
#10 b = 1; ci = 1;
#10 a = 1;
b = 0; ci = 0;
#10 ci = 1;
#10 b = 1; ci = 0;
#10 b = 1; ci = 1;
end

design g1 (dout1, dout2, a, b, ci);
endmodule
```

The instructor conducted student surveys to get assessment on the method of using wrong examples as a tool for teaching. Students thought wrong examples would give them better understanding of course materials, help them memorize information more accurately, and help them with better information retrieval.

5 Plan and conduct effective class discussion

Useful strategies can be taken by instructors to plan and conduct class discussions more effectively when using wrong examples as a tool for teaching.

a) Give students some correct examples to follow before showing wrong examples or asking students to work on in-class exercises.

Some students are unwilling to actively think of problem solutions if they feel the questions are too hard. In the beginning, the instructor should not give too hard problems to students to discourage them from participating in the class active learning activities. The instructor should guide students to follow several steps to solve hard problems. So the instructor should provide the basic correct examples which are necessary for students to get familiar with the subject.

b) Give students enough time to think about challenging problems after class and ask them to bring the solutions back for in class discussion.

When collecting wrong examples from students, the instructor should consider using the class time efficiently. If one challenging problem needs a lot of time for students to solve, the instructor should ask students to solve it after class and bring the answer back for discussion in class. The instructor should also encourage students to use the block diagram, waveforms, the state table and the other visualization tools to present their results and save the class discussion time.

c) Leave some problem-solving topics to lab assignments. This allow students to use lab equipment to figure out solutions, ask students to discuss the problems they have, the mistakes they make and the procedure of how they solve their problems in their lab reports.

The instructor can assign some problems as lab exercises. Students apply the knowledge they have learnt from lectures on some general problems and on solving problems with the real-world applications. In the lab environment, students can use computer tools, and testing equipment such as logic analyzers to test and verify their designs and to analyze their problems.

d) Organize in class PowerPoint presentations of student lab projects.

For small size class, individual presentation can be conducted. For large size class, group projects can be selected and presented.

6 Conclusions

Using wrong examples as a tool for teaching helps students actively engage with the teaching material. The goal of this approach is to expose commonly made problems to all students to avoid making similar mistakes. It looks at the course materials from different perspectives. Comparison between correct answers and wrong solutions helps students broaden their views, develop critical thinking, improve their understanding of course materials, and help information storage and retrieval. Wrong examples can come from instructors and students. Useful strategies are presented for planning and conducting class discussion effectively.

7 References


