A Comparison of Hands-On versus Remote Laboratory Experience for Introductory Microprocessors Courses

Dr. Brock J. LaMeres
Assistant Professor
Electrical & Computer Engineering Dept
Montana State University - Bozeman

Dr. Carolyn Plumb
Director of Educational Innovation
College of Engineering
Montana State University - Bozeman

Overview

MONTANA STATE UNIVERSITY | College of ENGINEERING

- The Research Questions:

For the laboratory component of an introductory microprocessors course, can the level of student understanding:

> ***1) be <u>improved</u> by adding measurement using logic analyzers?***
>
> ***2) be <u>improved or maintained</u> when conducting the lab experiments fully online?***

- Project Relevance:

To improve student understanding of a core subject within all EE & CpE undergraduate curriculums.

The lab experience in engineering courses presents one of the larger barriers to offering fully online engineering education. Proving the level of understanding can be maintained when offering a lab online provides a model for deploying online education of embedded systems courses.

A method of collecting assessment data that can be deployed on other topics.

Overview

- The Experiment:

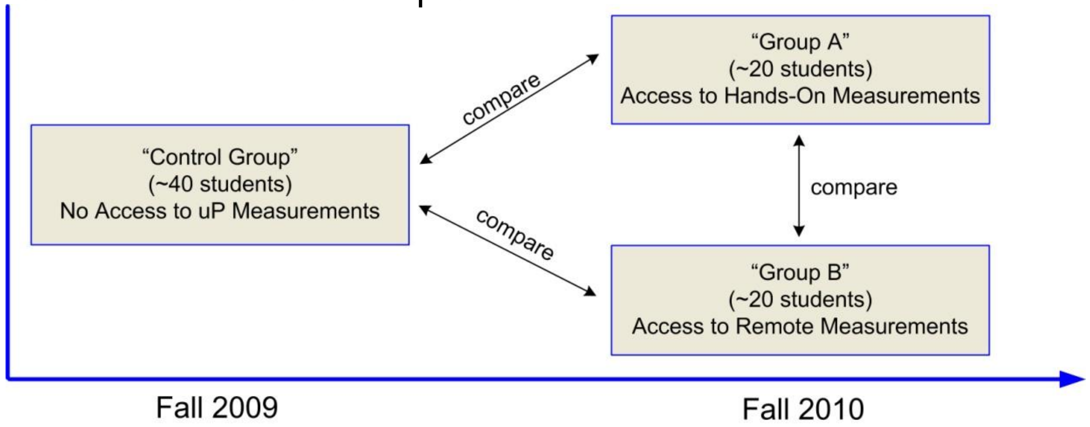
1) Develop a set of assessment tools to collect data on student understanding on 5 learning objectives.

2) Collect assessment data on a control group (Fall 2009) that conducts its lab exercises using the traditional, hand-on, non-measurement based approach.

3) Augment the existing labs:

- to include a measurement component using logic analyzers
- so that they can be completed fully online (including performing the measurements)

4) Collect assessment data on two experiments groups (Fall 2010) to see if student understanding of the 5 learning objectives was maintained or improved.



Assessment Tool Development

- Our Learning Objectives

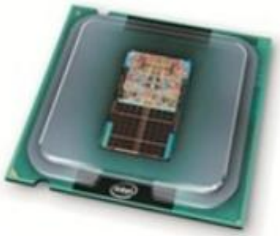
1) Describe the basic architecture of a stored-program computer;

2) Describe the addressing modes of a microprocessor;

3) Describe a typical I/O interface and understand its timing;

4) Analyze a timing diagram of the interaction between the microprocessor and memory;

5) Synthesize a timing diagram of a given READ/WRITE cycle between the microprocessor and memory.



Assessment Tool Development

- We developed three types of assessment tools

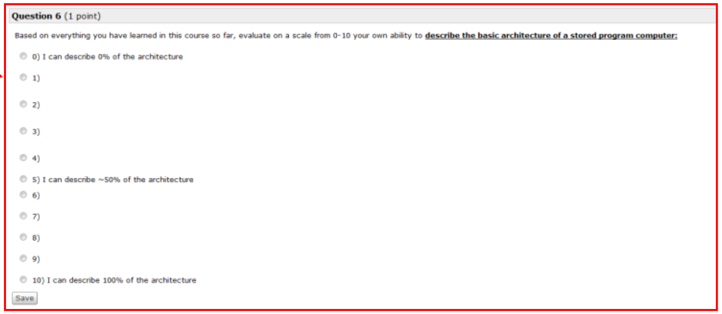
1) Self Evaluation Surveys (pre/post key labs)

- students were asked about their own knowledge about the objective topics before and after conducting the labs in which interventions were introduced.

- a 0-10 scale was used where (0 is no knowledge, 10 is proficient)

- scores were collected using an auto-graded quiz within the Desire2Learn system.

Survey Question	Objective
Based on everything you have learned in this course so far, evaluate on a scale from 0-10 your own ability to describe the basic architecture of a stored program computer:	1
Based on everything you have learned in this course so far, evaluate on a scale from 0-10 your own ability to describe the addressing modes used in a microprocessor:	2
Based on everything you have learned in this course so far, evaluate on a scale from 0-10 your own ability to describe the functional operation and timing dependencies of a microprocessor I/O interface:	3
Based on everything you have learned in this course so far, evaluate on a scale from 0-10 your own ability to analyze a timing diagram of the interaction between a microprocessor & memory:	4
Based on everything you have learned in this course so far, evaluate on a scale from 0-10 your own ability to synthesize a timing diagram of the interaction between a microprocessor & memory:	5


Question 6 (1 point)

Based on everything you have learned in this course so far, evaluate on a scale from 0-10 your own ability to **describe the basic architecture of a stored program computer:**

0) I can describe 0% of the architecture
1)
2)
3)
4)
5) I can describe ~50% of the architecture
6)
7)
8)
9)
10) I can describe 100% of the architecture

Save

Assessment Tool Development

2) Weighted Multiple Choice

- Multiple choice questions were developed that had answers with varying levels of *correctness*.

- This allowed a more accurate numeric indication of the level of understanding compared to an all-right, all-wrong response.

<u>Multiple Choice Question Example (Objective #1)</u>

Which of the following most completely describes the function of the stack in a microcontroller?

A The stack is in ROM and is used to access constant data used in your programs.
(0 points)

B The stack is in RAM and is used to store temporary variable data and subroutine return addresses using indexed addressing modes.
(1 points)

C The stack allows you to have nested subroutines in your programs.
(2 points)

D The stack is used to store registers but you have to initialize the stack pointer register first.
(3 points)

E The stack is in RAM and is used to store temporary variable data and subroutine return addresses.
(5 points)

- answers were randomized for each student taking the quiz.

Assessment Tool Development

MONTANA STATE UNIVERSITY | College of ENGINEERING

3) Short Answer Questions Graded with a Weighted Rubric

- Students entered <150 word responses to short answer questions.

- A grading rubric was developed that allowed a consistent scoring approach.

- A grading *calibration* session was held with TA's, the instructor, and various grad students in order to provide the graders with guidance on how to assign scores.

Short Answer Question Example (Objective #2)

Why would you use indexed addressing to find data in a table rather than some other addressing mode, such as direct addressing?

Full credit (3 points)
Indexed addressing allows the program to step through a table of data in a loop because instructions exist to increment or decrement the index register. The effective address of an indexed register is the contents of the register plus a constant, fixed offset. Thus in a loop one can step through a table and compare the known against its look-up value. Direct addressing, on the other hand, is an addressing mode that directly addresses a single memory location each time it is executed. The effective address cannot be changed by the program. To use direct addressing one would have to write a program that separately addressed each location in the look-up table.

Partial credit (2 points)
The effective address of the indexed addressing instruction can be changed in the loop where a direct address instruction cannot.

Partial credit (1 point)
Indexed addressing is easier to use than direct addressing.

No credit (0 point)
"None of the elements of a correct answer listed above are present"

Assessment Tool Development

- These tools were used across 5 laboratories that focused on the learning objectives.

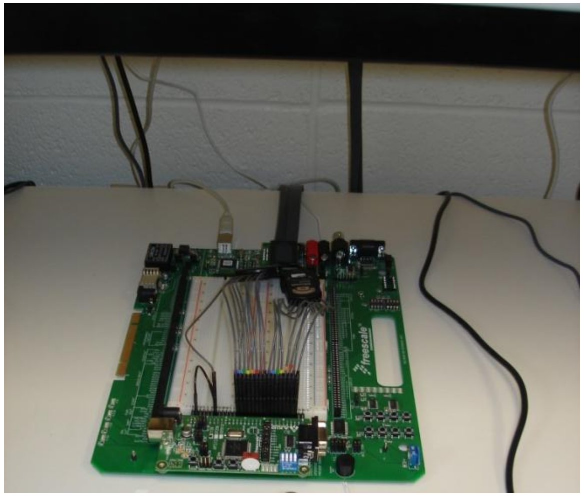
  - there were 11 labs in this course
  - 7 labs (3-9) pertained to the 5 learning objectives in this study
  - pre/post surveys were given in labs 3 and 9

- A total of 43 measures were used to collect data

Laboratory Experiment	Outcome(s)	Assessment Tool(s)
1 – Introduction to uP HW/SW	-	-
2 – LED Parallel I/O	-	-
3 – Addressing Modes	1,2,3,4,5	Self Evaluation Pre-Survey
4 – Addressing Tables	2	1 Multiple Choice (MC) 1 Short Answer (SA)
5 – Addressing the STACK	1 2	4 Multiple Choice (MC) 2 Short Answer (SA) 2 Multiple Choice (MC)
6 – Reading/Writing External I/O	2 3	1 Multiple Choice (MC) 1 Short Answer (SA) 6 Multiple Choice (MC) 1 Short Answer (SA)
7 – External Interrupts	3 5	1 Multiple Choice (MC) 2 Short Answer (SA) 5 Multiple Choice (MC)
8 – Multiple Interrupts	4 5	2 Multiple Choice (MC) 2 Short Answer (SA) 2 Short Answer (SA)
9 - Timers	1, 2, 3, 4, 5	Self Evaluation Post-Survey
10 - Timers	-	-
11 – A/D Converter	-	-

Lab Setup

- This courses uses the FreeScale HCS12 microcontroller on a student evaluation board



- Students use the *CodeWarrior Development Environment* to program the processor

  - students program in assembly

- A Tektronix TLA5210 Logic Analyzer was used to observe signals on the eval board

  - the probes were connected by the instructor and NOT moved during the lab.

Lab Setup

MONTANA STATE UNIVERSITY | College of ENGINEERING

- The logic analyzer enabled conducting the labs remotely.

  - The logic analyzer is a Windows XP system.

  - CodeWarrior was installed on the logic analyzer

  - Student used Windows *Remote Desktop Connection* to remotely log onto the instrument.

  - The instrument was connected to the eval board through a USB cable for programming

  - The analyzer's probes were connected to the eval board to provide measurement capability.

  - A web cam could be used to observe LEDs on the eval board.

Lab Setup

- The logic analyzer enabled conducting the entire lab remotely.

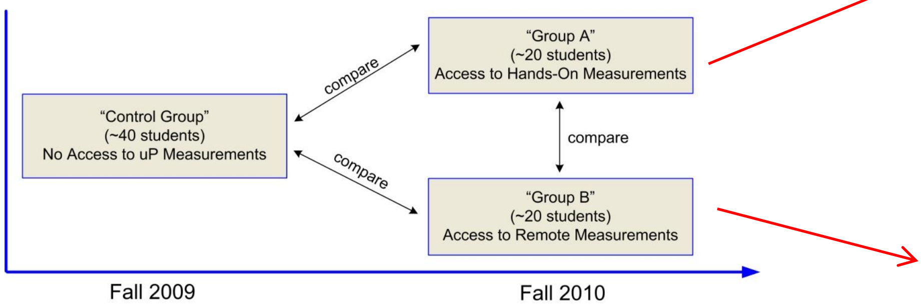
  - A set of 4 remote golden (& quarantined) lab stations were created.
  - Students could log into the stations from any other windows box & perform the lab.
  - Most students (90% conducted the experiments in the lab to get assistance from the TA
  - Some students (~10%) conducted the experiments at home or at other locations on campus
  - Students were not required to be in the lab, the chose where to conduct the labs.

Lab Setup

- The Fall 2010 class was divided into two groups

  1) Students working in the lab using the logic analyzer right in front of them (hands-on)
  2) Students accessing the remote stations from elsewhere (online)

- Both groups performed the exact same lab experiments



Lab Setup

- Seven labs focused on our five learning objectives

  Lab 3 – Addressing Modes

  Lab 4 – HEX to ASCII

  Lab 5 – Addressing the STACK

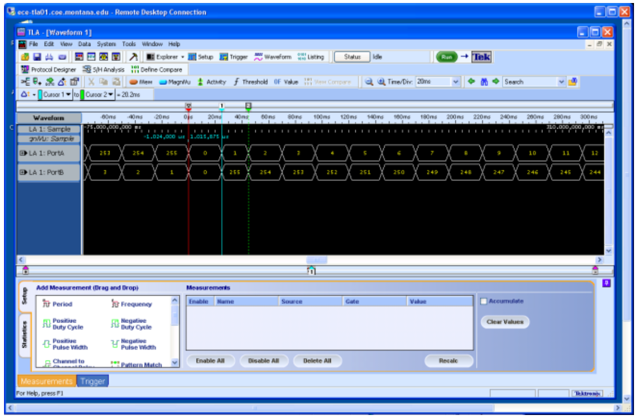
  Lab 6 – Reading and Writing External IO

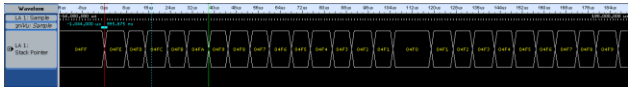
  Lab 7 – Instruction Speed & External IO

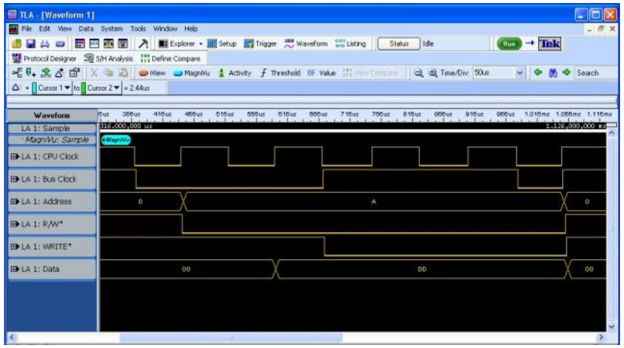
  Lab 8 – Interrupts

  Lab 9 - Multiple Interrupts

- Each lab contained a measurement component







Outcome Results (Survey)

- We performed an ANCOVA analysis on the post survey responses using the pre survey data as the covariant.
- The ANCOVA showed no significant differences among the three groups on the post survey responses that could be attributed to the group.
- For all 5 post survey questions, the differences among the three groups were predicted by the initial responses.

What does this mean?

- Our sample might have been too small (specifically the remote group) to find a significant difference.

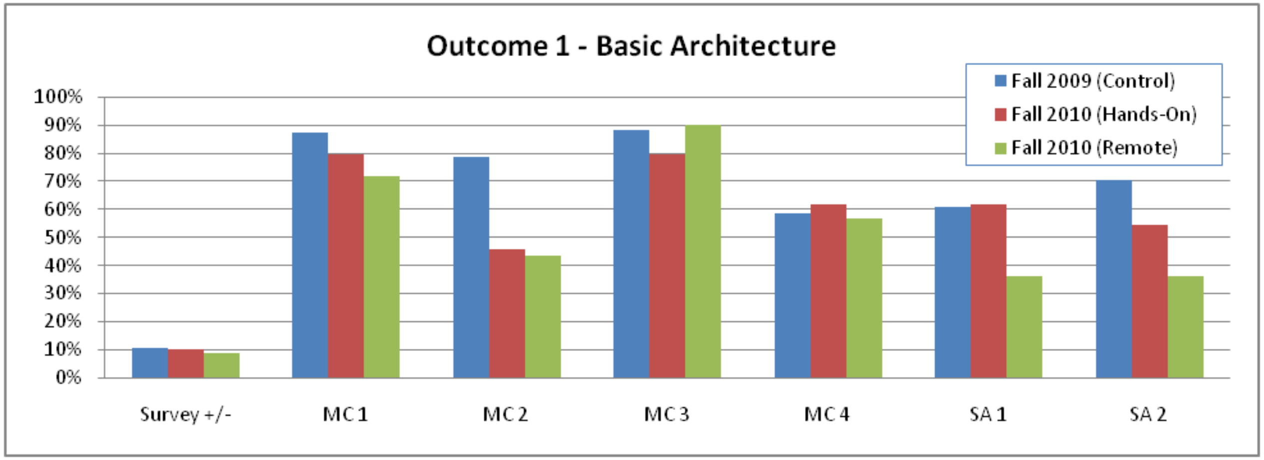
- The two experimental groups **did not** perceive greater learning that the control.

- The remote group **did perceive** the same level of learning as the other groups.

Outcome Results

MONTANA STATE UNIVERSITY | College of ENGINEERING

- Outcome #1: Describe the basic architecture of a stored program computer

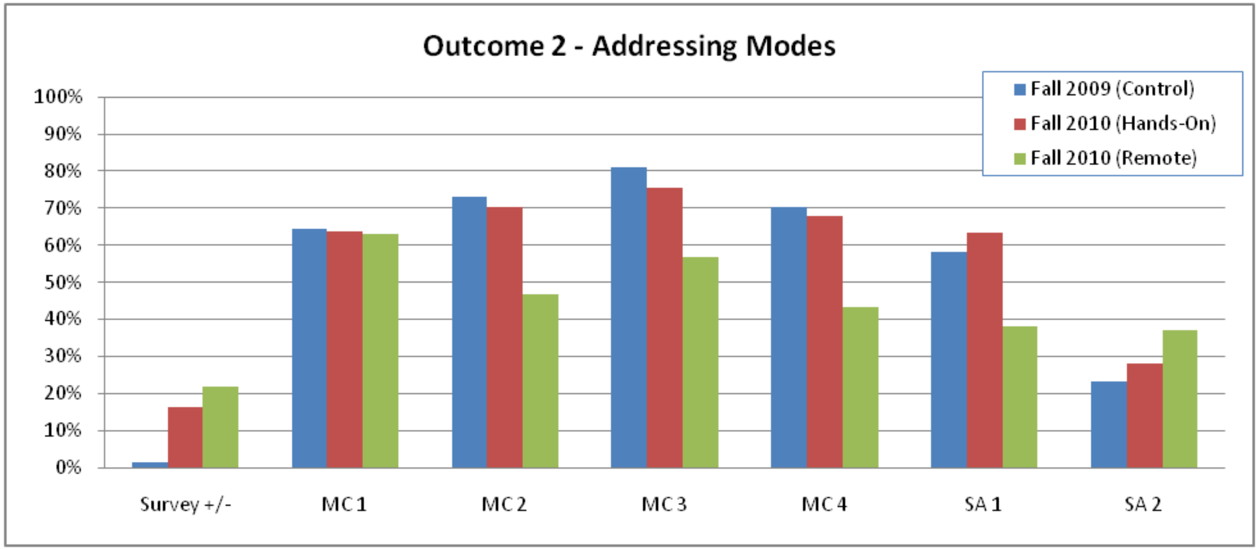


	Control	Hands-On	Online
Self Evaluation Survey (post-pre)	10.5%	10.2%	8.8%
Average MC/SA Scores	74.1%	63.8	55.7%

- There was **slight decrease** in the hands-on group MC/SA scores.
- There was a **notable decrease** in the remote group MC/SA scores.

Outcome Results

- Outcome #2: Describe the addressing modes of a computer



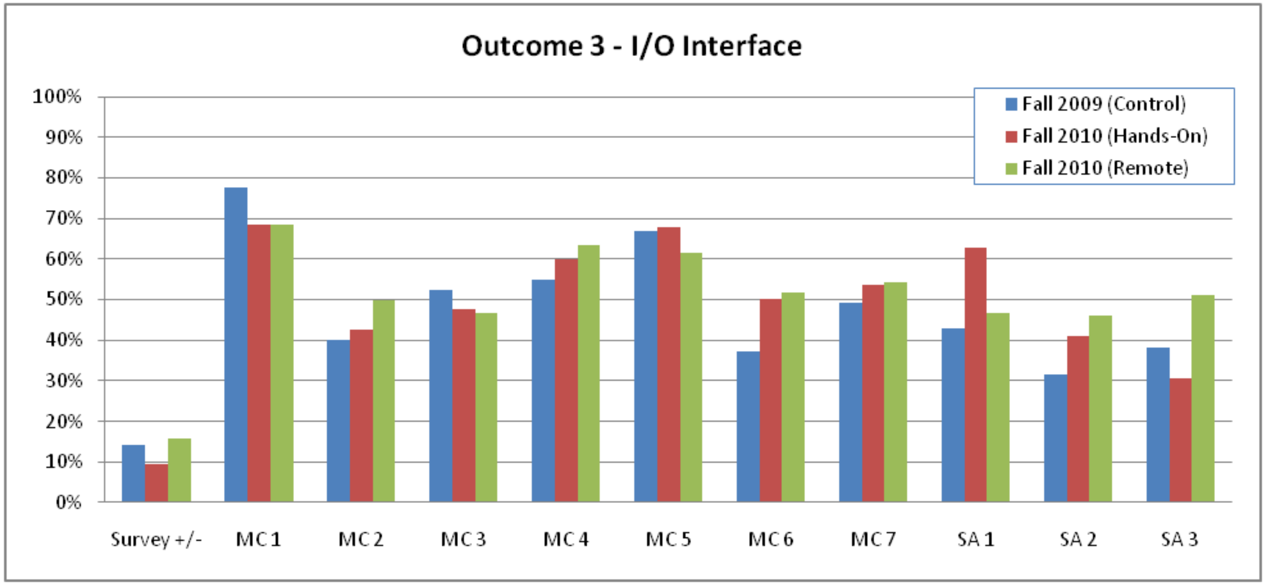
	Control	Hands-On	Online
Self Evaluation Survey (post-pre)	1.3%	16.3%	22.0%
Average MC/SA Scores	61.8%	61.5%	47.4%

- There was **little difference** in the hands-on group MC/SA scores.
- There was a **slight decrease** in the remote group MC/SA scores.

Outcome Results

MONTANA STATE UNIVERSITY | College of ENGINEERING

- Outcome #3: Describe a typical IO interface and describe its timing

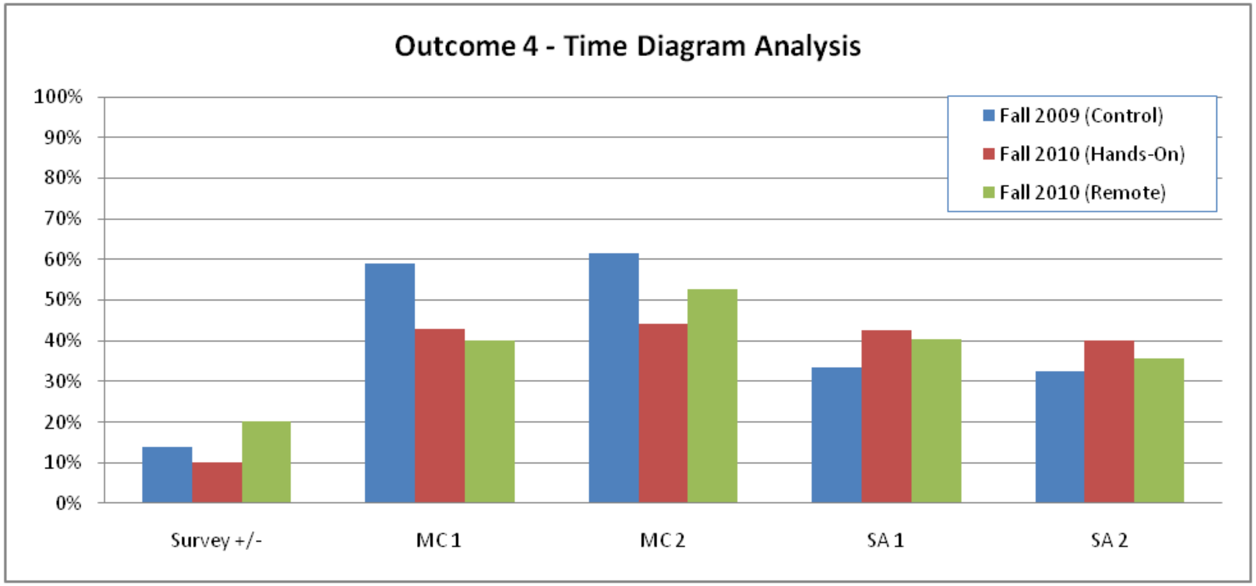


	Control	Hands-On	Online
Self Evaluation Survey (post-pre)	14.2%	9.3%	16.0%
Average MC/SA Scores	49.1%	52.5%	54.0%

- There was **little difference** in the hands-on group MC/SA scores.
- There was a **little difference** in the remote group MC/SA scores.

Outcome Results

- Outcome #4: Analyze a timing diagram of the uP to memory interface of a computer

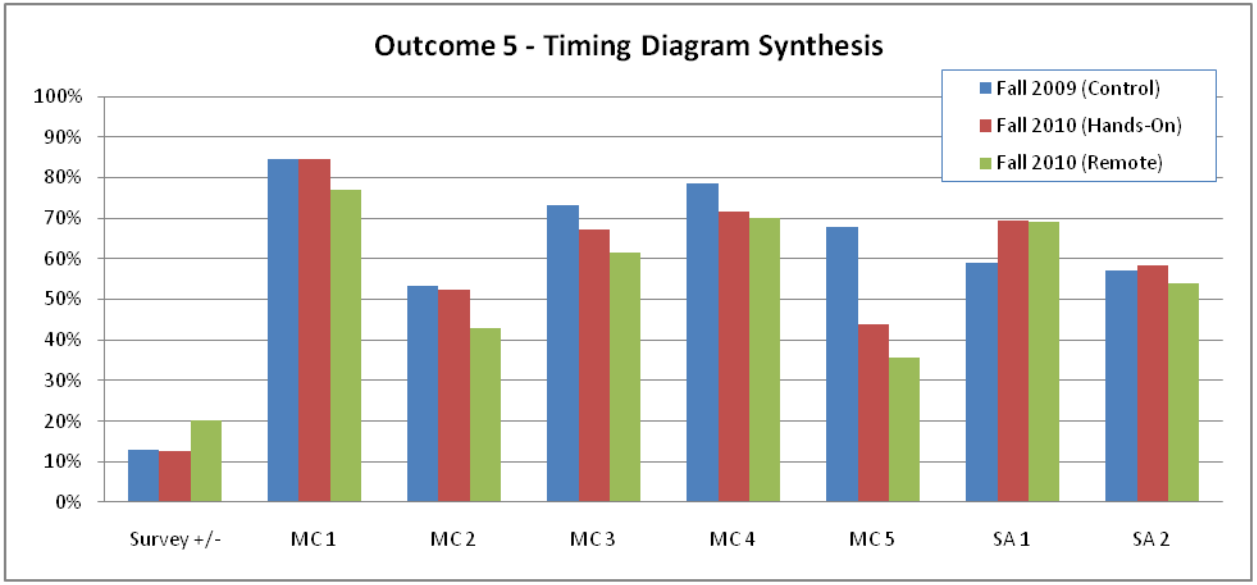


	Control	Hands-On	Online
Self Evaluation Survey (post-pre)	13.9%	10.2%	20.0%
Average MC/SA Scores	46.6%	42.5%	42.3%

- There was **little difference** in the hands-on group MC/SA scores.
- There was a **little difference** in the remote group MC/SA scores.

Outcome Results

- Outcome #5: Synthesize a timing diagram of the uP to memory interface of a computer



	Control	Hands-On	Online
Self Evaluation Survey (post-pre)	13.0%	12.6%	20.3%
Average MC/SA Scores	67.7%	63.9%	58.6%

- There was **little difference** in the hands-on group MC/SA scores.
- There was a **little difference** in the remote group MC/SA scores.

Outcome Results

- In general, there was not a significant statistical difference in perception of learning between the control and the two experiments groups across all 5 learning objectives.
- There was a slight improvement when using measurement (hands-on and remote) on objectives that required visualization in the MC & SA assessment tools.
- There was no notable difference between the hands-on and online groups.
- **How is this data meaningful?**

  - Digital concepts requiring visualization can be improved using measurement. This could be extended to other digital courses in addition to microprocessor architecture.

  - Lab components of digital courses have the potential to be offered remotely without significantly degrading the understanding of key topics.

MONTANA STATE UNIVERSITY | College of ENGINEERING

Questions ?