Measuring the Impact of Adaptive Learning Modules in Digital Logic Courses

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Overview

The purpose of this project is to **develop and test a set of adaptive learning course materials to address background deficiencies in computer engineering.** The interventions proposed will target a sequence of introductory digital logic courses that are found in every ABET accredited computer engineering program.

Motivation

Can an adaptive, e-learning environment that provides personalized instruction improve student understanding of computer engineering?

Student Interest – Students lose interest when course material is *either* too hard **or** too easy.

Background Deficiencies - Students often lack the necessary prerequisite knowledge in introductory engineering courses due to their varied backgrounds and different high school curricula.

Large Entry-Level Courses – The sheer number of students in introductory courses prevents teachers from providing personalized instruction.

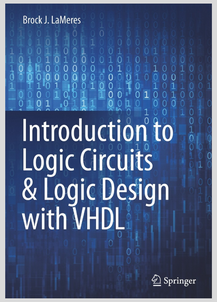
Remote Delivery – Online instruction often lacks the instructor interaction that can be provided in a live offering.

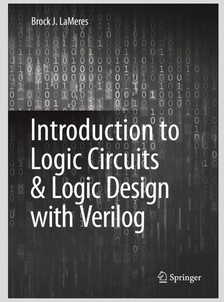
Project Plan

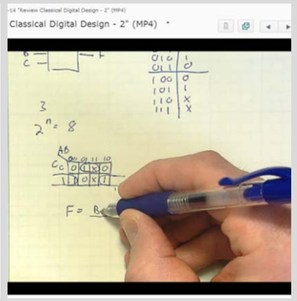
1) Create introductory-level logic circuits curriculum.
2) Analyze baseline level of understanding and identify sections suitable for adaptive learning.
3) Develop and test impact of adaptive learning.
4) Refine modules based on mixed-method data.

1) Digital Logic Curriculum

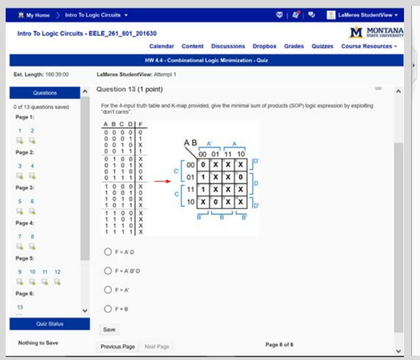
Delivery – Two new textbooks + >100 instructional videos.

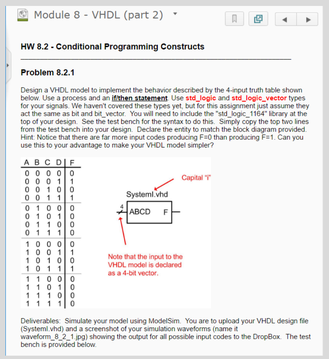




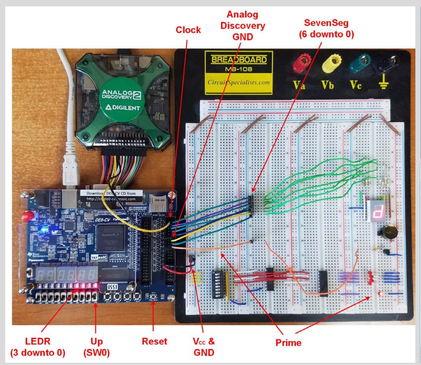


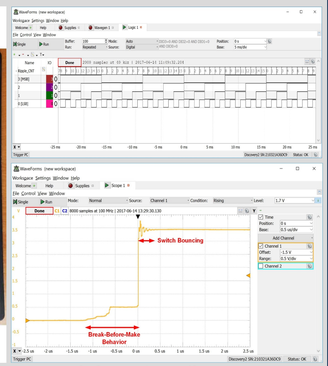
Assessment – 600+ multiple choice & VHDL design problems.





Laboratory Experience – Fully portable lab kit provides hands-on experience with both classical and modern (HDL) design.

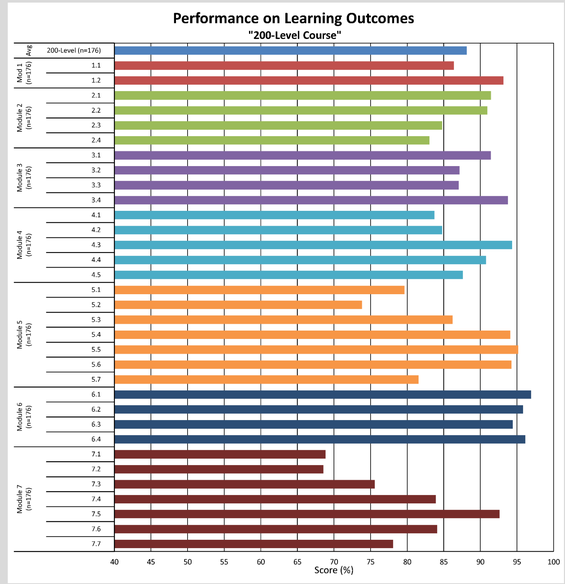




Based on Analog Discovery 2, Terasic DE0-CV FPGA Board, & 74HC Family Parts

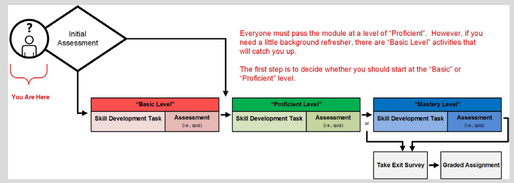
2) Baseline Understanding

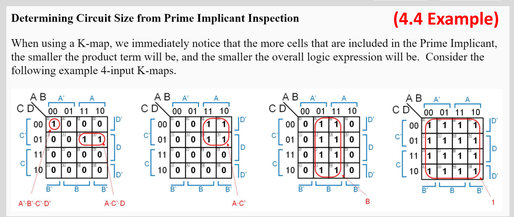
Learning Objective	Learning Outcome
The overall learning goal of this module is to:	*After completing this module, a student will be able to:*
Module 1: To understand the basic principles of analog and digital systems.	**1.1:** Describe the fundamental differences between analog and digital systems.
	1.2: Describe advantages of digital systems compared to analog systems.
Module 2: To understand the basic principles of binary number systems.	**2.1:** Describe the formation and use of positional number systems.
	2.2: Convert numbers between different bases.
	2.3: Perform binary addition and subtraction by hand.
	2.4: Use two's complement numbers to represent negative numbers.
Module 3: To understand the basic electrical operation of digital circuits.	**3.1:** Describe the functional operation of a basic logic gate using truth tables, logic expressions, and logic waveforms.
	3.2: Analyze the DC and AC behavior of a digital circuit to verify it is operating within specification.
	3.3: Describe the meaning of a logic family and the operation of the most common technologies used today.
	3.4: Determine the operating conditions of a logic circuit when driving various types of loads.
Module 4: To understand the basic principles of combinational logic design.	**4.1:** Describe the fundamental principles and theorems of Boolean algebra.
	4.2: Analyze a combinational logic circuit to determine its logic expression, truth table, and timing information.
	4.3: Synthesis a logic circuit in canonical form (Sum of Products or Product of Sums) from a functional description.
	4.4: Synthesize a logic circuit in minimized form (Sum of Products or Product of Sums).
	4.5: Describe the causes of timing hazards in digital logic circuits and the approaches to mitigate them.
Module 5: To understand the basic principles of hardware description languages.	**5.1:** Describe the role of hardware description languages in modern digital design.
	5.2: Describe the fundamentals of design abstraction in modern digital design.
	5.3: Describe the modern digital design flow based on hardware description languages.
	5.4: Describe the fundamental constructs of VHDL.
	5.5: Design a VHDL model for a combinational logic circuit using concurrent modeling techniques.
	5.6: Design a VHDL model for a combinational logic circuit using a structural design approach.
	5.7: Describe the role of a VHDL test bench.
Module 6: To understand the basic principles of medium scale integrated circuit logic.	**6.1:** Design a decoder circuit using both the classical digital design approach and the modern HDL-based approach.
	6.2: Design an encoder circuit using both the classical digital design approach and the modern HDL-based approach.
	6.3: Design a multiplexer circuit using both the classical digital design approach and the modern HDL-based approach.
	6.4: Design a demultiplexer circuit using both the classical digital design approach and the modern HDL-based approach.
Module 7: To understand the basic operation of sequential logic circuits.	**7.1:** Describe the operation of a sequential logic storage device.
	7.2: Describe sequential logic timing considerations.
	7.3: Design a variety of common circuits based on sequential storage devices.
	7.4: Design a finite state machine using the classical digital design approach.
	7.5: Design a counter using the classical digital design approach and using an HDL-based, structural approach.
	7.6: Describe the finite state machine reset condition.
	7.7: Analyze a finite state machine to determine its functional operation and maximum clock frequency.



3) Adaptive Learning Modules

- Learning outcomes 4.4 (Logic Minimization) and 5.5 (VHDL Concurrent Signal Assignments) were selected for intervention due to high-level of student confusion observed by instructors.
- Modules pilot tested in fall-16, spring-17, and summer-17 on students from three universities . Performance on subsequent homework was measured and focus groups were conducted.





Conclusion

- A significant improvement in the associated homework score was observed for students with GPAs between 2.5-3.0. This confirms adaptive learning can help with background deficiencies.
- Majority of results were damped by ceiling effect, so it isn't clear if modules are impacting mastery.
- Focus groups revealed students wanted modules to be optional, multi-mode (both text & video), and are not necessary for every section.
- A module for section 7.4 is necessary.

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