

“Flipping the Classroom” in an Introductory IT Course

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UPPSALA
UNIVERSITET



Swedish Institute of
Computer Science

MOTIVATION

Active learning

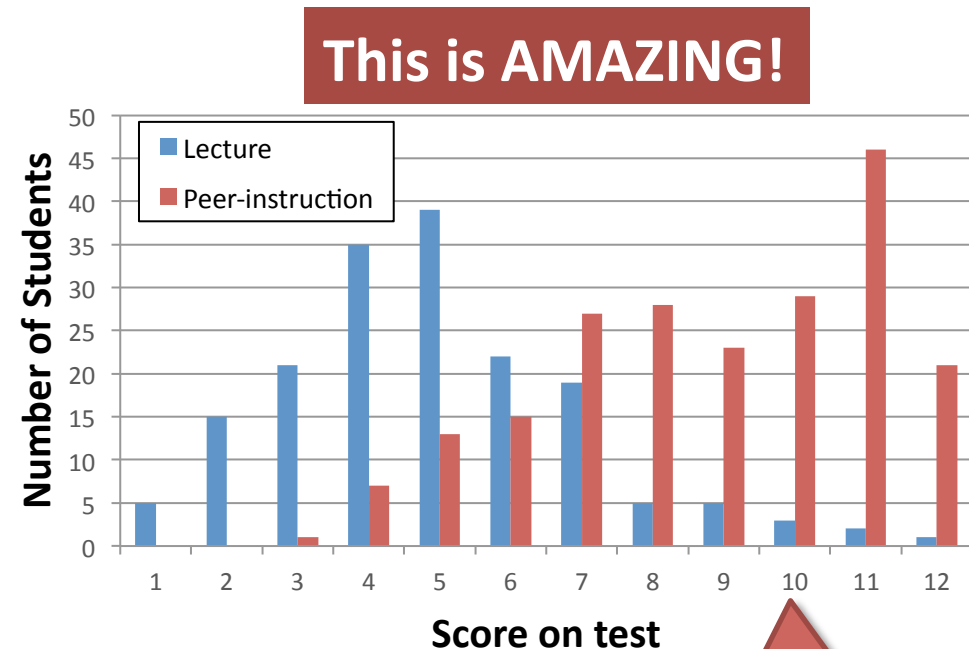
Lous Deslauriers, et al. (2011)

Experiment:

- **538 students** in a quantum mechanics class

For 1 week:

- ½ received 3 hours of **lectures** from an experienced teacher
- ½ received 3 hours of **peer-instruction**

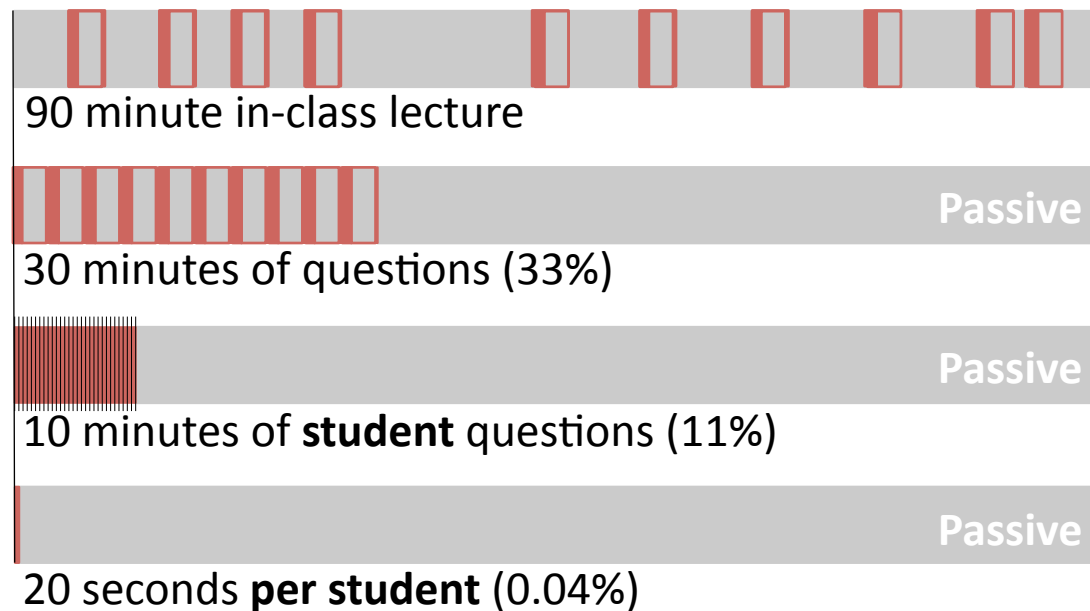


+20% attendance
+40% engagement

Peer-instruction was
2.5 std. dev. better!

Data reproduced from Louis Deslauriers, et al. "Improved Learning in a Large-Enrollment Physics Class." *Science* 332, 862 (2011).

How active are my lectures?



Ten 3-minute
questions

1 minute student
2 minutes teacher

30 students
in the class

30 minutes answering questions → **99.6% passive** for students

Technology inspiration



23,000 students pass Stanford's artificial intelligence course at the same time.

Sebastian Thrun

Udacity/Stanford University, 2011

Sebastian finally got **online** education right:

- **Interactive** online lectures
- **Top-quality** instructors

I want to use this technology to do better **in-class** teaching.

FLIPPING THE CLASSROOM

Flipping the Classroom

	At Home	In-Class	
Traditional Lectures	<div>Solve Problems Active Alone</div>	<div>Listen to Lecture Passive With Teacher</div>	Wasting a great resource
Flipped Classroom	<div>Listen to Lecture Passive Alone</div>	<div>Solve Problems Active With Teacher</div>	Much better use of the teacher
Flipped Classroom + Technology	<div>Interactive Lecture Active Alone</div>	<div>Solve Problems Active With Teacher With Peers</div>	Ultimate goal: Fully active, Peer teaching

What is an “Interactive Lecture”?

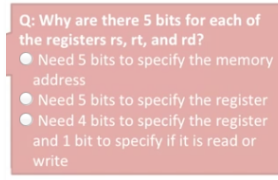
Short lecture segments + self-assessment quizzes

Video



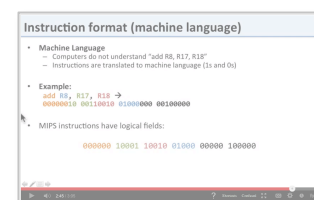
5-10 minutes

Quiz



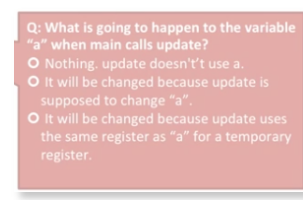
1-2 questions

Video



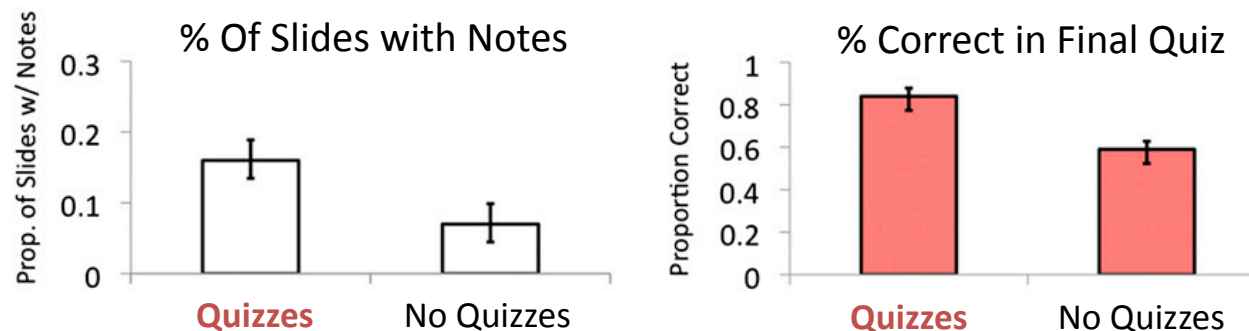
5-10 minutes

Quiz



1-2 questions

Do interactive lectures help learning?



- **2x increase** in notes
- **20% better** learning
- **50% decrease** in mind wandering

K. Szpunar, et. al. “Interpolated memory tests reduce mind wandering and improve learning of online lectures.” PNAS, vol. 110, no. 16. 2013.

Flipping the Classroom

Goals:

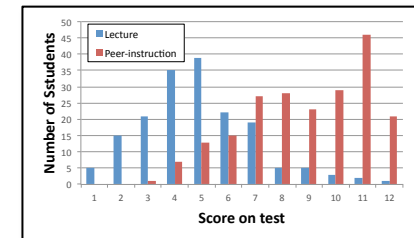
- Use the **teacher time to help teach**, not read the book
- Maximize **interactive learning** time

Not a new idea:

- Eric Mazur peer instruction (Harvard, 1990s)
- J. Wesley Baker 2000: “sage on the stage” → “guide on the side”
- Khan Academy

“Hybrid” or “Blended” learning:

- Combine the **best of online and in-class**
- Use information from online lectures to direct in-class learning



What Do I Do?

At home

- Online **lectures** before class
(Short 5-10 minute video segments)
- 10-20 self-assessment **quizzes**

In-class

- **Review** self-assessment quizzes
- Answer **questions** from online lectures
- Peer practice **problems** in small groups

Demo from an Uppsala course

(Platform is a joint development project with the Swedish Institute for Computer Science.)

MAKING LECTURES INTERACTIVE

Making lectures interactive

1. Divide into 5-10 minute chunks

The grid displays 42 thumbnails of lecture slides, numbered 1 to 42. The slides cover topics such as:

- Instruction Set Architecture 2
- Contents
- Review: instructions
- Review: execution
- Instruction format (machine language)
- Instruction fields
- Question: number of bits
- Constants (immediates)
- MIPS instruction formats
- Sign extension
- Loading immediate values (constants)
- Addresses in branches and jumps
- Jump address examples: loops
- What kind of branches are in programs?
- Loading larger values
- Summary: machine code and immediates
- Procedure calls
- Procedure call terminology
- How to do a procedure call
- Jump-and-link
- Procedure call in detail
- Problem: argument registers
- Problem: result registers
- Problem: temporary registers
- The real problem: lack of coordination
- MIPS register conventions
- MIPS register convention details
- MIPS register names and conventions
- Fixing up the example (arguments/results)
- Fixed register/arguments
- Saving and restoring registers
- Saving registers on the stack
- Who saves what?
- Nested calls
- Example 1: saving registers
- Calling saving registers in detail
- More convenient names for registers
- Example 2: which registers to save?
- Example 2: saving to the stack
- Example 2: what not to save
- Example 2 in detail
- Summary: procedure calls

Making lectures interactive

The screenshot displays a presentation interface with 15 slides. The slides are organized into sections, each indicated by a small icon and a title:

- Section 1: Translation to machine code (3)**
 - Slide 1: Title slide 'Instruction Set Architecture 2'.
 - Slide 2: 'Contents' slide listing topics like 'Translation to machine code', 'Procedures', and 'Other bits'.
 - Slide 3: 'Review: instructions' slide showing a table of instructions.
 - Slide 4: 'Review: execution' slide showing a diagram of the execution process.
- Section 2: Small constants (4)**
 - Slide 5: 'Instruction format (machine language)' slide showing a diagram of the instruction format.
 - Slide 6: 'Instruction fields' slide showing a diagram of the instruction fields.
 - Slide 7: 'Question: number of bits' slide asking for the number of bits for various fields.
 - Slide 8: 'Constants (immediates)' slide showing a diagram of constants.
 - Slide 9: 'MIPS instruction formats' slide showing a diagram of MIPS instruction formats.
 - Slide 10: 'Sign extension' slide showing a diagram of sign extension.
 - Slide 11: 'Loading immediate values (constants)' slide showing a diagram of loading immediate values.
- Section 3: Jumps and Branches (3)**
 - Slide 12: 'Addresses in branches and jumps' slide showing a diagram of addresses.
 - Slide 13: 'Jump addresses example: loops' slide showing a diagram of jump addresses.
 - Slide 14: 'What kind of branches are in programs?' slide showing a bar chart of branch types.
- Section 4: Large constants (1)**
 - Slide 15: 'Loading larger values' slide showing a diagram of loading larger values.

1. Divide into 5-10 minute chunks

2. Organize

Making lectures interactive

The presentation slide shows a sequence of 19 slides, organized into sections:

- Translation to machine code (4):** Slides 1-4. Slide 1: 'Instruction Set Architectures 2'. Slide 2: 'Contents'. Slide 3: 'Review: instructions'. Slide 4: 'Review: execution'.
- Small constants (5):** Slides 5-9. Slide 5: 'Instruction encodings'. Slide 6: 'Instruction format (machine language)'. Slide 7: 'Instruction fields'. Slide 8: 'Question: number of bits'. Slide 9: 'Small constants'.
- Jumps and Branches (4):** Slides 10-13. Slide 10: 'Constants (immediate)'. Slide 11: 'MIPS instruction formats'. Slide 12: 'Sign extension'. Slide 13: 'Loading immediate values (constants)'.
- Large constants (2):** Slides 14-15. Slide 14: 'Addresses in branches and jumps'. Slide 15: 'Addresses in branches and jumps'.
- Other slides:** Slide 16: 'Jump addresses example: loops'. Slide 17: 'What kind of branches are in programs?'. Slide 18: 'Large constants'. Slide 19: 'Loading larger values'.

1. Divide into 5-10 minute chunks

2. Organize

Making lectures interactive

The image shows a sequence of presentation slides from a lecture on 'Instruction Set Architectures 2'. The first slide is crossed out with a large red 'X' and a yellow box with '??' next to it. The subsequent slides are organized into sections: 'Translation to machine code (4)', 'Small constants (5)', 'Jumps and Branches (4)', and 'Large constants (2)'. Each section contains multiple slides with diagrams, code snippets, and questions. The slides are numbered 2 through 25.

1. Divide into 5-10 minute chunks

2. Organize

3. Add questions

This is the hard part.

- Choosing questions
- Writing questions

At Home: **Interactive** lectures

The screenshot shows a video player interface for a lecture on 'Control Hazards' and 'Speeding up branches'. On the left is a sidebar menu with topics like 'ISA 1', 'ISA 2', 'Arithmetic', 'Caches 1', 'Caches 2', 'Processor Control and Datapath', 'Processor Pipelining', and 'Pipeline Hazards'. The main video area displays a slide titled 'Speeding up branches' with a bulleted list: 'The problem is that it takes 3 cycles to resolve branches' and 'Can we improve on this by changing the pipeline or adding hardware?'. Below the text is a diagram of a 5-stage pipeline (IF, ID, EX, MEM, WB) with arrows indicating branch resolution delays: 1 cycle from ID, 2 cycles from EX, and 3 cycles from MEM. A blue callout bubble points to the diagram with the text 'Can ask a question directly in the video or click "confused"'. Another blue callout bubble points to the video player's progress bar with the text 'Every student answers 10-20 questions for every lecture'. A third blue callout bubble points to a 'Correct' feedback box with the text 'Self-assessment quizzes integrated into the video lecture'. A fourth blue callout bubble points to the same feedback box with the text 'Immediate feedback on correct/incorrect answers'. The feedback box contains the text: 'Correct. We access the register file in the ID stage, so we cannot move the branch calculation (which needs those values to know if it should branch) any earlier.' The video player at the bottom shows a progress bar at 4:54 / 9:20 and icons for shortcuts, confused, and settings.

Control Hazards

Speeding up branches

- The problem is that it takes 3 cycles to resolve branches
- Can we improve on this by changing the pipeline or adding hardware?

1 cycle delay from ID

2 cycle delay from EX

3 cycle delay from MEM

Can ask a question directly in the video or click "confused"

But no need for hardware

Correct

We access the register file in the ID stage, so we cannot move the branch calculation (which needs those values to know if it should branch) any earlier.

Every student answers 10-20 questions for every lecture

Self-assessment quizzes integrated into the video lecture

Immediate feedback on correct/incorrect answers

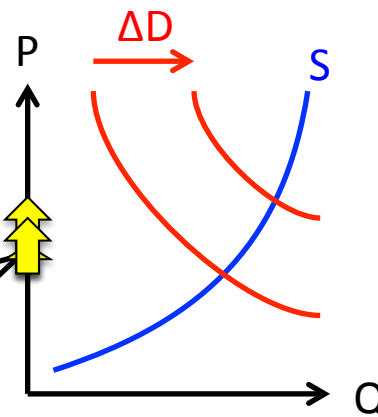
Maximize interactivity & collect data

Interactive lectures

Economics: supply and demand

Draw an arrow showing what happens to the price as the demand changes as shown below.

Correct:
The price goes up because the supply is not completely elastic



4:54 / 9:20



Shortcuts

Confused



Interactive lectures

Economics: supply and demand

History: The start of the First World War

Put the following events in order

July Ultimatum

Russia mobilizes

Austria-Hungary declares war

Ferdinand assassinated

Britain declares war on Germany

Germany invades Belgium

France mobilizes

4:54 / 9:20



Shortcuts

Confused



Interactive lectures

Economics: supply and demand

History: The start of the First World War

Put the following events in order

Incorrect:

France initially redrew its troops from the border to avoid any incidents. It was only after Germany invaded Belgium that France mobilized.

Ferdinand assassinated

July Ultimatum

Austria-Hungary declares war

Russia mobilizes

France mobilizes

Germany invades Belgium

Britain declares war on Germany

4:54 / 9:20



Shortcuts

Confused



YouTube

Interactive lectures

Economics: supply and demand

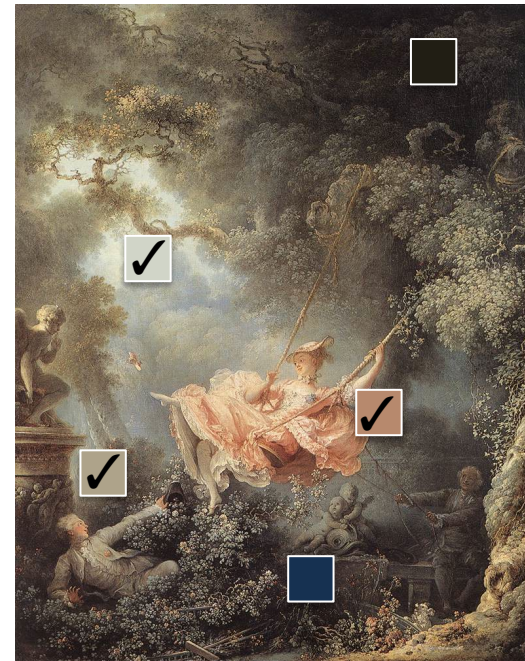
History: The start of the First World War

Art: The Rococo color pallet

Select the colors used in this work that differentiate it from the earlier Baroque pallet.

Correct:

The Rococo pallet uses more “playful” pastels and lighter colors in place of the Baroque's intense, darker colors and tones.



L'Escarpolette (The Swing). Jean-Honoré Fragonard, 1766



4:54 / 9:20



Shortcuts

Confused



Interactive lectures

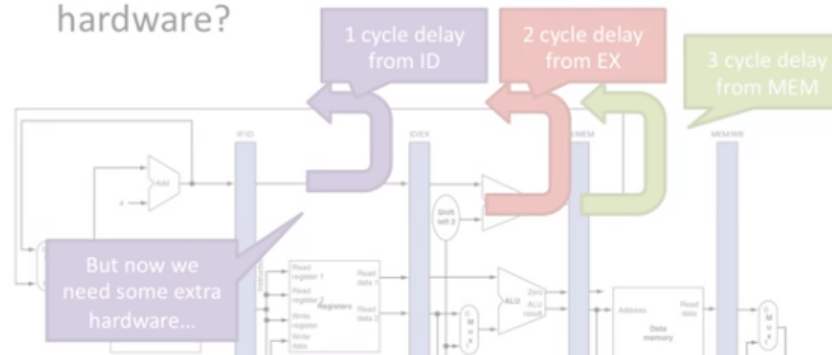
Economics: supply and demand

History: The start of the First World War

Art: The Rococo color pallet

Computer Science: Speeding up branches

- The problem is that it takes 3 cycles to resolve branches
- Can we improve on this by changing the pipeline or adding hardware?



Q: Can we move the branch logic to the IF stage?

- ☐ Yes, we need more hardware
- ☐ No, we need the register values
- ☐ Maybe, but some branches won't work.

Many fields, many types of questions

IMPROVING IN-CLASS TEACHING

Using the information from the online lectures.

Teacher's View: **What** did students learn?



Do not need to review this material

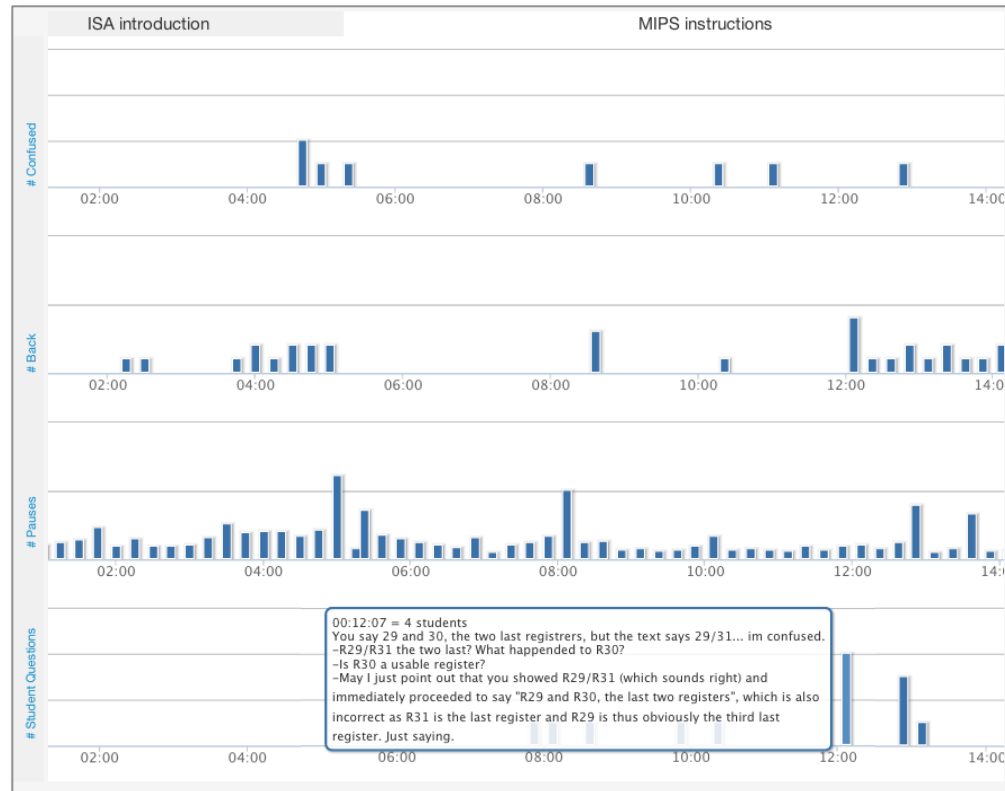
Review if we have time

Definitely review!

And probably improve the lecture material.

Know where to spend in-class time *before* coming to class

Teacher's View: **Where** did students have trouble?



Confused

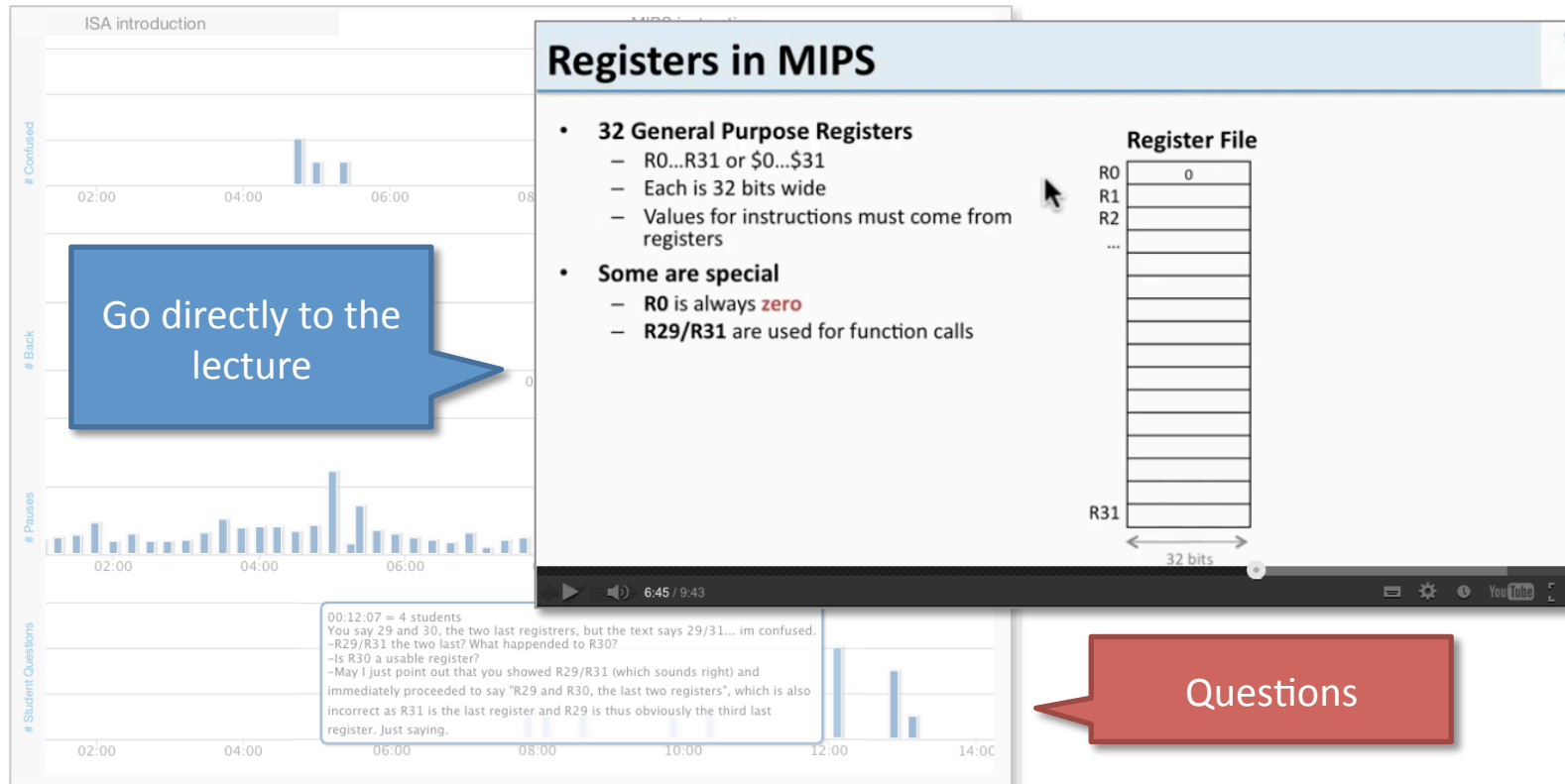
Rewind

Pauses

Questions

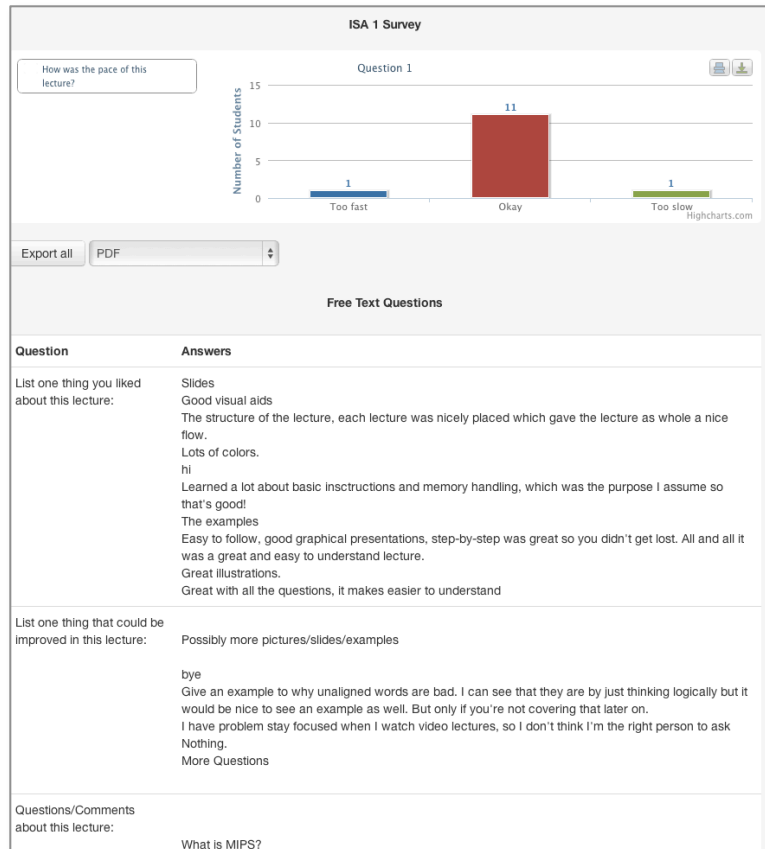
Lecture Time →

Teacher's View: **Where** did students have trouble?



Understand *where* students are confused and have questions

Teacher's View: Responding to student feedback



Multiple choice

Free text

Teacher's View: Responding to student feedback

ISA 1 Survey

Hide inappropriate/repeated questions

Question: Questions/Comments about this lecture:

Hide	Groups	
<input checked="" type="checkbox"/>	<input type="checkbox"/>	1 No.
<input type="checkbox"/>	<input checked="" type="checkbox"/>	2 Explain why you use an adder for PC +4, is it not better to create a special adder that just add 4 to the input. Would go faster? Since it is more specialized. Great question. Yes, it would go faster (but not much). When the processor designer puts in an adder that always adds 4, the CAD tools will optimize the adder for always adding 4. We just draw it that way to make it clear that it's the same kind of operation as a regular adder with +4. Save
<input type="checkbox"/>	<input type="checkbox"/>	5 I thought that the ALU was more of a general counting block used in for example loops for adding 1 or 100 or whatever is needed. Here it seems to be hardwired to add 1 or 4 (for the PC). Unless a branch is taken that is. Perhaps there's some kind of default values for the different counters. The adder for the PC update always adds 4. The regular ALU can do all sorts of things: add (whatever its two inputs are; register/immediate), and, or, xor, etc. Delete
		7 A good lecture

Question

Answers

List one thing you liked about this lecture:

Slides
Good visual aids
The structure of the lecture, each lecture flow.
Lots of colors.
hi
Learned a lot about basic instructions and that's good!
The examples
Easy to follow, good graphical presentation was a great and easy to understand lecture.
Great illustrations.
Great with all the questions, it makes easy.

List one thing that could be improved in this lecture:

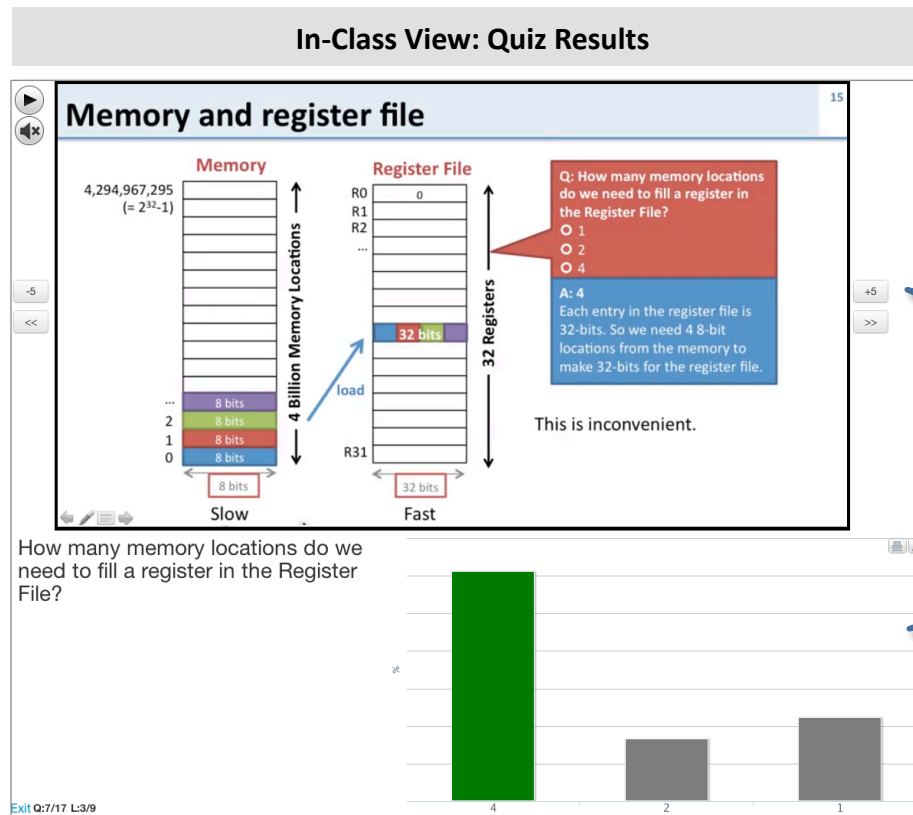
Possibly more pictures/slides/examples.

Send the same answer to multiple questions at once

Reply to anonymous questions and comments

Show the students you care about their feedback and questions

In-Class: Using the data to help teaching



Step through the question and solution

Student quiz results

In-Class: Using the data to help teaching

In-Class View: Questions

Registers in MIPS

- **32 General Purpose Registers**
 - R0...R31 or \$0...\$31
 - Each is 32 bits wide
 - Values for instructions must come from registers
- **Some are special**
 - R0 is always **zero**
 - R29/R31 are used for function calls
- **A few special registers**
 - PC (Program Counter): current instruction

Register File

R0	0
R1	
R2	
...	
R31	

32 bits

May I just point out that you showed R29/R31 (which sounds right) and immediately proceeded to say "R29 and R30, the last two registers", which is also incorrect as R31 is the last register and R29 is thus obviously the third last register. Just saying.

Is R30 a usable register?

You say 29 and 30, the two last registers, but the text says 29/31... im confused.

R29/R31 the two last? What happened to R30?



Questions grouped by 30 second intervals

4 student had questions at the same place

Use online information *easily* in class

Implementation: In-class

- **Review** self-assessment **quizzes**
 - Teacher knows which questions students had trouble with
 - Use in-class time effectively
- **Review** student **questions** and **feedback**
 - Can prepare ahead of time
 - Build trust with the students that you listen

This is for free:
Know where the students need help and better feedback

- **Practice** **problems**
 - Small group practice problems
 - Interact with other students and teachers

This is the goal:
Spend the in-class time working with the material, not lecturing!

In-Class: Peer learning with practice problems

2) How far does a loop branch?

Identify the instruction for the jump, and fill in the constant needed to jump to that point.

Hint: This code increments i inside the loop until it reaches 10. At that point the loop should exit.

offset
bytes

```

-16  addi $t0, $zero, $zero    # i = 0
-12  addi $t1, $zero, 10      # j = 10
-8   addi $t0, $t0, 1         # i++
-4   slt $t2, $t0, $t1
-0   bne $t2, $zero, -3     # jump to ?
  
```

-3 instructions: -12
bytes, plus 4 bytes
= -8 bytes

-3 instructions:
don't forget we
always do PC+4!

10 minutes to work, then
walk through the
solution

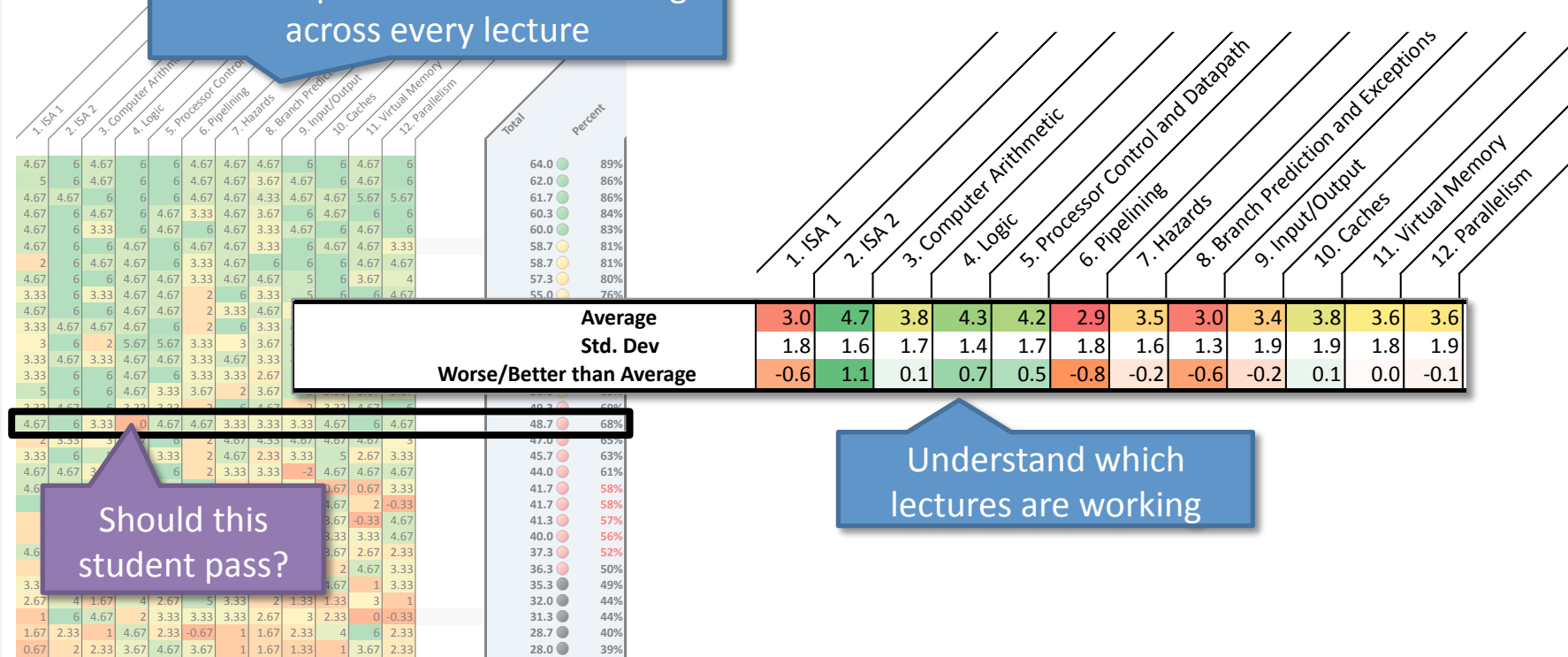
Provide printed out
copies of the questions



Active learning with peers

Future: Connecting outcomes and teaching

72 short questions: test knowledge across every lecture



Quantitatively tie exam performance to lecture content

Results

- **Increased student interaction**
 - 20 seconds per lecture → **60 minutes per lecture**
 - *Every student answers 10-20 questions for every lecture*
- **Students loved it**
 - Online lectures and questions
 - In-class problem solving
 - Tremendous feedback to/from students
- **Most fun I've had teaching in years**

5 LESSONS LEARNED

(although I don't have all the answers)

1. Students love this approach

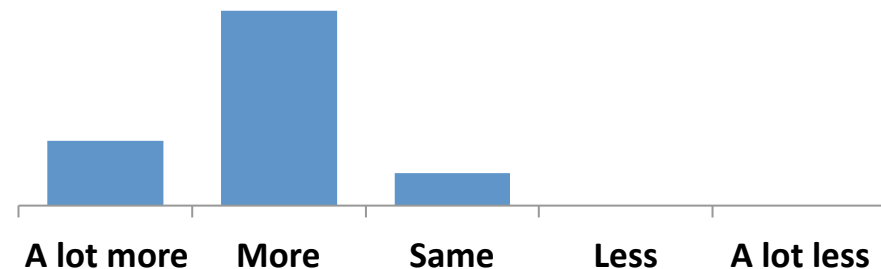
Takes more time, but worth it

- Resist required lectures and practice problems (at first)

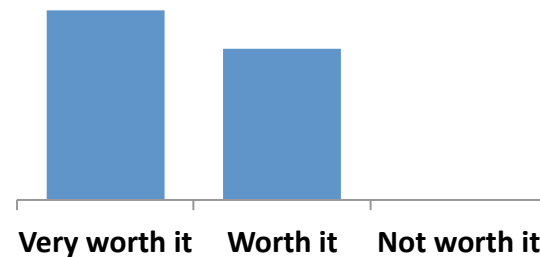
Appreciate:

- **Interactive** lectures
- Rewind/**review** lectures
- Asking **questions** online
- In-class **practice** problems

Time Relative to Other Courses



Time Value



Student Quotes

What was good?

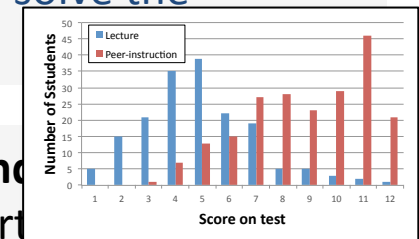
The whole concept of **video lectures** is **excellent**. It lets you play, repeat or pause. You **lose** the possibility of **dialog during the lectures**, but we get this at the **practice sessions** so this is not a problem.

What could have been better?

Always a **minimum of 2 questions on the quizzes**, and sometimes **more** of those questions in the middle of the lecture. Always a **footnote as well when getting the wrong thing on the quizzes**, it helps the learning.

I really **like the online lectures** and I **love the quizzes**.

I'm also **happy that the problem solving sessions are reasonably difficult** and that we have enough time so solve the problems. :D



In this course it was **mandatory** to attend through **lectures** and participate in **exercises** which essentially **doubled the time** spent on the course.

I would benefit more from traditional exercise sessions = handouts + **teacher solves the given problems**.

2. Amazing experience for the teacher

Interacting with the students

- Much **more fun** than lecturing
- Much **more rewarding** than lecturing

Know problem areas/questions before class time

- Prepare review material
- Prepare material to answer questions

Most fun I've had teaching in years

3. Recording isn't the time-consuming part

Most common concern is extra time to record

- Record in 5-10 minute chunks
- Software/hardware cheap/free

If you have good lectures, then the recording is easy.



4. Producing questions is hard

1 minute questions (online quizzes)

(10-20 per 90 minute online lecture)

- Identify key concepts from lecture
- Produce good short questions

What kind of questions?

10 minute questions (in-class)

(5-10 per 90 minutes of class time)

- Develop multi-part questions
- Address different student levels

How many questions?

100 minute questions (at home)

(1-2 per week of class time)

- Labs/essays (same as before)

How hard should they be?

5. Adapting to feedback is hard

More feedback *per lecture* than for the whole class previously

- Great, but now I feel I have to re-do all my slides...
- How to triage comments?
- How to aggregate comments over time?

New types of feedback

- Confused/paused in the lectures
- Self-assessment quiz results

40% of the students point out errors

- Never happened before
- Depressing the first time

12 problems
pointed out in one
lecture

1. Q11.1.1 It was impossible to choose the right answer, because when I clicked submit button, canvas scrambled all the alternatives, but my answer didn't change with them.
2. Q11.4.1 I saw two "Need to uniquely identify the data" – answers
3. One question had the same (correct) answer listed twice.
4. Q11.4-1. Same alternative is given twice but only one of them gives the correct answer.
5. Q11.4.2 What is difference between loading data into the cache and writing to the cache?
6. Q11.4: Two answers have the same text but only one of them is correct.
7. Q11.4 had two identical answers. The two last parts had an annoying sound in the background.
8. Quiz 11.4 Question 1 had two answers that were the same and only one of them was right.
9. Question 11.4.1 has two answers that say the same thing.
10. Slide 80: "% of cache misses = (#cache hits / #cache accesses)". Doesn't this formula rather give "% of cache hits"?
11. I assume that the calculation for miss ratio wasn't correct in the slide, % of cache misses \neq (#cache hits / # memory accesses). The right part should be the hit ratio and thus the miss ratio should be 1 - hit ratio.
12. In the first examples in the last video, why was the cycle to access the cache counted twice if it was a miss? That is both hit and miss time are counted.

THE FUTURE & CONCLUSIONS

Moving forwards

More teachers and courses (and move outside of IT)

- Today: 10 courses, 500 students at UU, SU, KTH

Increase student interactivity

- More self-assessment quiz types (arrows, boxes, numeric, etc.)
- Peer grading
- Integration with exams (identify at-risk students early)
- Learn from other subjects what they need

Reduce teacher overhead

- **Funding for teacher time is key**
- Better tools for teachers
- Best practices guide
- Enable sharing courses/content
(between teachers, departments, campuses, universities)

Uppsala-KTH-Chalmers

Key questions

Teaching:

- How do we provide **incentives** to teachers to adopt better methods? (time and motivation)
- How do we **learn** what works from our teachers? (tools and techniques)
- How do we **disseminate** what we learn?

Strategic:

- How much of our teaching time is **active** vs. **passive**?
- How much of our teaching time can be **replaced with online content**? (Harvard/MIT/Stanford)
- How can we shift to **interactive in-class teaching *by default***?

Would you like to try this in your class?

1. **Contact** me and we can discuss what you need

- david.black-schaffer@it.uu.se

2. **Prepare** a few test lectures

- Split into 5-10 minute chunks
- Develop in-lecture self-assessment quizzes
- Design in-class peer practice problems

3. **Record**

(Not the time-consuming part)

4. **Test** with your students

- Tell them why you are doing this
- Collect feedback