

Investigative Science Learning Environment: Turning our students into collaborative participants in the practice of physics

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I started teaching as a physics teacher in
Moscow, Soviet Union in 1982.

What made me think about teaching physics differently

My principal Yuri Zavel'ski (geography teacher),
1984

**What is it that you REALLY want
your students to take away
from your courses?**



What made me think about teaching physics differently

My student Arkadii Ostrovski,
graduate of 1988, in 1989

**I do not remember anything
but X-rays...**



The main idea

It is not just the product that is important. The process is KEY.

Thinking like a physicist becomes the **MAIN GOAL** of learning physics.

BUT! To achieve it students need learn physics by actually “making” it together and in this process they will learn to think like physicists.

How do we know that this happens? In other words, how do we assess it?

The first implementation of the new approach in 1990-1995

10% of my Moscow students became physics majors after graduating HS – they actually wanted to be physicists

(before that it was about 1%).

Rutgers



Department of Physics
and Astronomy

Graduate School of
Education



Thanks to

Alan Van Heuvelen



Thanks to



Alan Van Heuvelen



Suzanne Brahmia



Xueli Zou

Thanks to



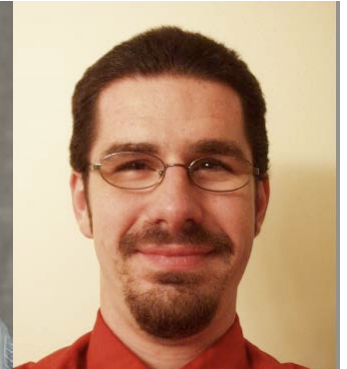
Alan Van Heuvelen



Suzanne Brahmia



Xueli Zou



Let's try this approach together

Let's reflect on the steps we took to figure it out

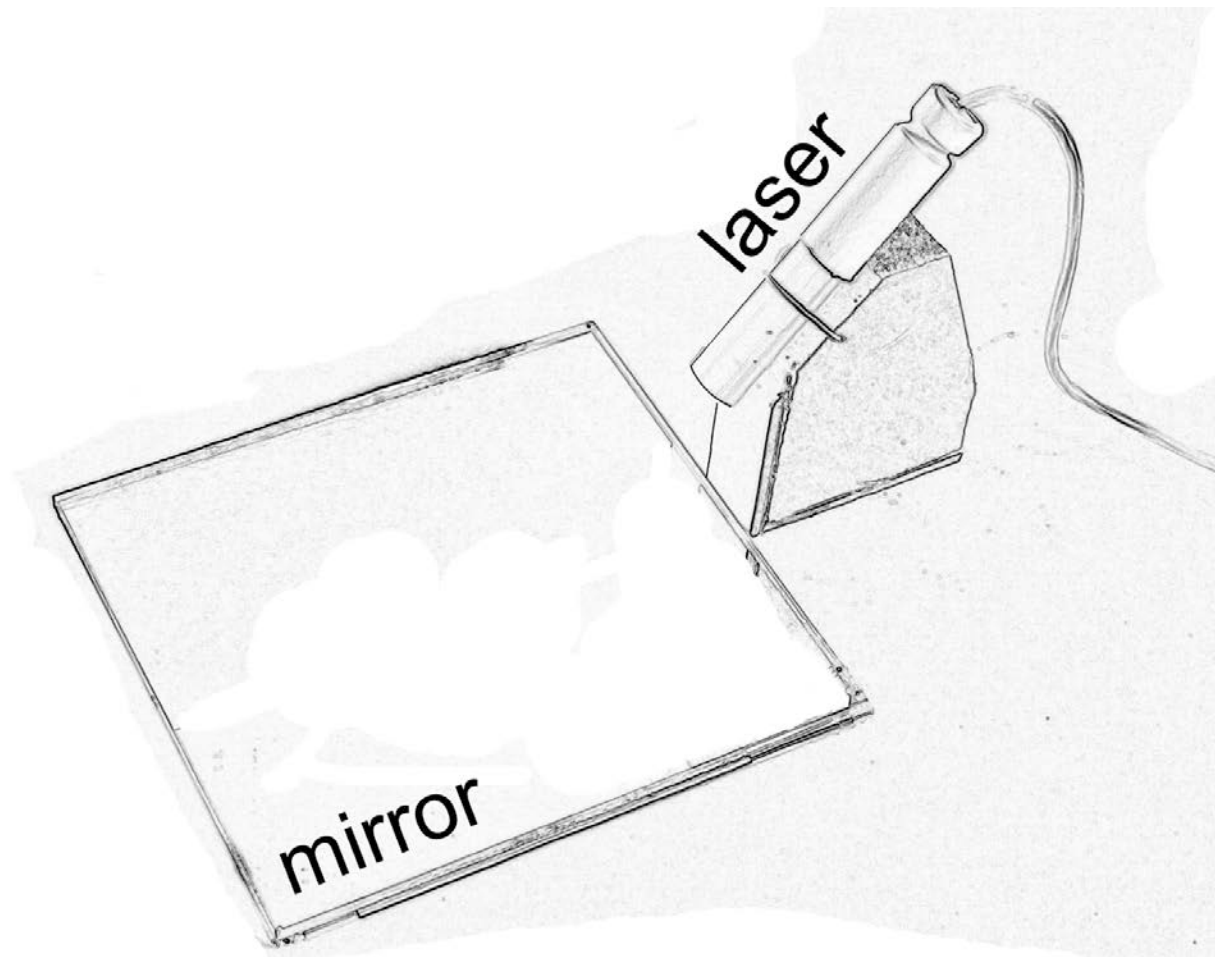
We noticed something and agreed what we saw.

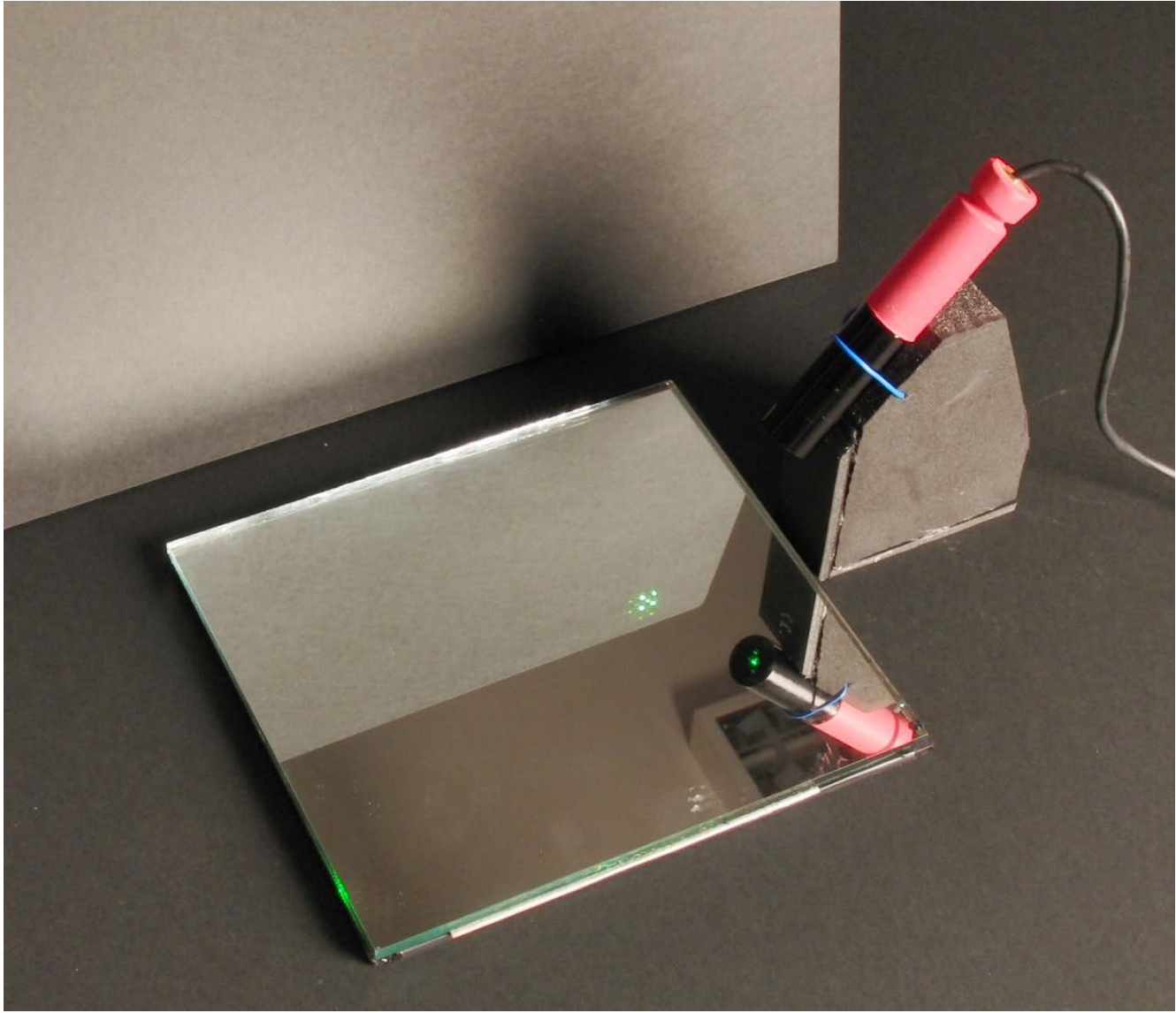
We came up with several explanations.

We ruled them out one by one through new experiments.

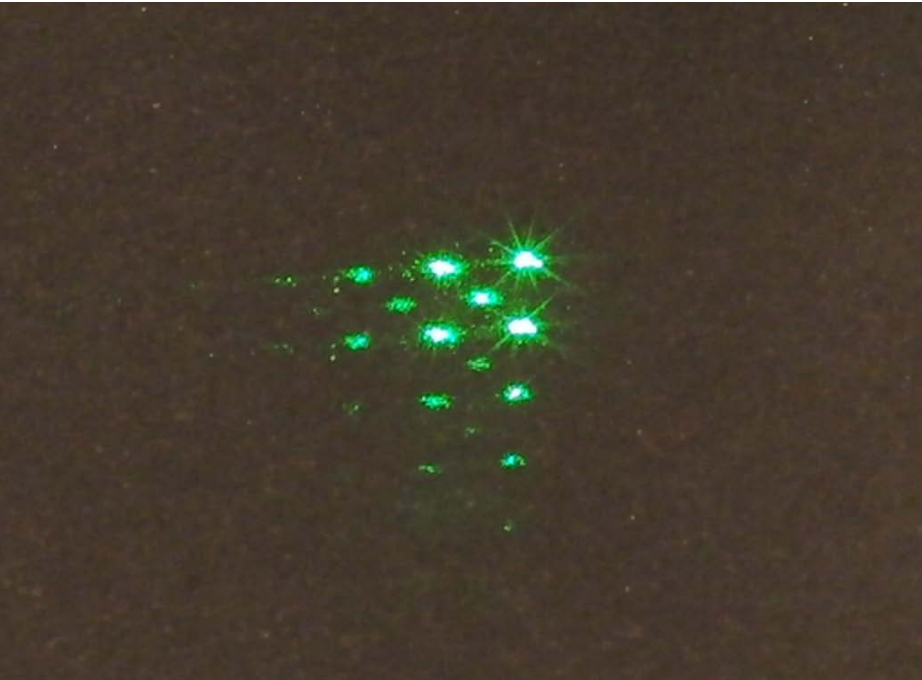
We are left with the one we could not rule out.

Another quick example



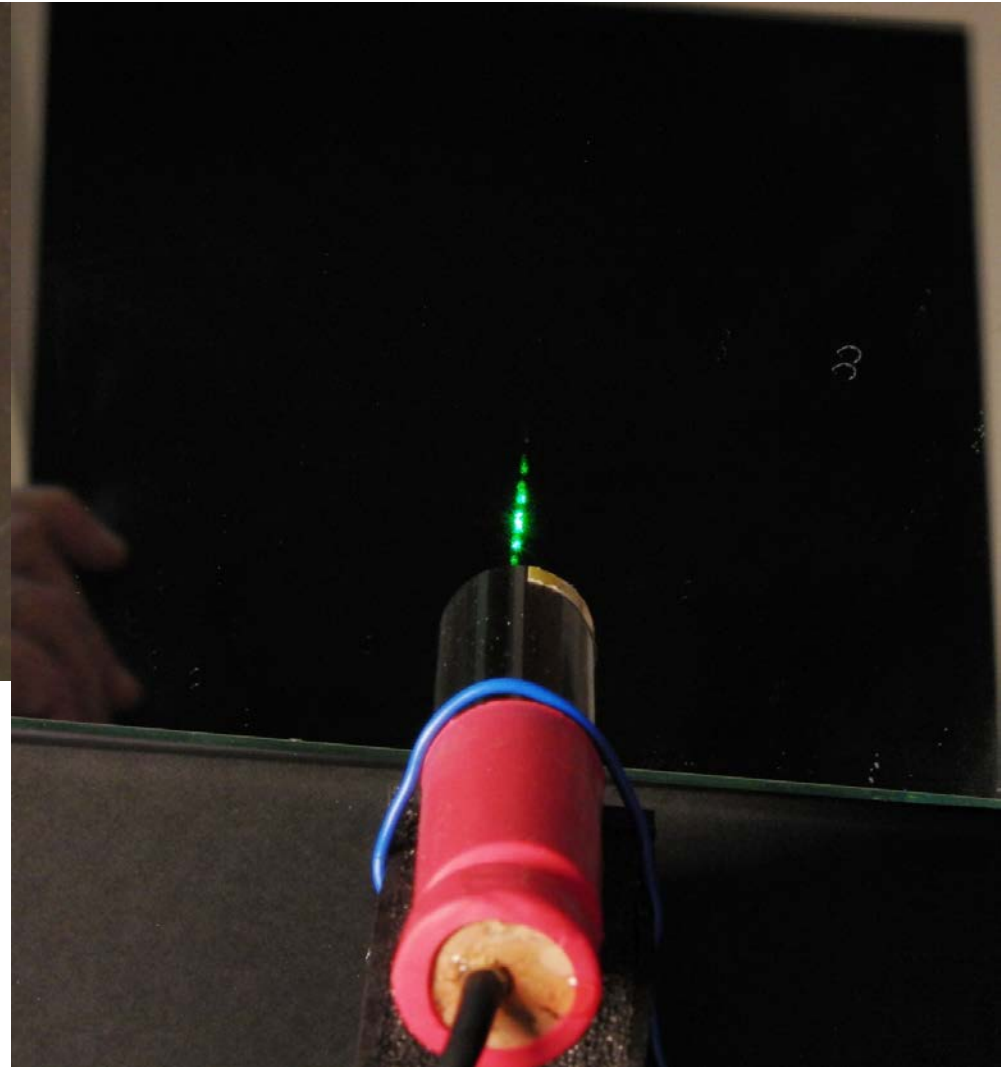


And this is what happens

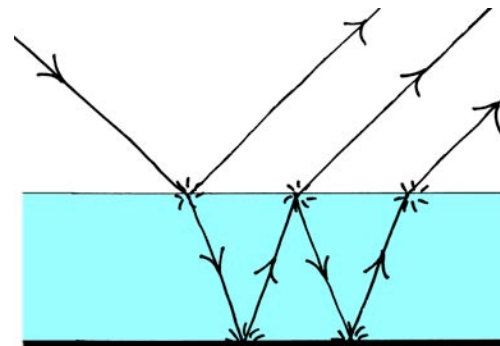
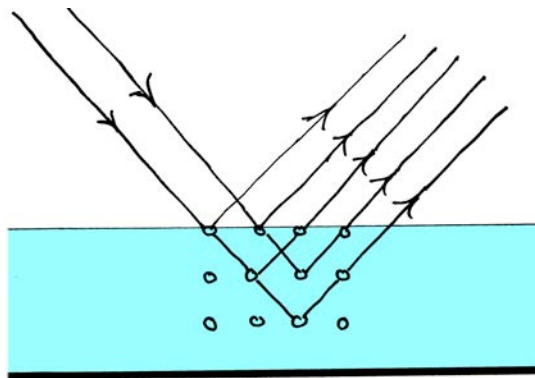
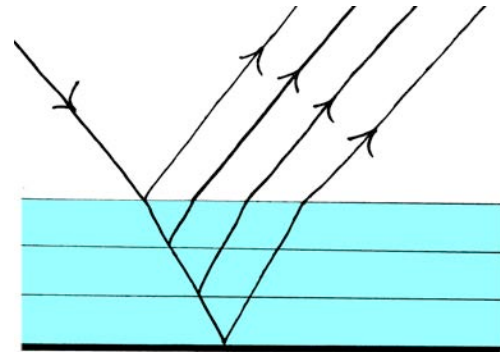
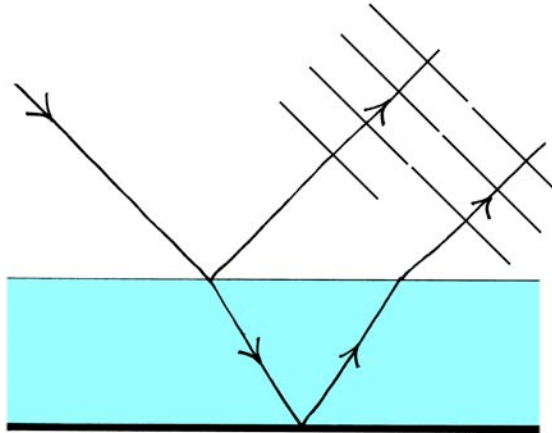


Looking at the mirror

Looking along the beam



This is what undergraduate physics majors
came up with



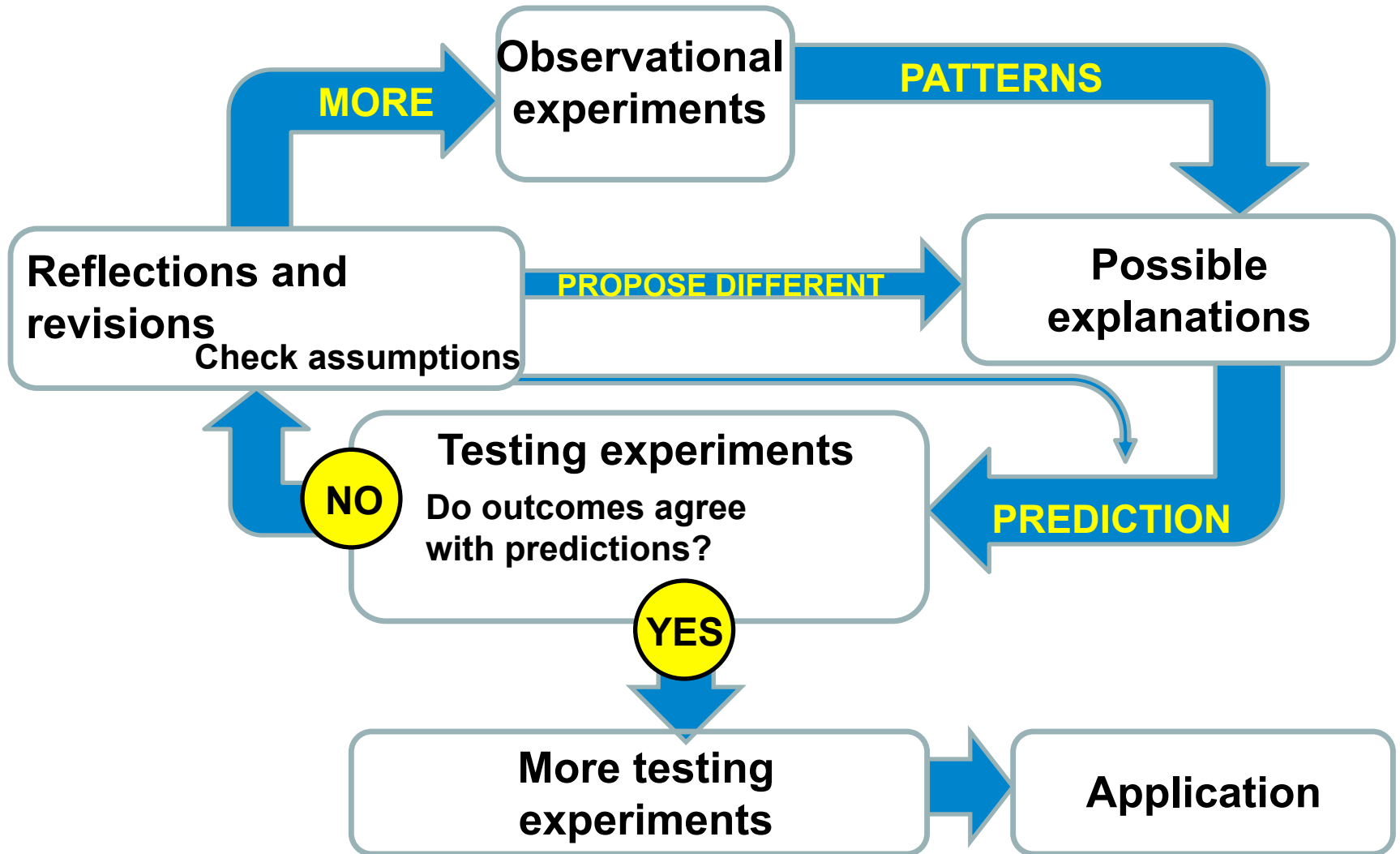
**Interference-based
explanations**

**Reflection-based
explanations**

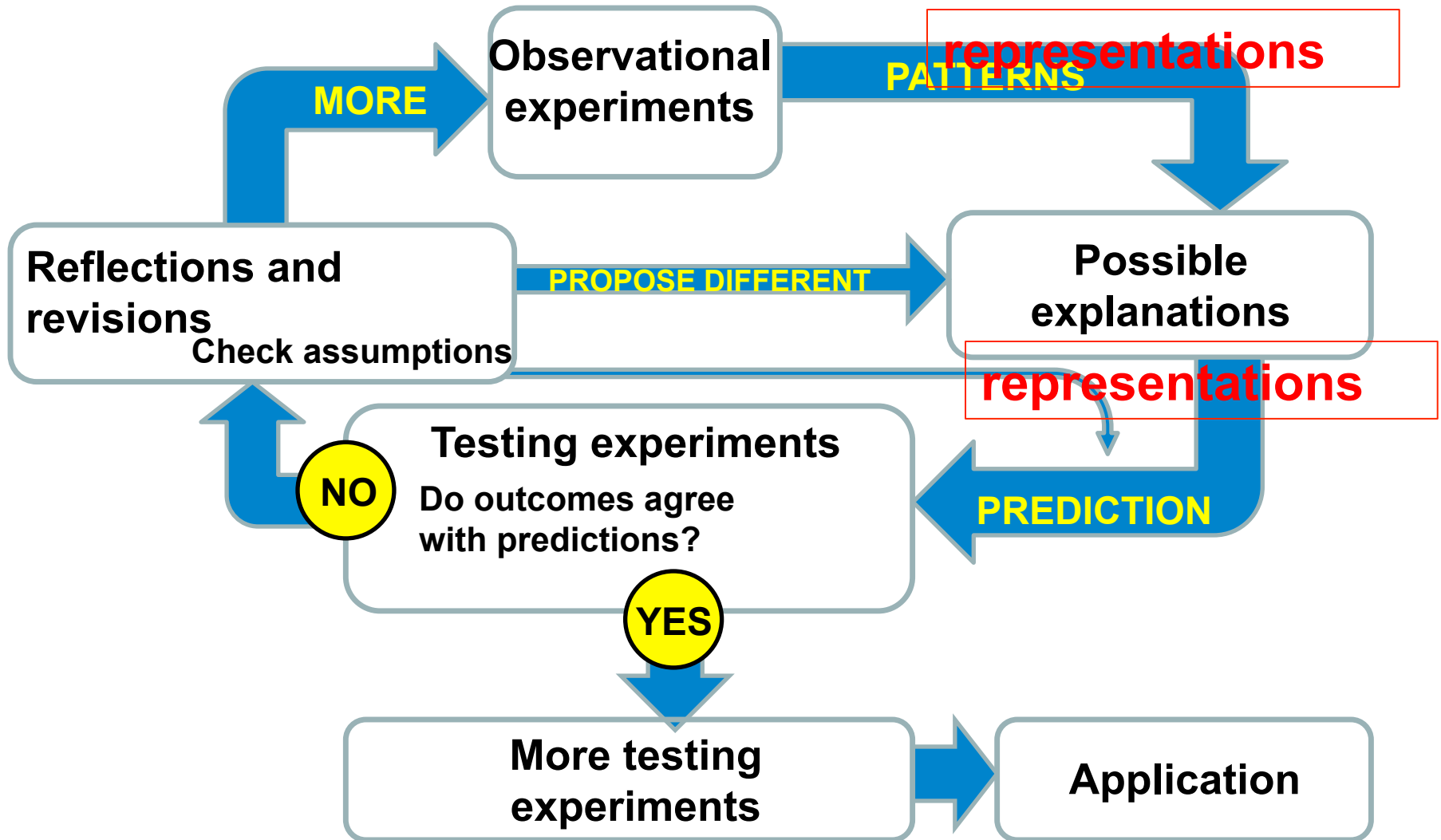
I will not show how to test these explanations – I encourage the physicists in this room to do it when the talk is over and everyone else can read about them in

Etkina, E. (2015) Students of physics: Listeners, observers or collaborative participants in the the practice of physics? *American Journal of Physics*, 83 (8), 669-679.

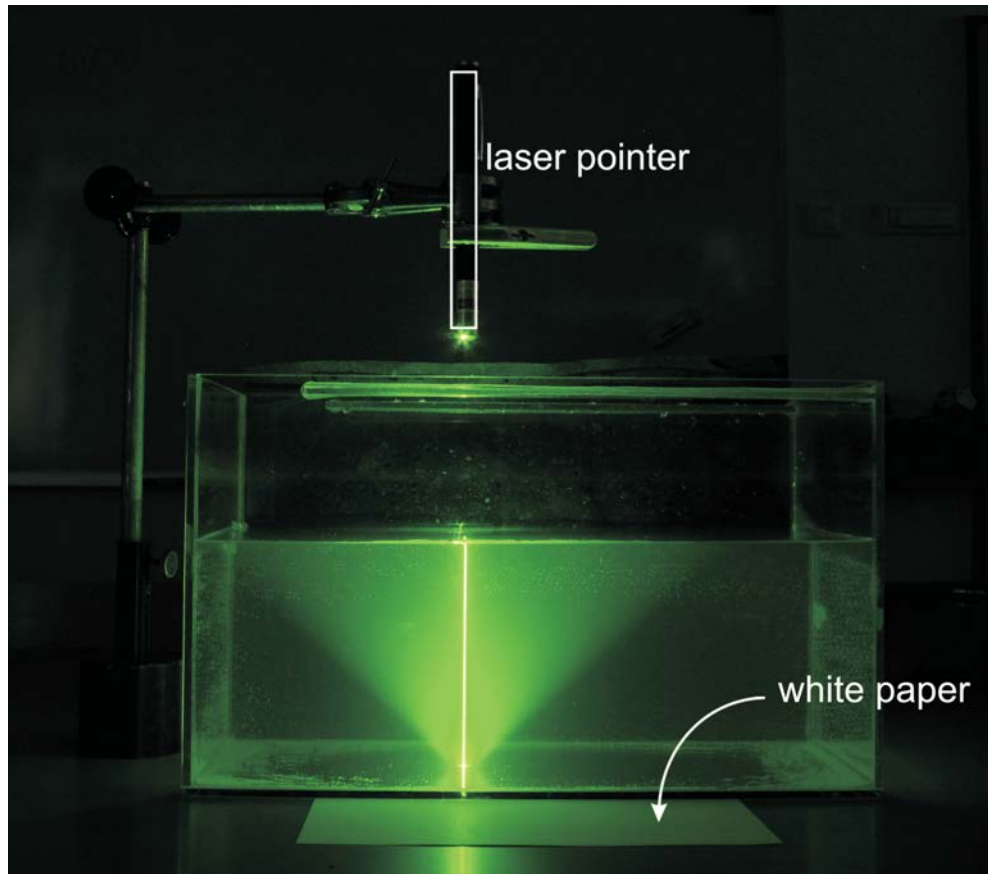
Investigative Science Learning Environment - ISLE cycle



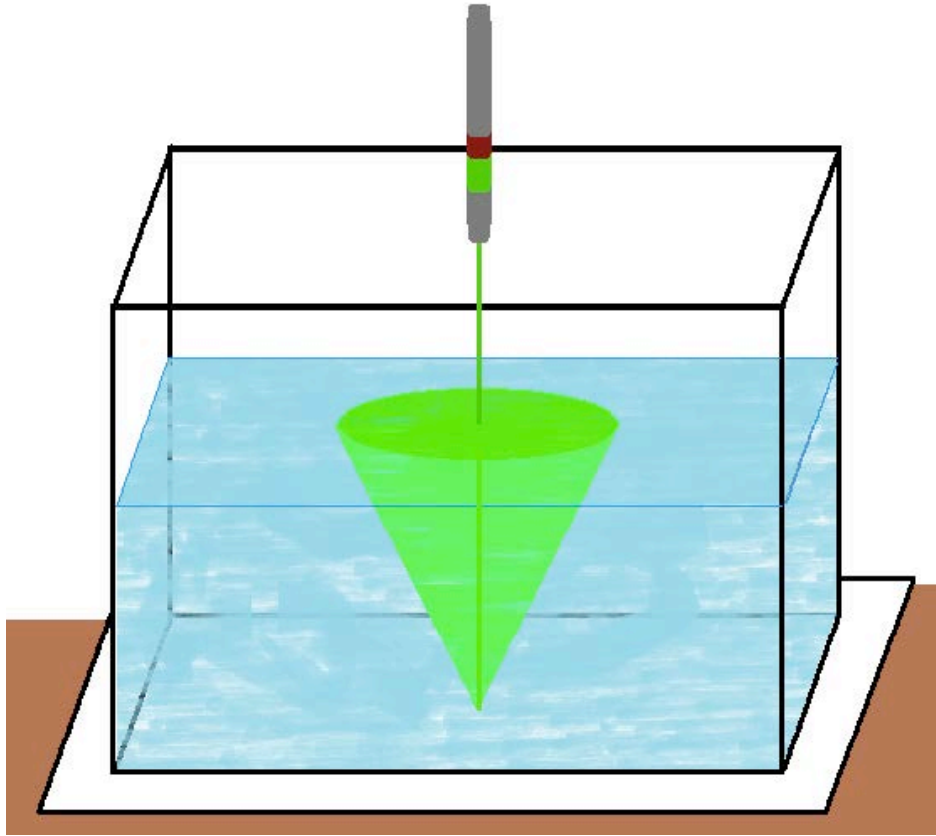
Investigative Science Learning Environment - ISLE cycle



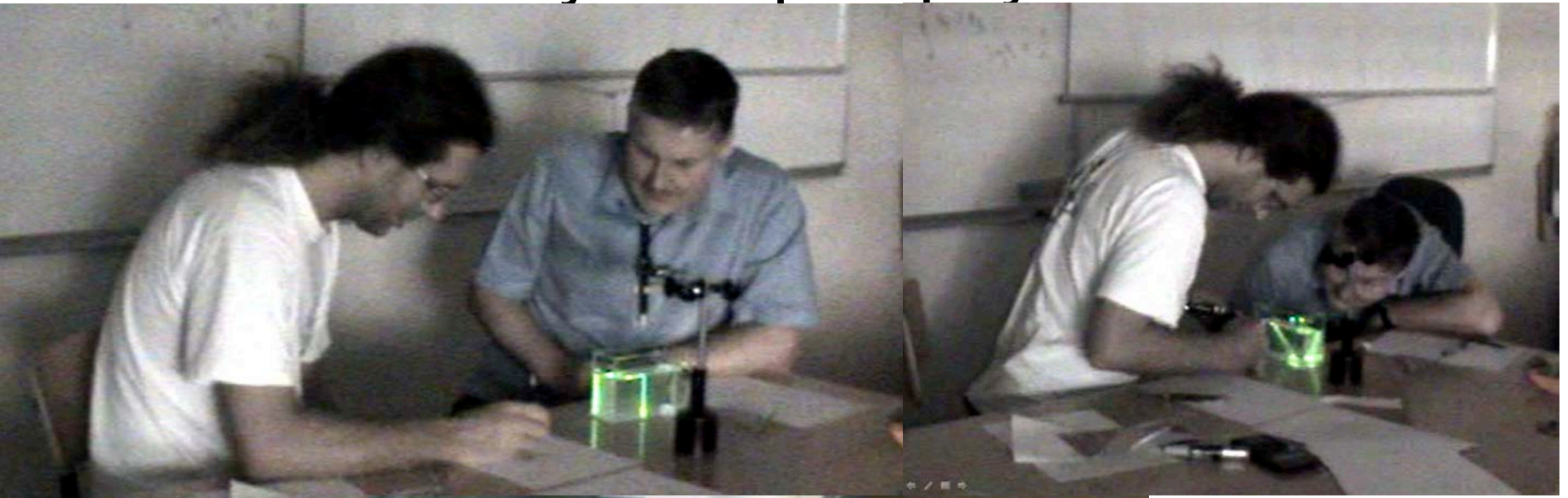
How do we know that physicists actually work this way? (Remember the goal is to teach students to think like physicists)



Etkina, Planinšič, and Vollmer, 2013.

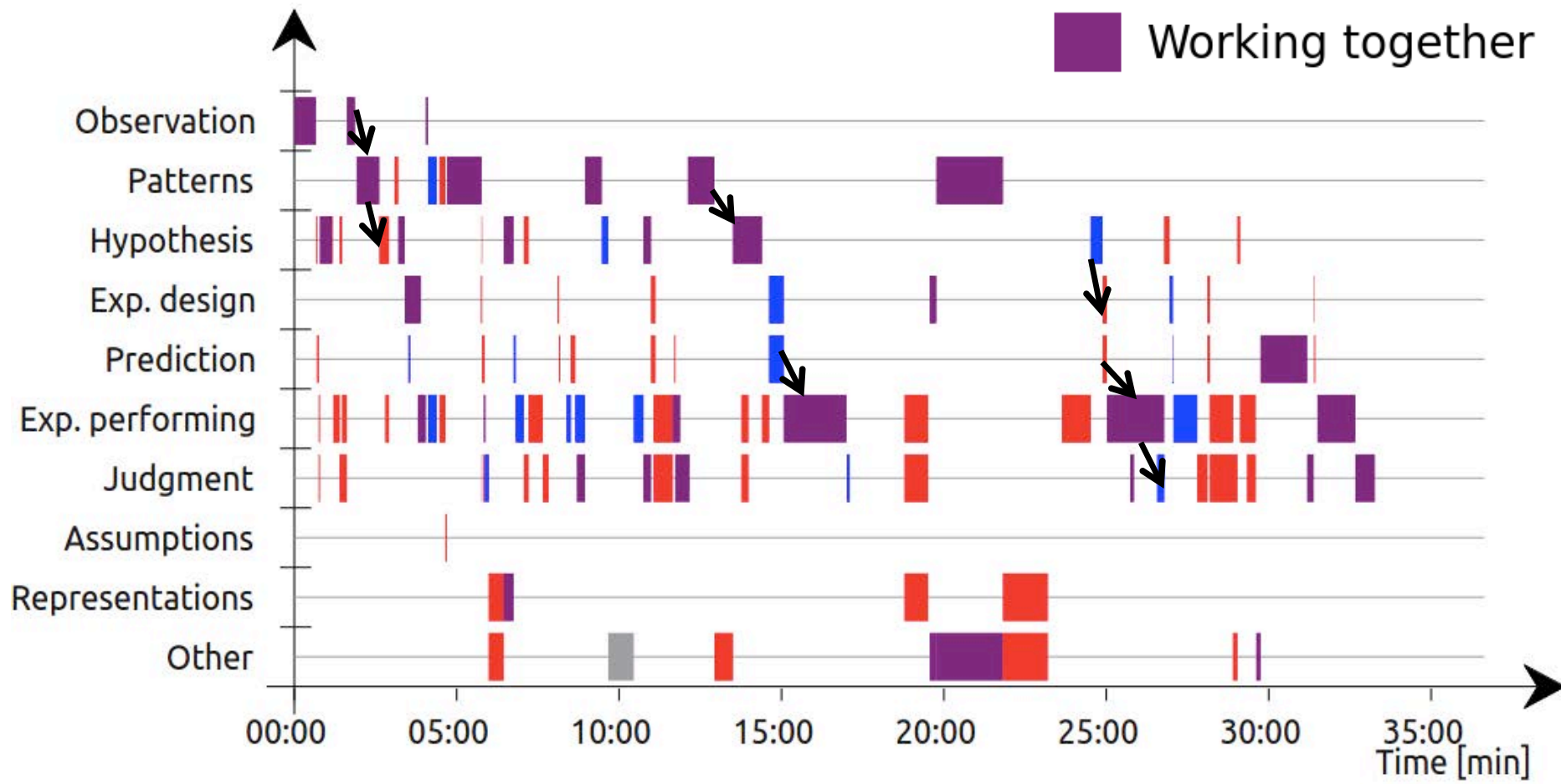
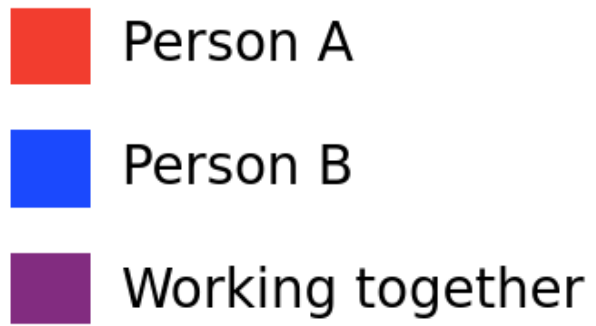


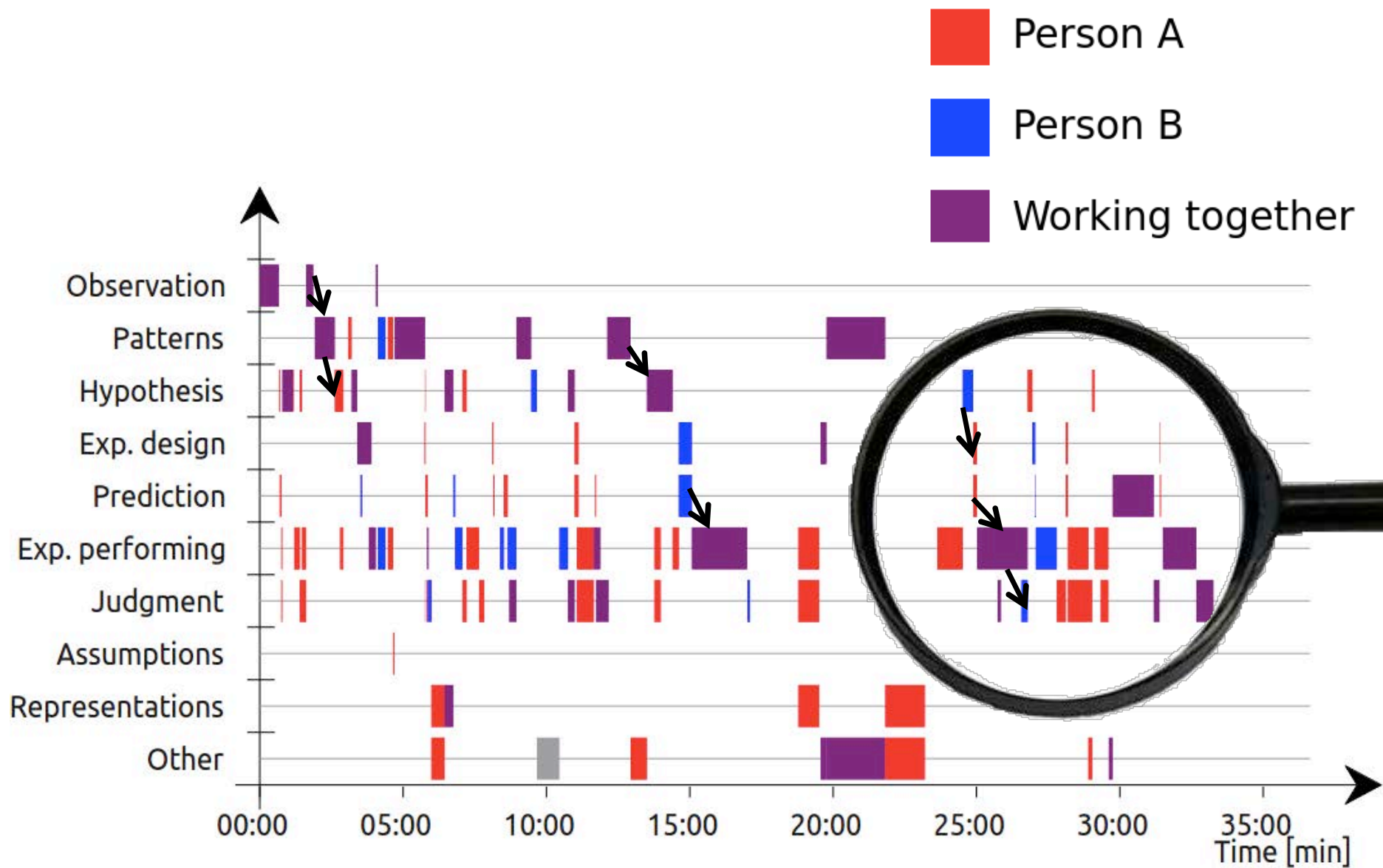
Study of expert physicists



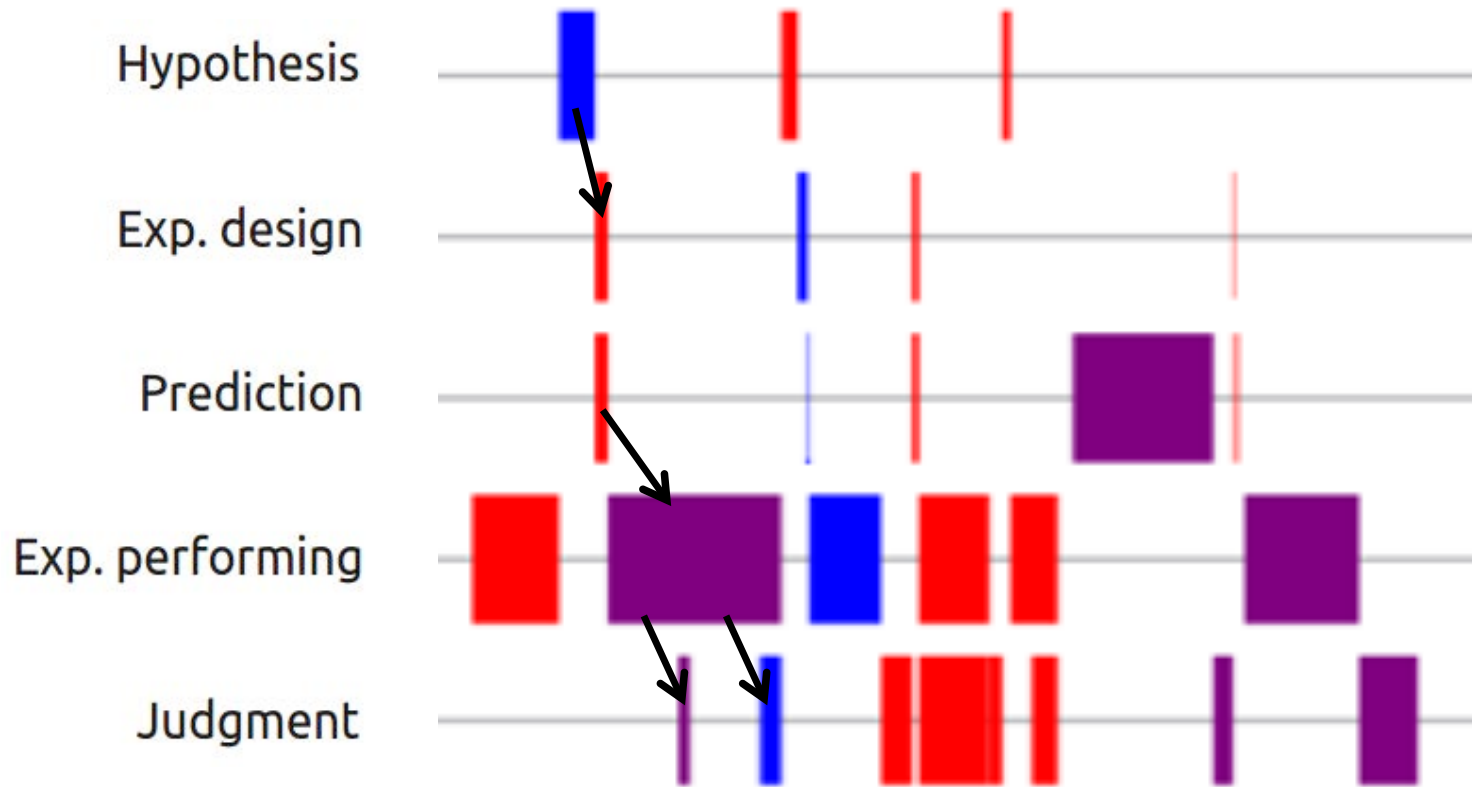
Poklinek, Planinsic and
Etkina, 2015

Timeline of events

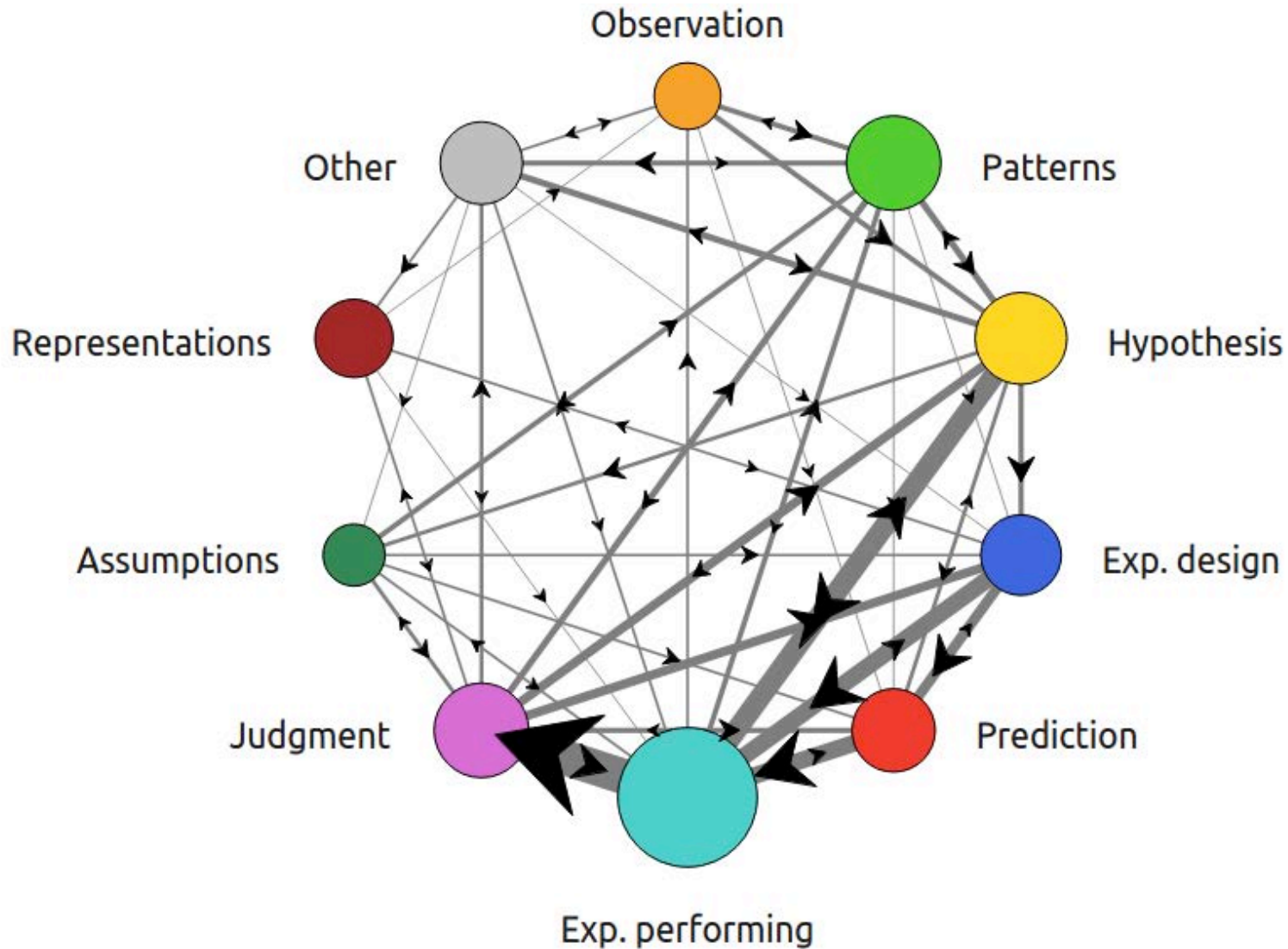




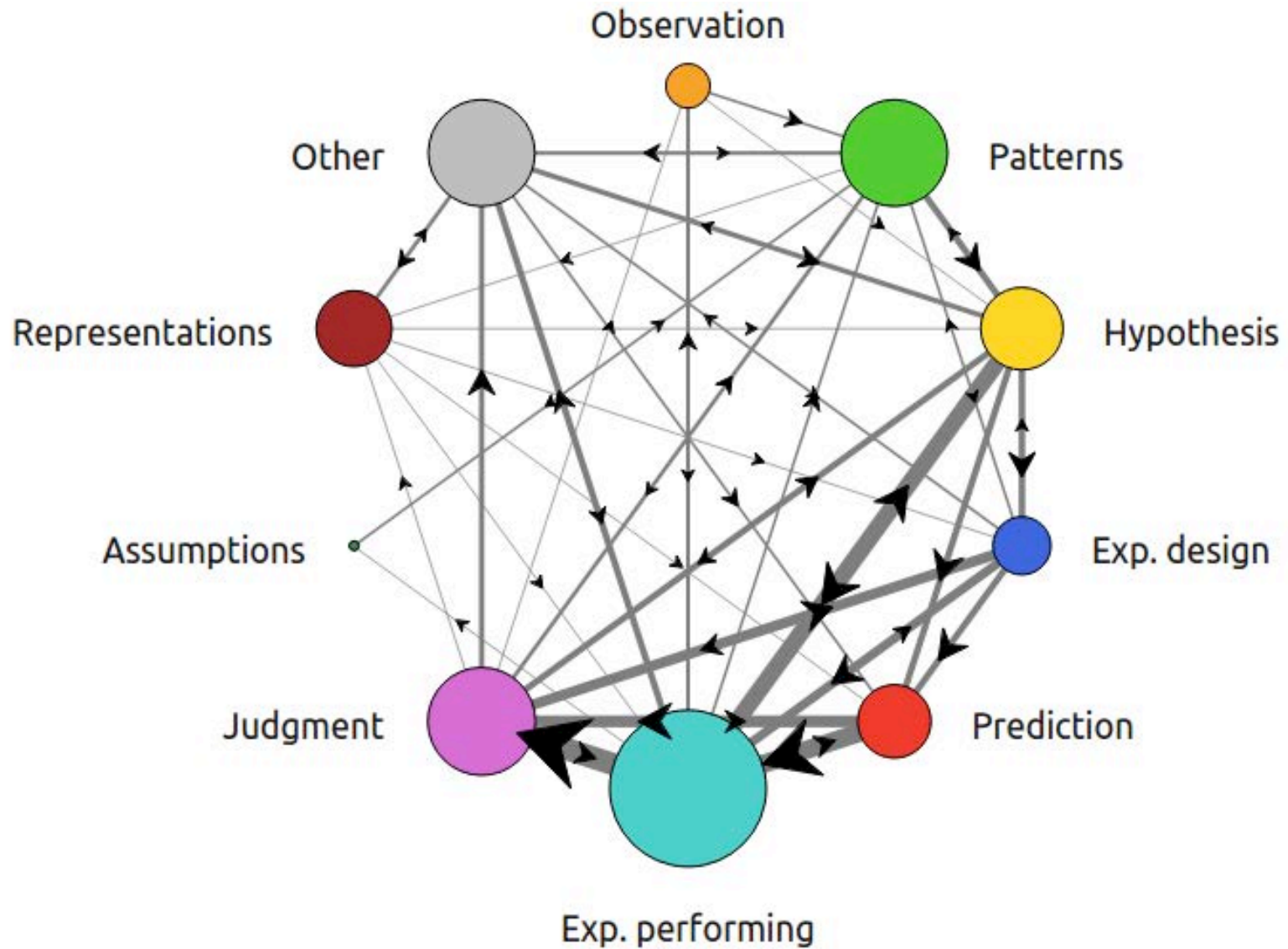
Patterns in expert reasoning and actions



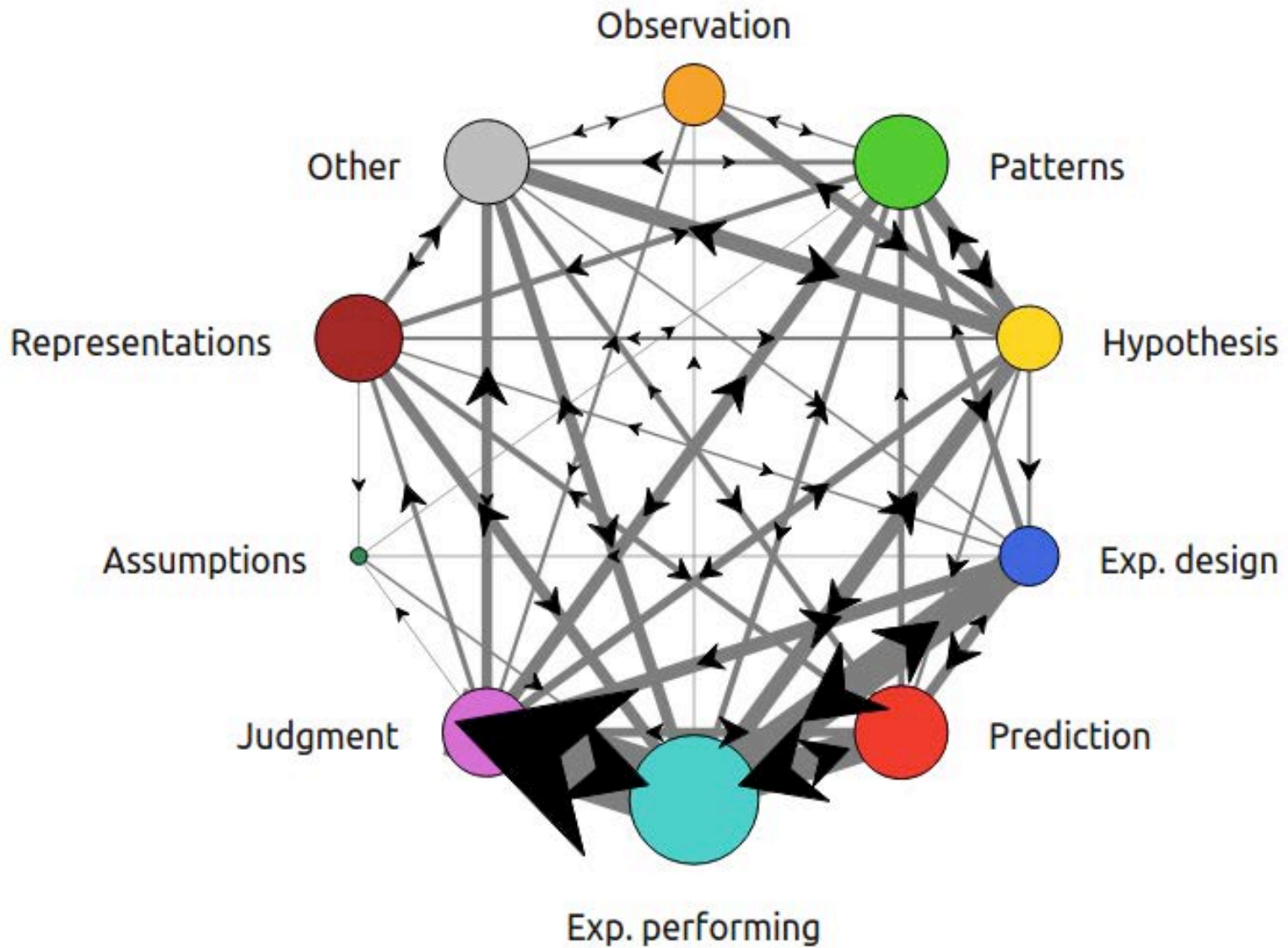
Transition graph for experimental physicists



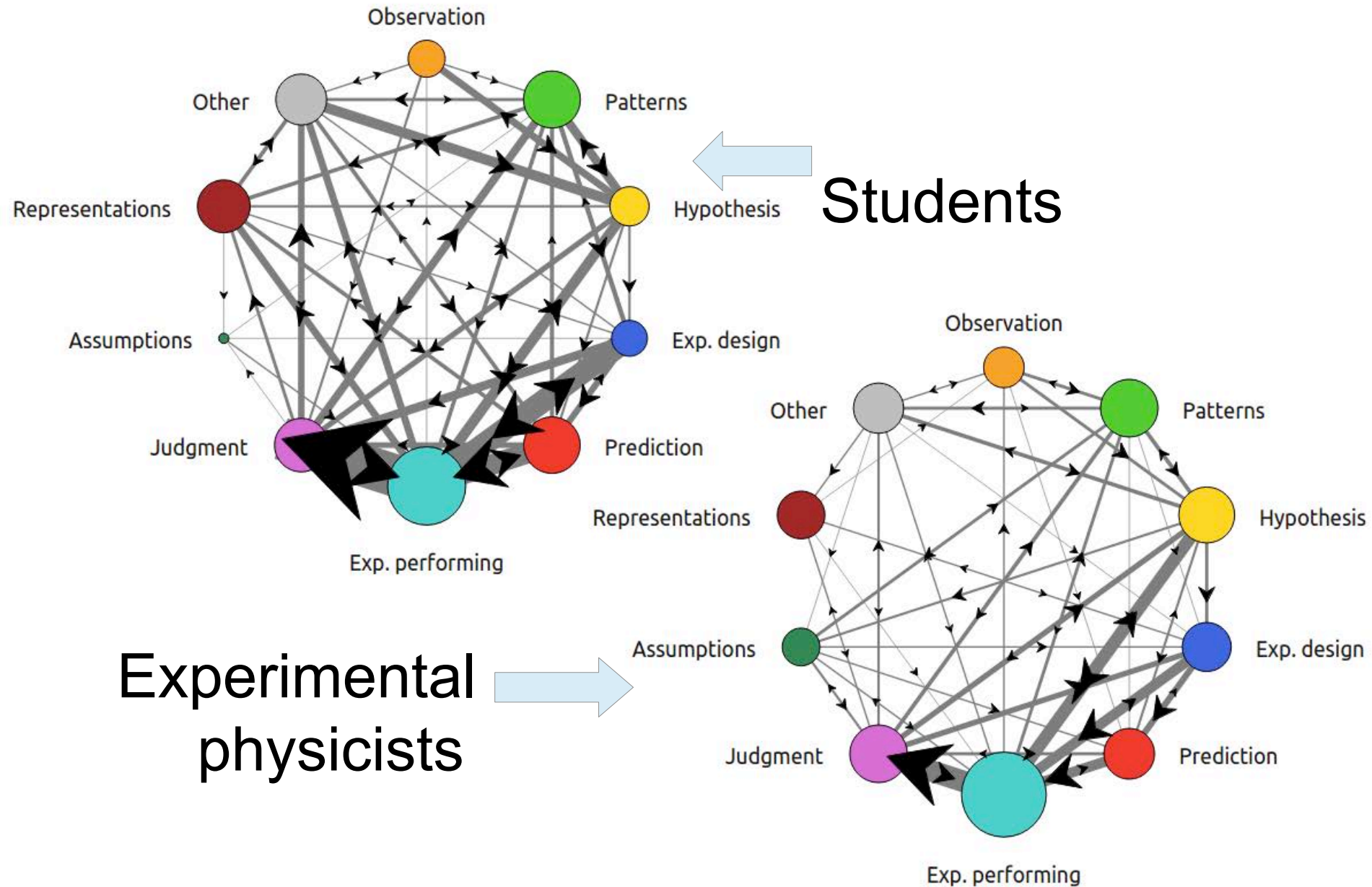
Transition graph for pharmacists



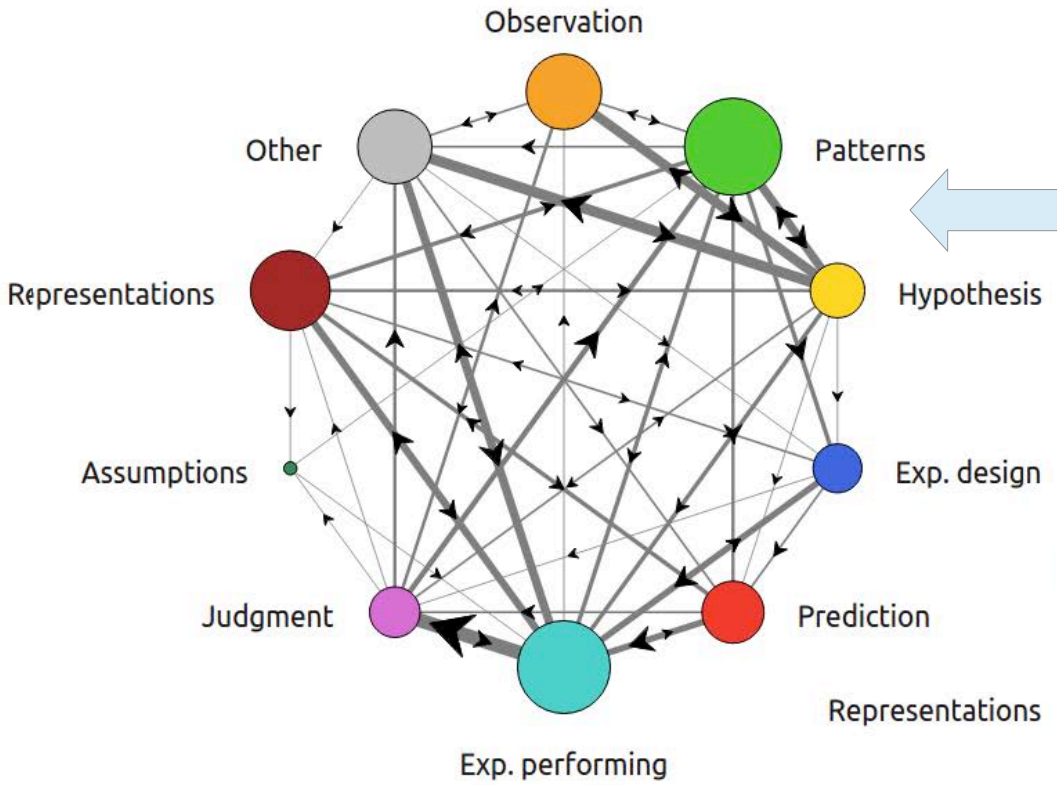
Transition graph for students



Comparison students - experts

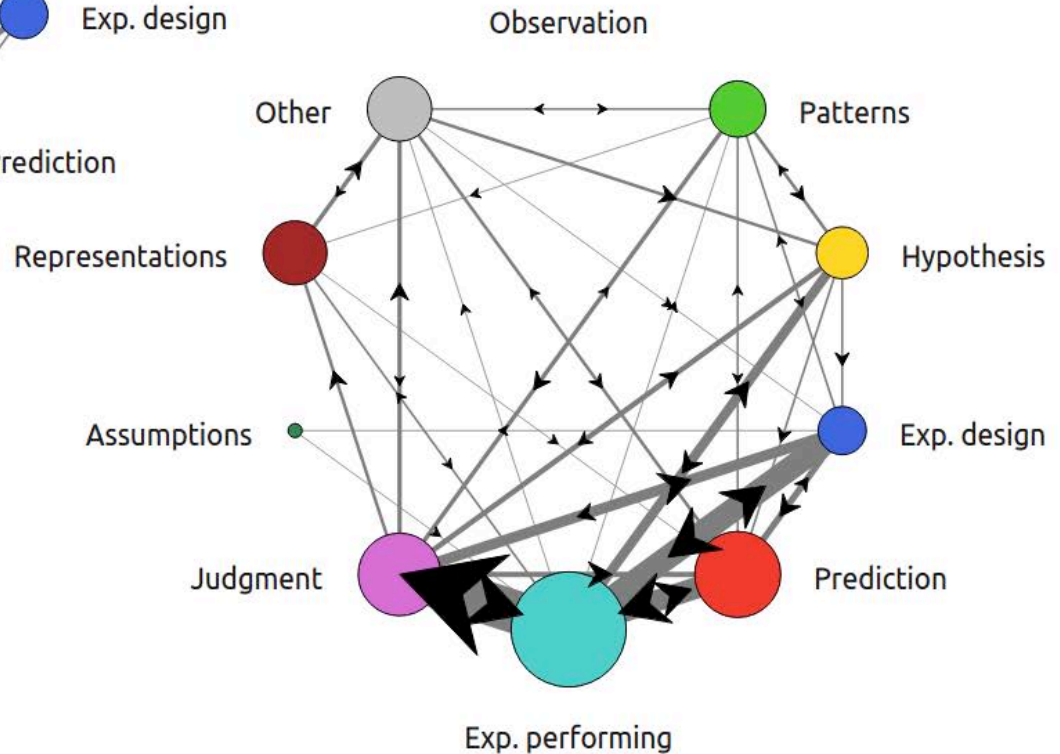


Students: time evolution



0 – 45 min

45 – 91 min



Summary of the study

It looks like ISLE cycle does indeed reflect what experts do when they solve experimental problems.

When doing problem solving the experts collaborate closely and are not afraid to propose “crazy ideas” and test them immediately.

Novices when faced with the same problem at first exhibit different behaviors but very quickly “adopt” expert behaviors.

How do we assess if students are learning to think like scientists?

We can observe them – and record and analyze what they are doing.

We can give them special tasks and assess their performance.

We can collect their work and search for evidence of “thinking like a physicist”.

But to do any of this we need to define what we are looking for.

Physicists (for example)

represent physical processes and ideas in different ways

design experimental investigations

collect and analyze data

devise and test ideas (mathematical models, mechanisms, etc.)

modify their ideas in light of new data

evaluate

communicate

Work together and do it again and again

What do we wish our students to learn? scientific abilities - list made by the Rutgers group in 2005

To represent physical processes and ideas

To design an experimental investigation (three types)

To collect and analyzing data

To devise and testing a qualitative explanation or a quantitative relation

To modify an explanation or a relation in light of new data

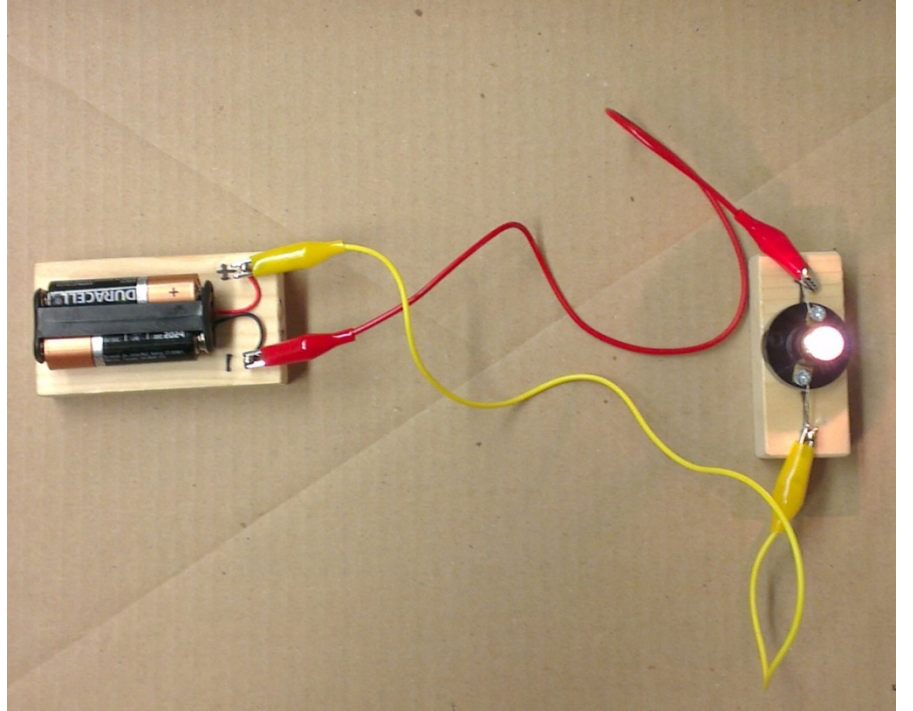
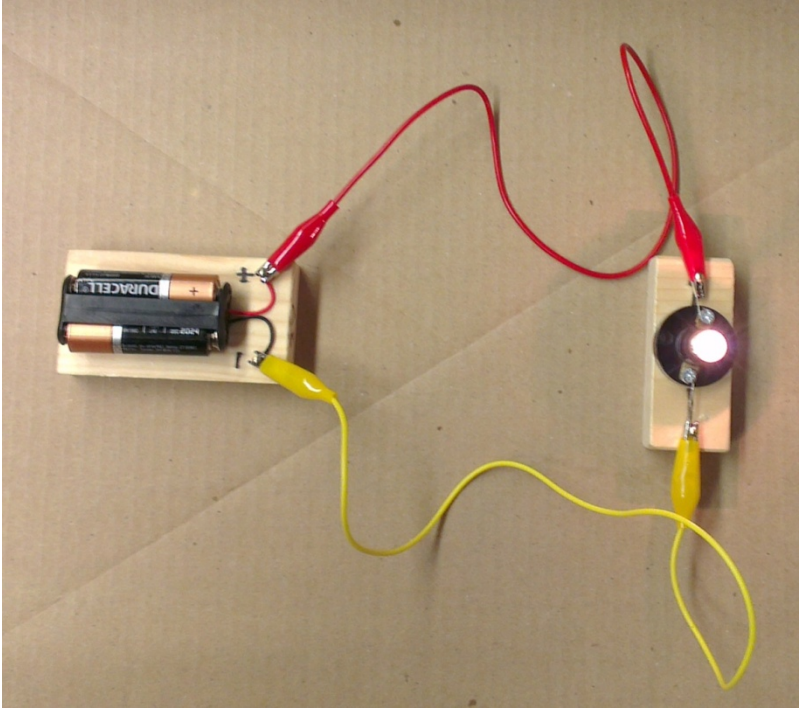
To evaluate (assumptions, solutions, experimental designs)

To communicate

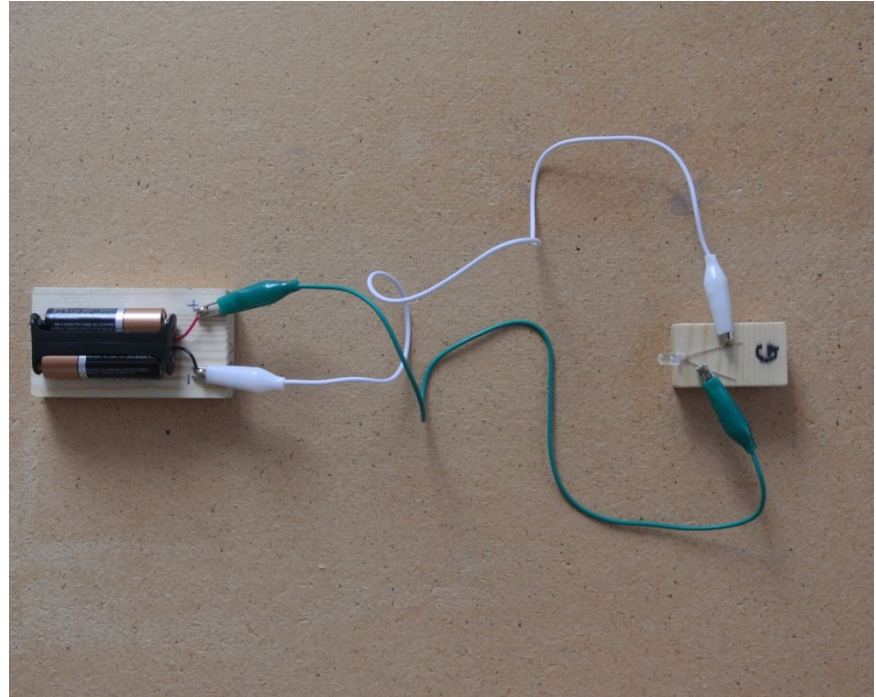
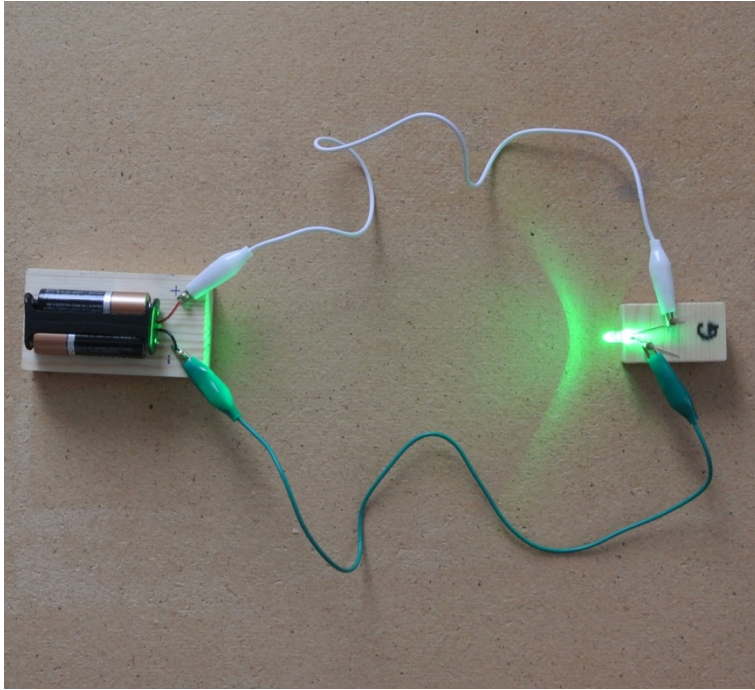
Example of a full ISLE cycle

Observational experiments Your goal is to make a circuit with the light bulb and make it glow and another one with the LED and make it glow.

Investigate how the order and orientation of the elements in a circuit (including the number of the batteries) affect the outcome of the experiment. **Compare and contrast the conditions for glowing of each light source.**



OBSERVATIONAL EXPERIMENTS



Patterns and explanations Describe the patterns that you found and present them in a table.

Devise several causal explanations for the observed patterns.

Kerry thinks that LEDs conduct and glow when current through them is in one direction and the voltage exceeds some minimal voltage;

Marcos thinks that LEDs conduct current in both directions (like a bulb) but glow only when the current is in one direction and voltage exceeds some minimal voltage.

What is the difference in Kerry's and Marcos' ideas? Design experiments to test both of them.

Testing experiments

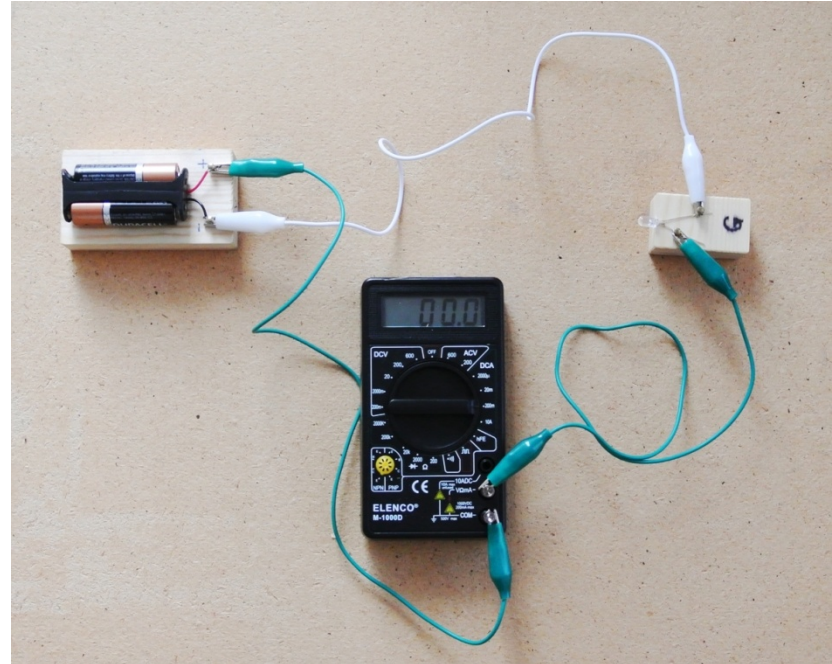
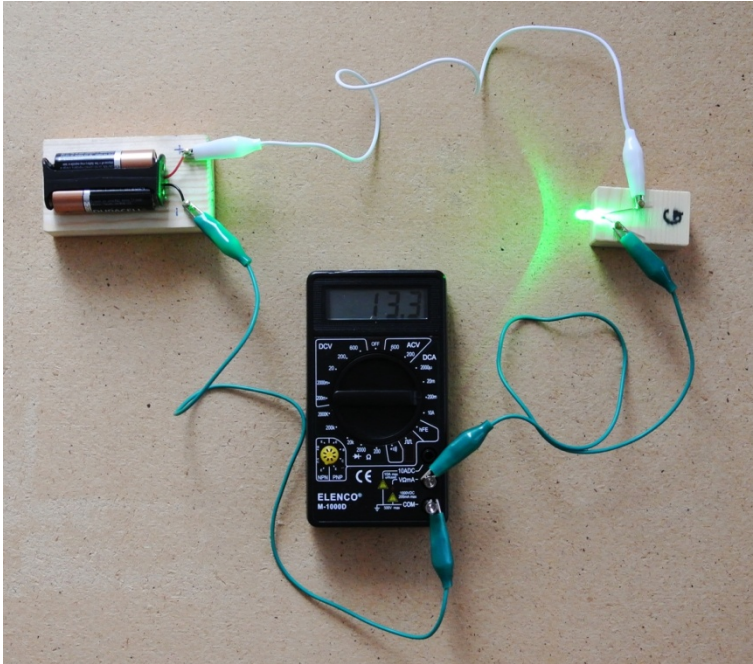
Propose experiments to test the explanations (do not perform them).

Use the explanations to make predictions of the outcomes of these experiments before you perform them. Write them here.

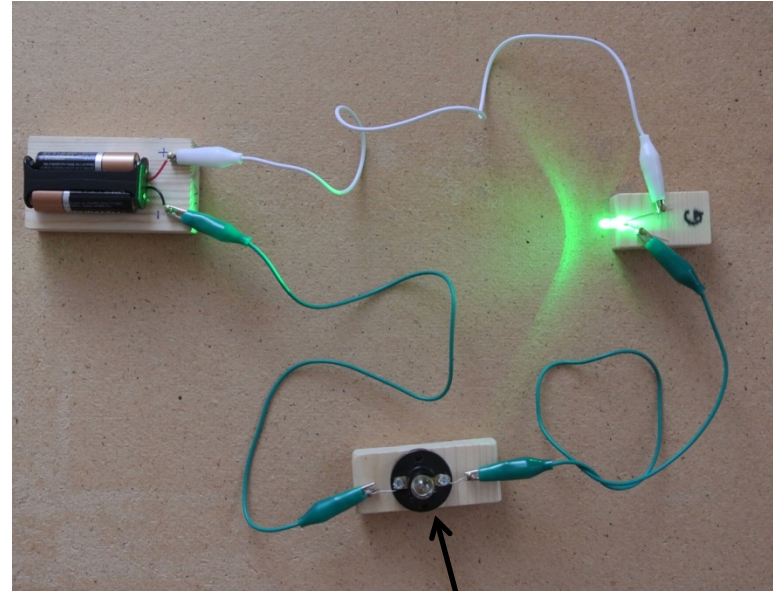
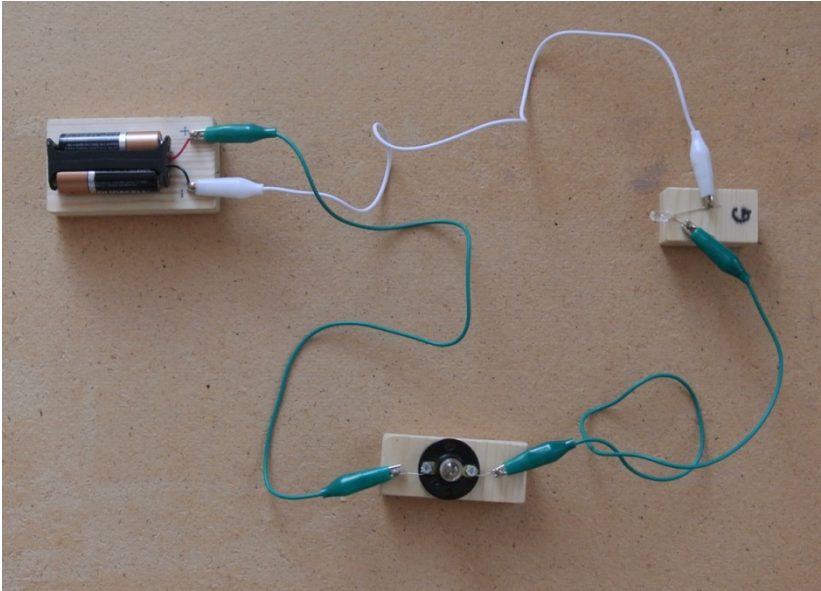
Perform the experiments and record the outcomes.

Make a judgment about both explanations.

TESTING EXPERIMENT 1



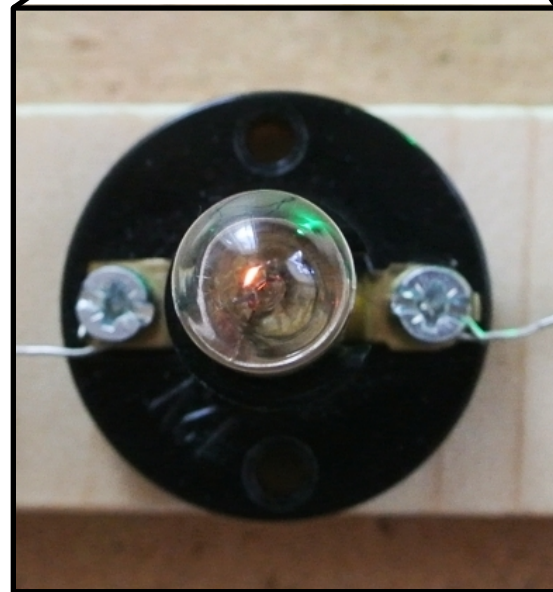
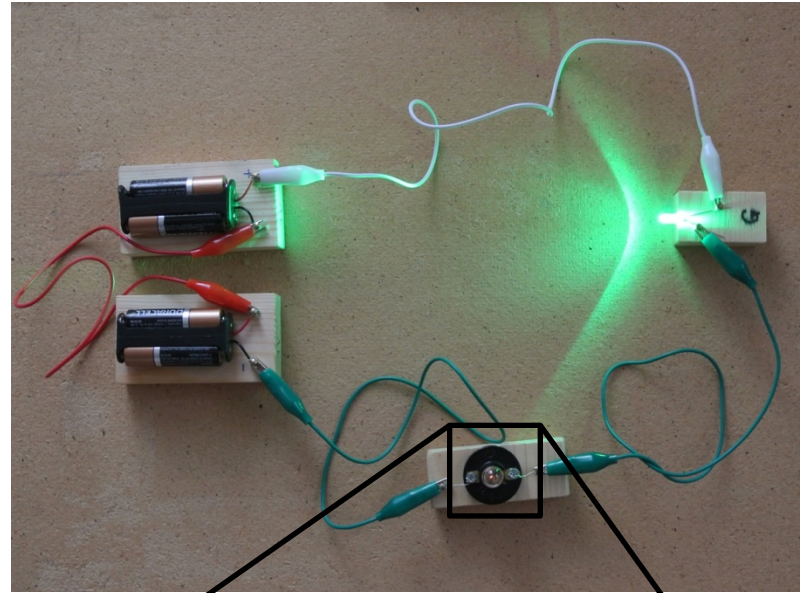
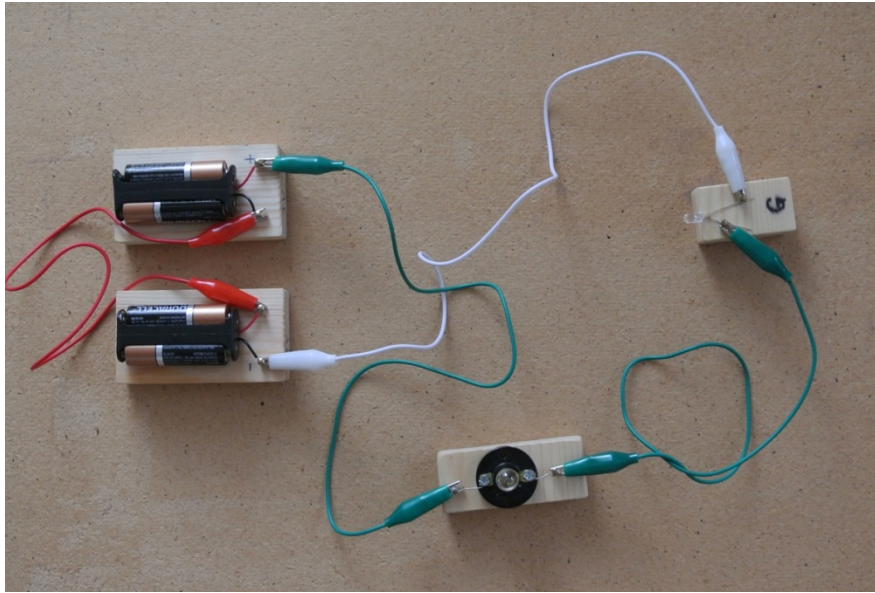
TESTING EXPERIMENT 2



Assumptions ...

Bulb does not
glow

IMPROVED TESTING EXPERIMENT 2



What will students learn here?

1. The difference between an LED and an incandescent light bulb.
2. The main properties of LEDs.
3. How to propose different explanations of the same observations and how to test them experimentally.

But my students have never designed an experiment – they cannot do this...

When students design their own experiments
they

are guided by questions that tell them what to think about
not what to do;

self-assess their work and improve it with the help of rubrics

Self-assessment rubric

LEVEL ABILITY	Missing (0)	Not adequate (1)	Needs improvement (2)	Adequate (3)
Is able to distinguish between a hypothesis and a prediction	No prediction is made. The experiment is not treated as a testing experiment.	A prediction is made but it is identical to the hypothesis.	A prediction is made and is distinct from the hypothesis but does not describe the outcome of the designed experiment.	A prediction is made, is distinct from the hypothesis, and describes the outcome of the designed experiment

Basic rubric structure

LEVEL ABILITY	Missing (0)	Not adequate (1)	Needs improvement (2)	Adequate (3)
<p>Small sub ability</p> <p>Drawing a force diagram</p> <p>Comparing results of two experiments</p>	<p>A student does not know that she/he needs to address this issue</p>	<p>A student knows that she/he needs to write something but what is written is vague (description of what is missing)</p>	<p>A student writes relevant things with some minor omissions (description of what is missing)</p>	<p>As perfect as we can expect (a list of all good stuff)</p>

ISLE classroom at Rutgers



Students testing their ideas



Symposium – student-invented ending of the lab



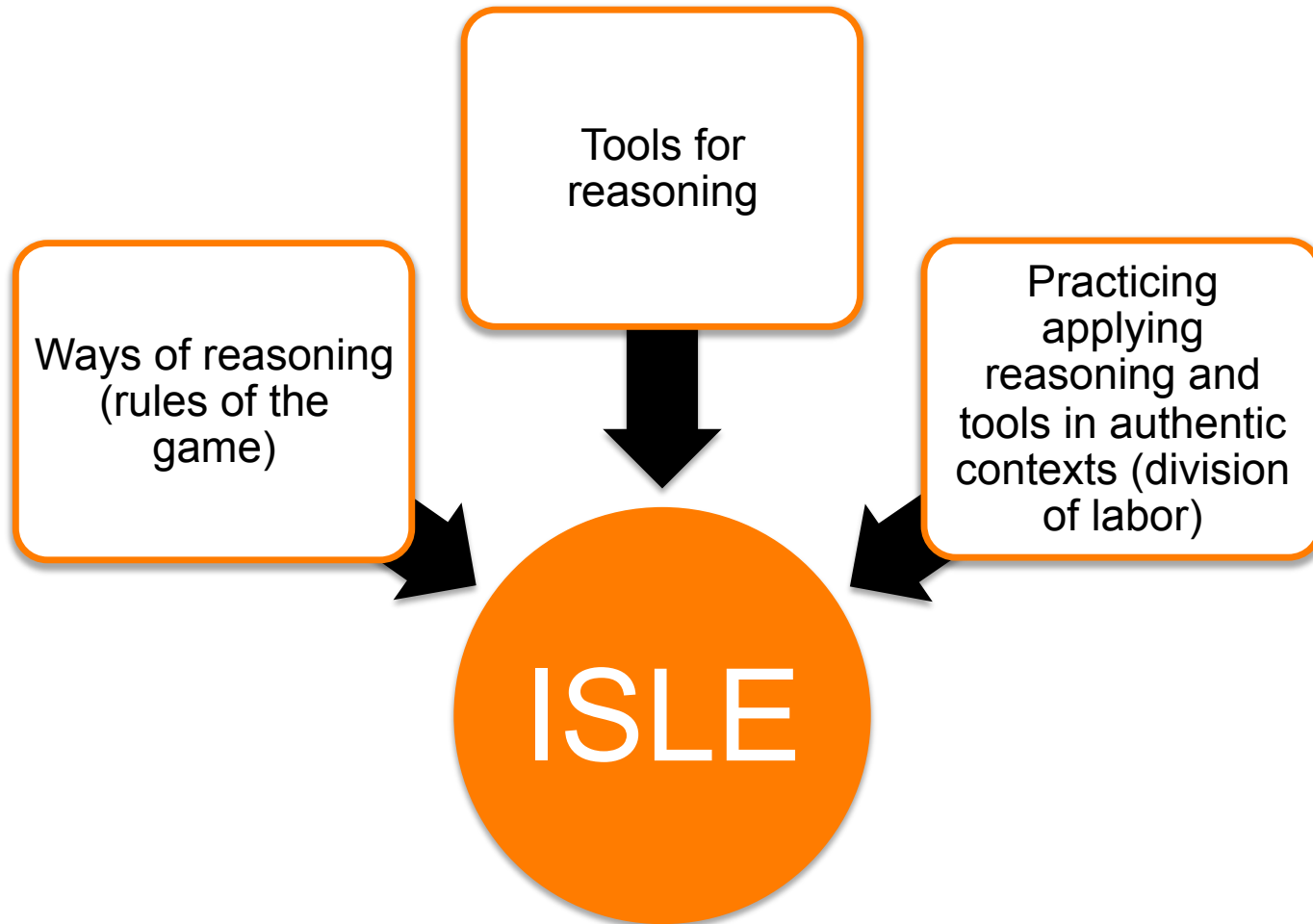
What is ISLE?

ISLE is kind of a philosophy for the instructors (what will my students do to come up with XX) and kind of a game for the students (how can I test my ideas?).

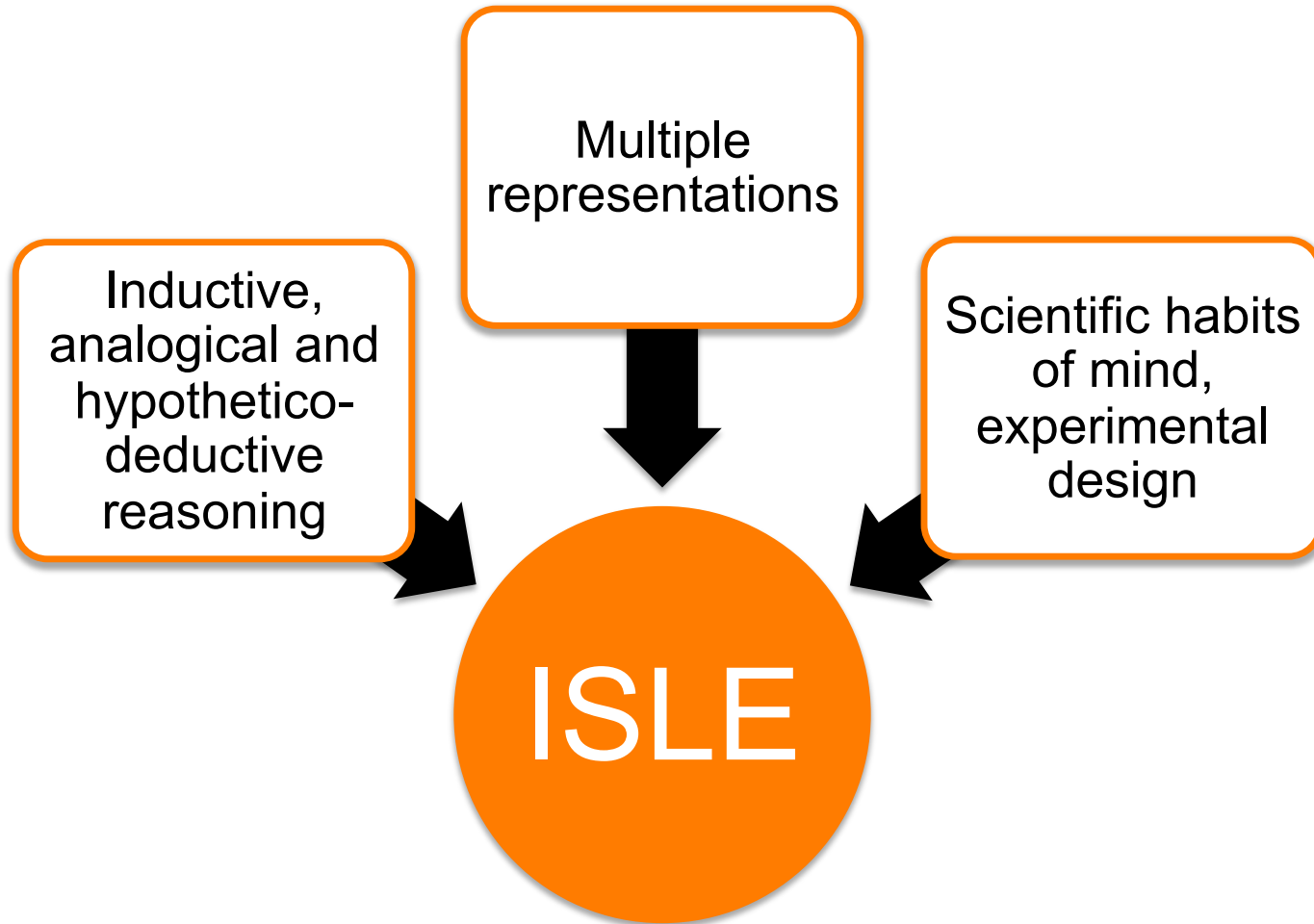
The most important thing: the students can explain how they know what they know.

ISLE philosophy be used in any course – science in the elementary school or a physics graduate course. Your TEAL classrooms are perfect for ISLE.

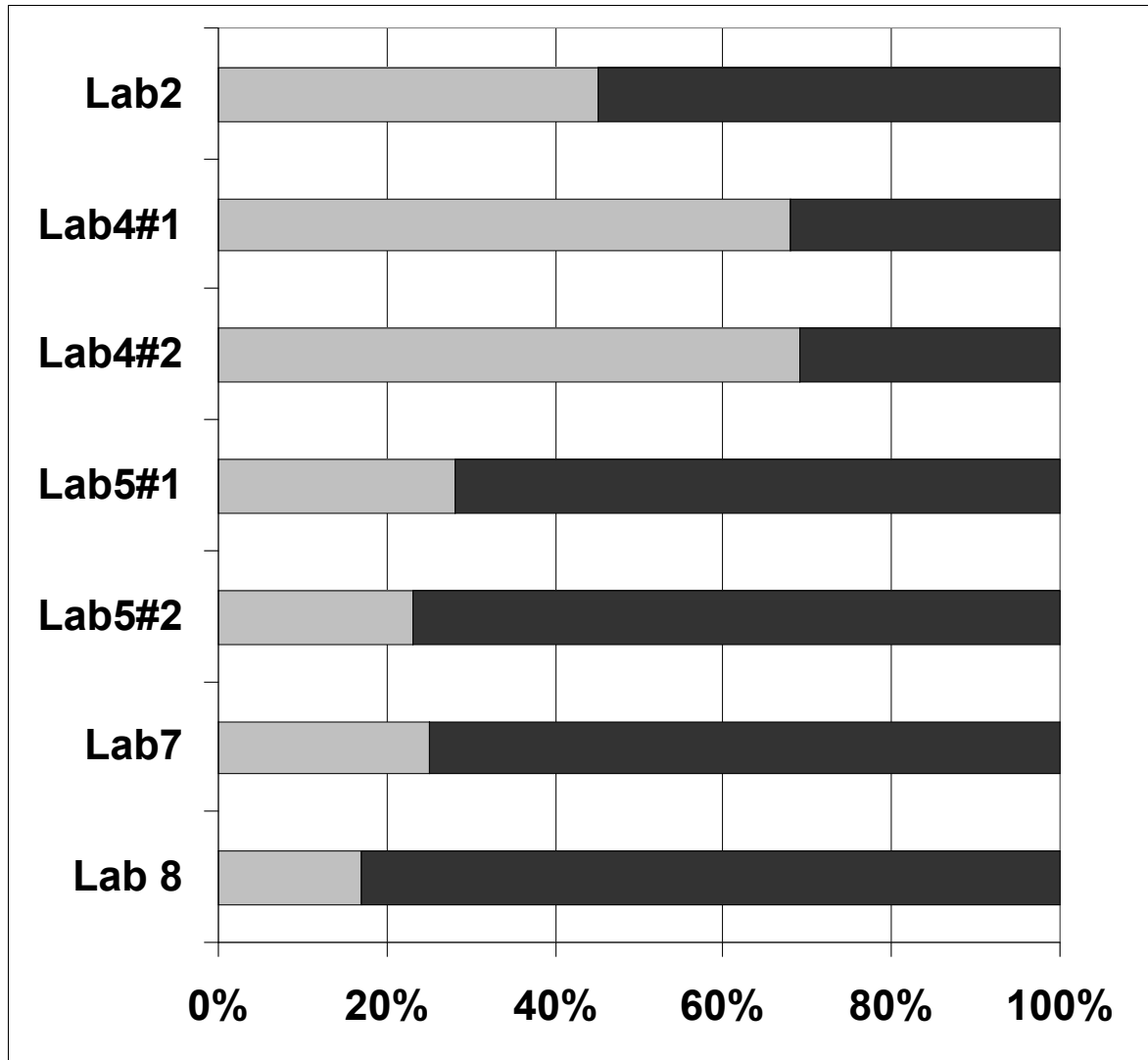
Three pillars of ISLE



Three pillars of ISLE



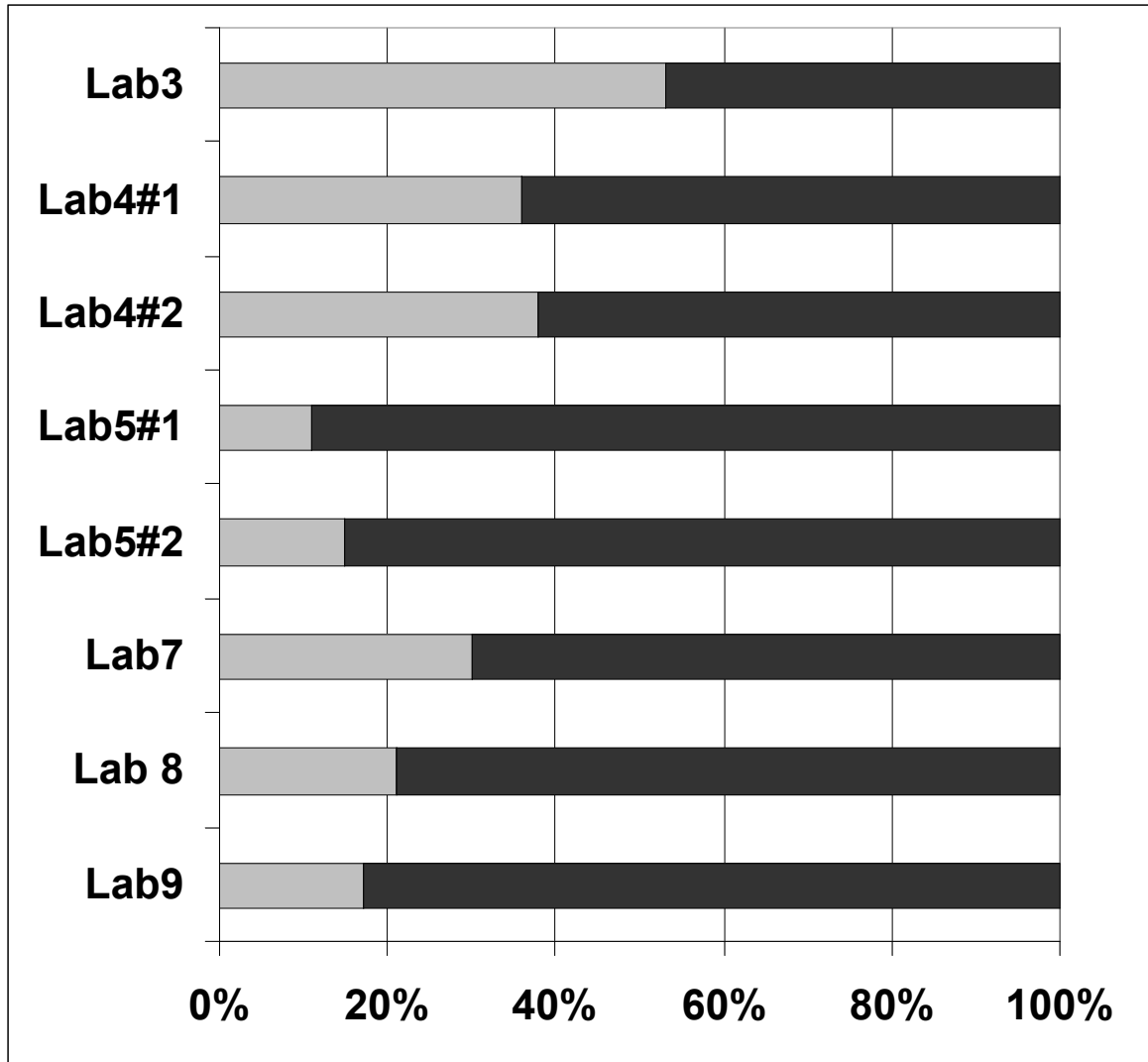
Ability to evaluate uncertainties estimating the largest percent uncertainty



0&1

2&3

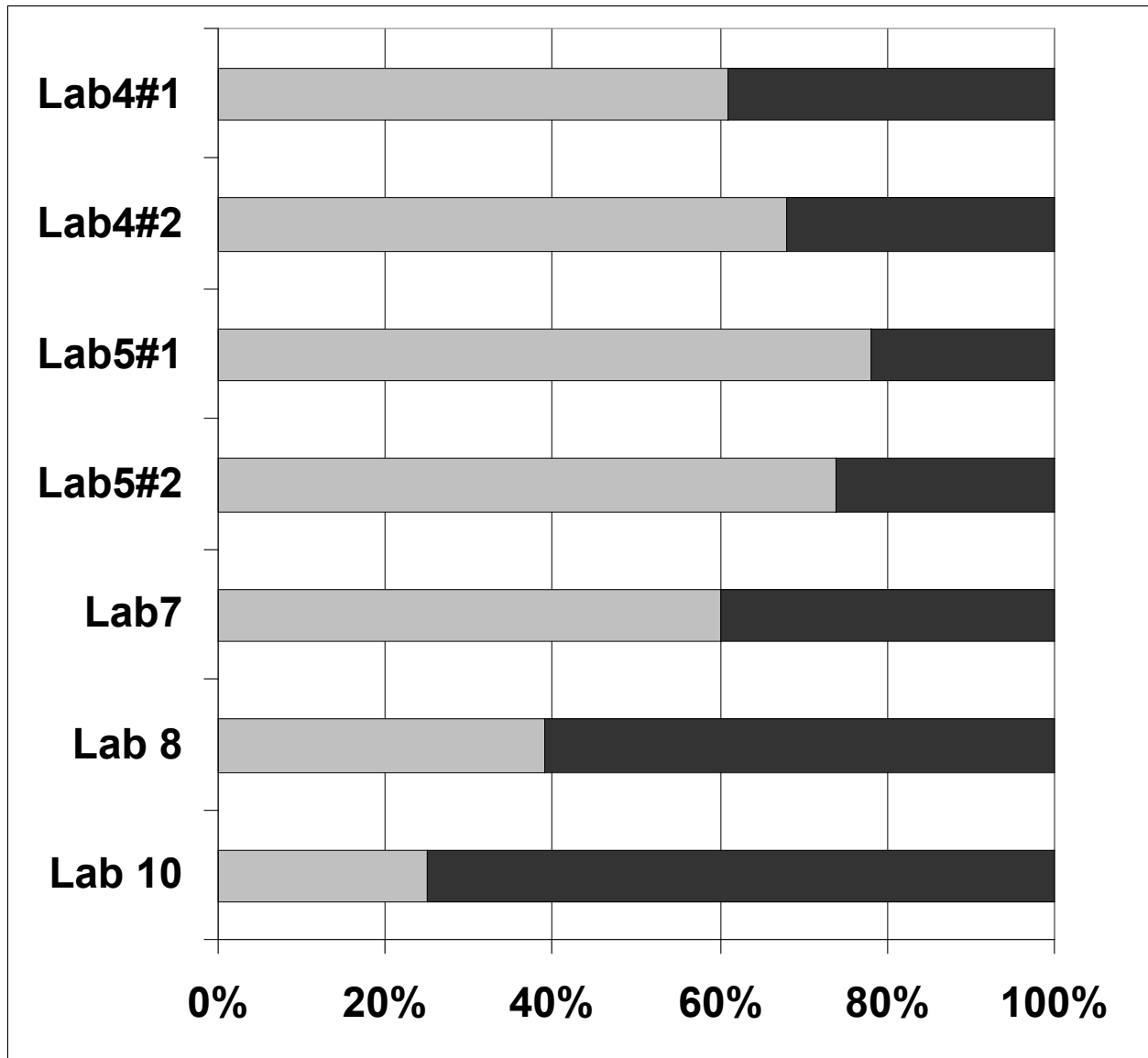
Ability to identify assumptions



0&1

2&3

Ability to evaluate assumptions



0&1

2&3

Do ISLE students know how they know something?

What will your students say if you ask them how do you know something?

2000

Alan Van Heuvelen: Do you remember Newton's second law?

Class: "Yes!" and many volunteered to say what it is.

AVH: How do you know it?

Class: You told us...

Non-ISLE students who answered all 4 Newton's 3rd law questions on FCI correctly

How do you know that Newton's third law is true?

001: Because I took physics 140. I don't know, I just know that...

013: I guess it's just an established law of physics.

014: I remember that from high school...

017: ...that law is probably one of the only things I took out of physics 114...

033: I remember from my physics class..."every action has an equal and opposite reaction."

037: ...just from having a physics class before...forces are always equal when they are opposing each other.

ISLE students

003: I know it's true experimentally. I could use two of those spring thingies we had in class that measures force, hook them up, and pull.

005: Punch a wall...The pain caused by punching a wall is a result of the force the wall exerts on the fist. As you increase the force behind your punch, the force the wall exerts on your fist increases proportionally, and therefore the pain you experience increases as well.

009: I know Newton's third law is true because my classmates and I assembled an experiment in which we allowed wheeled carts to collide.

010: I have, along with others, performed many experiments that support the claim and **have not found or devised an experiment that disproves it.**

But there is more to what students learn in the ISLE environment

**Experimental and control group
Same ISLE course**

Experimental group

Control group

ISLE labs, design

Non-design labs

Week 1-10

Comparison

**Designing a physics
experiment**

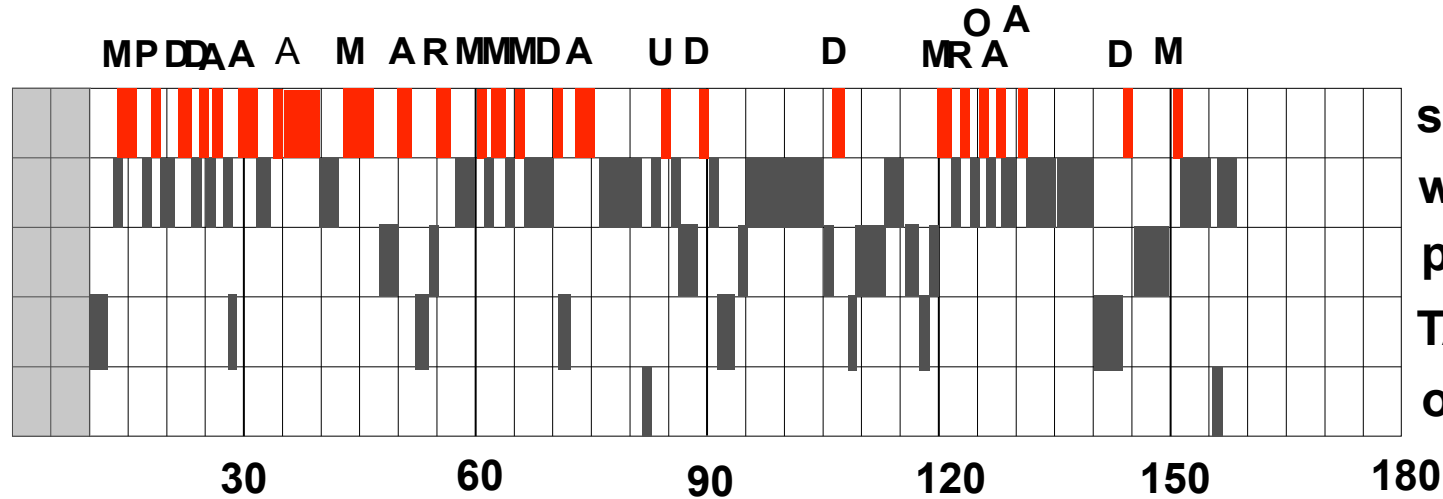
Week 12

**Designing a biology
experiment**

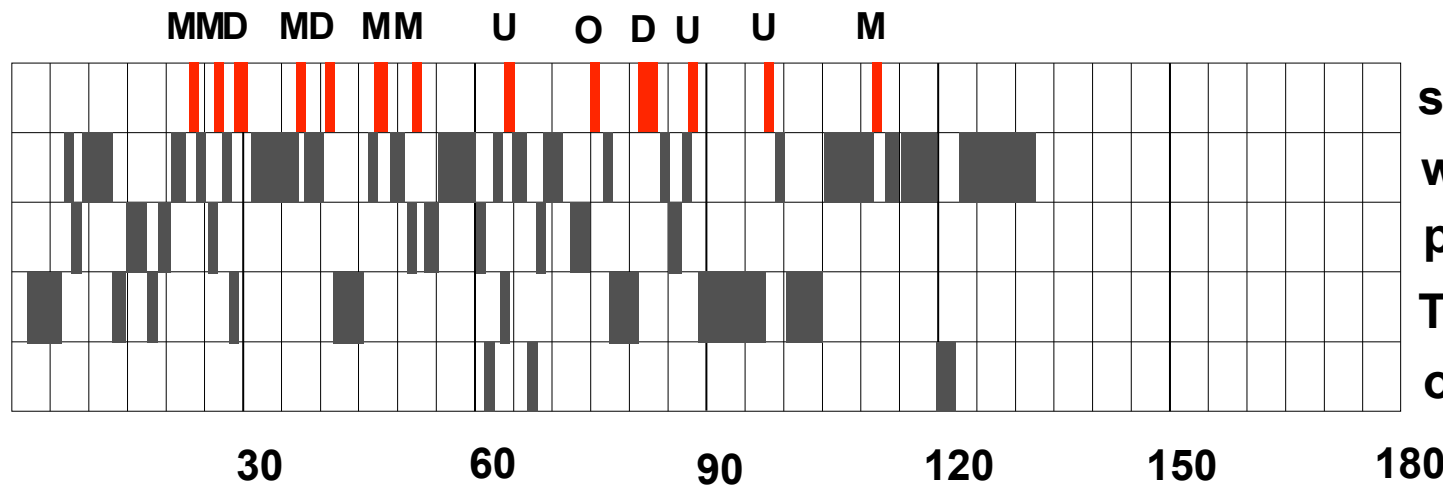
Week 13

Students' activities during semester labs

ISLE labs Group

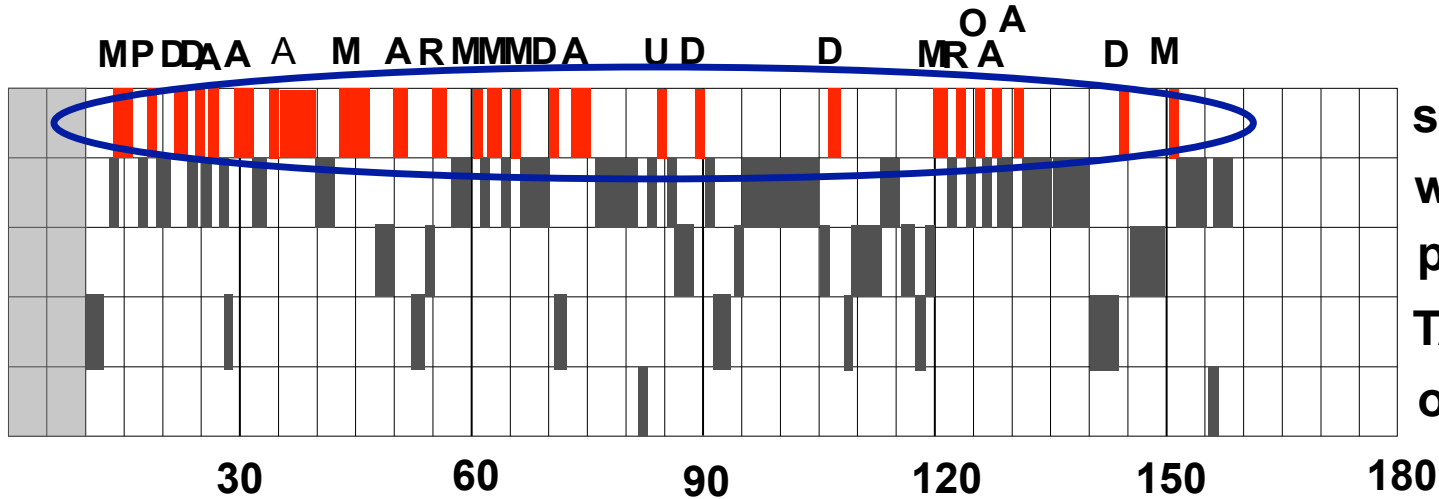


Non-ISLE labs Group

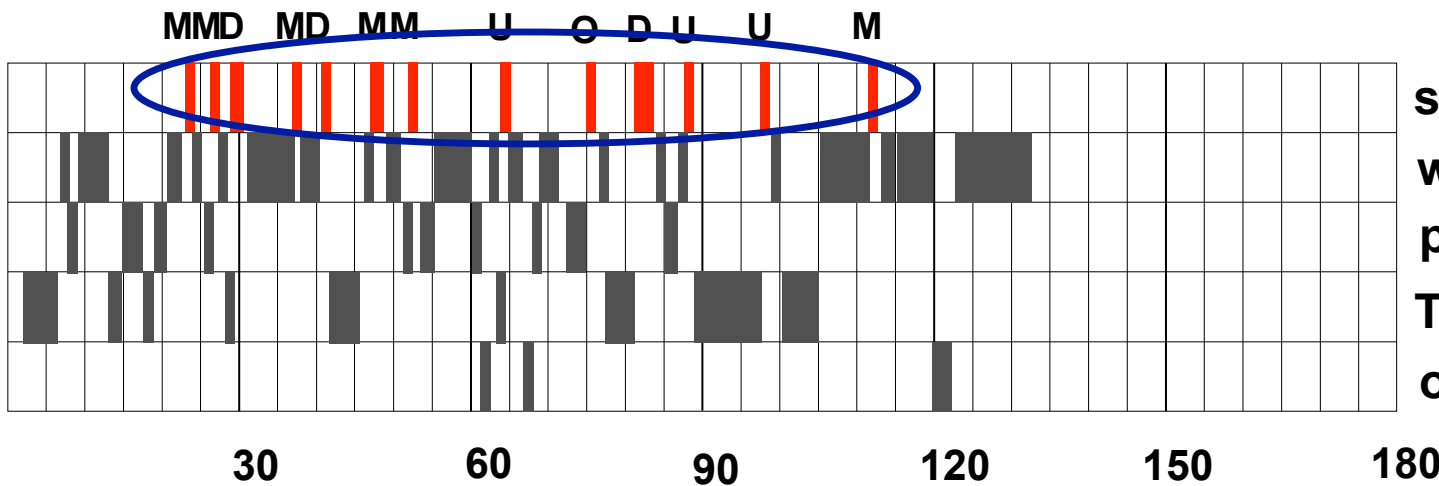


Students' activities during semester labs

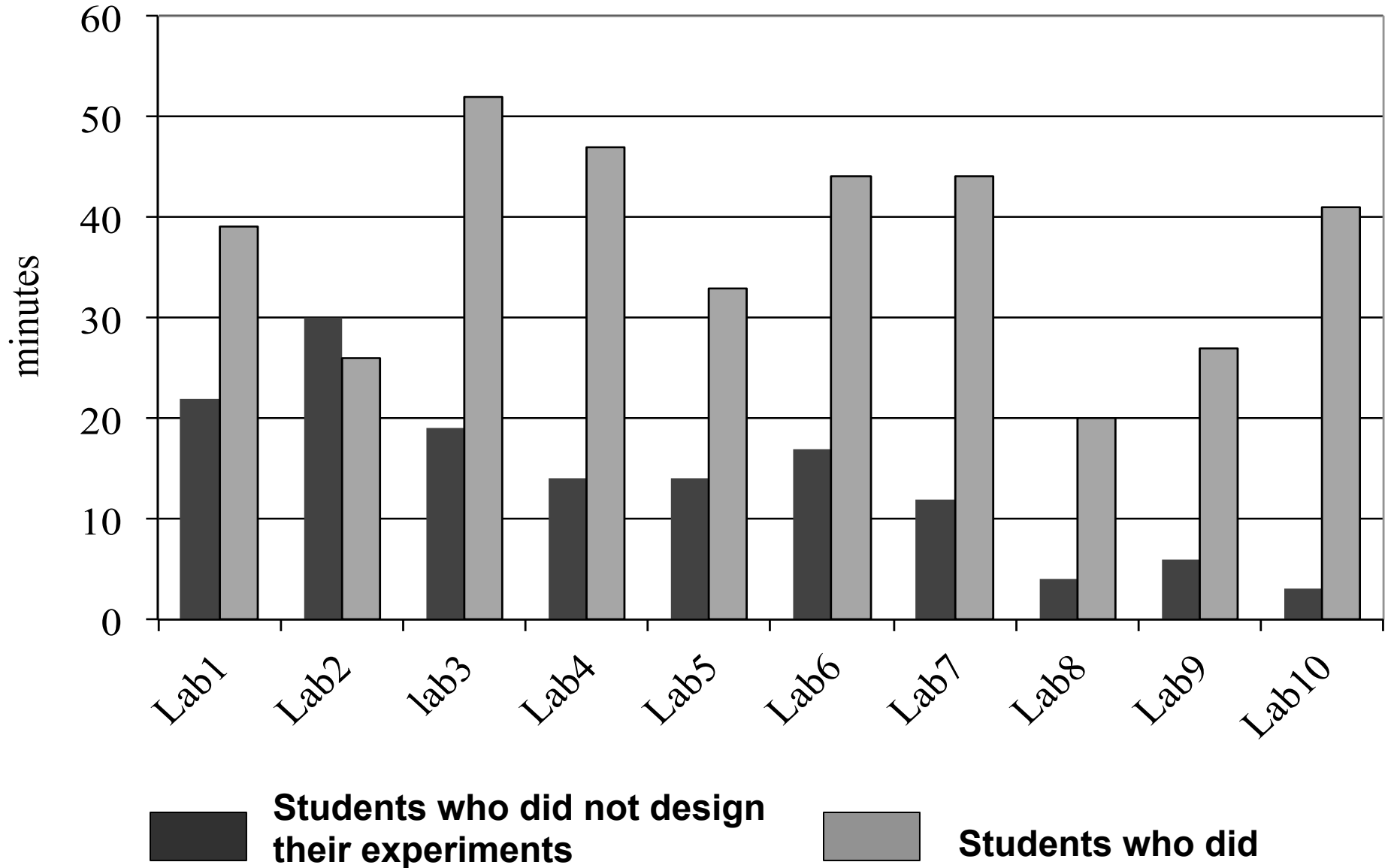
ISLE labs Group



Non-ISLE labs Group

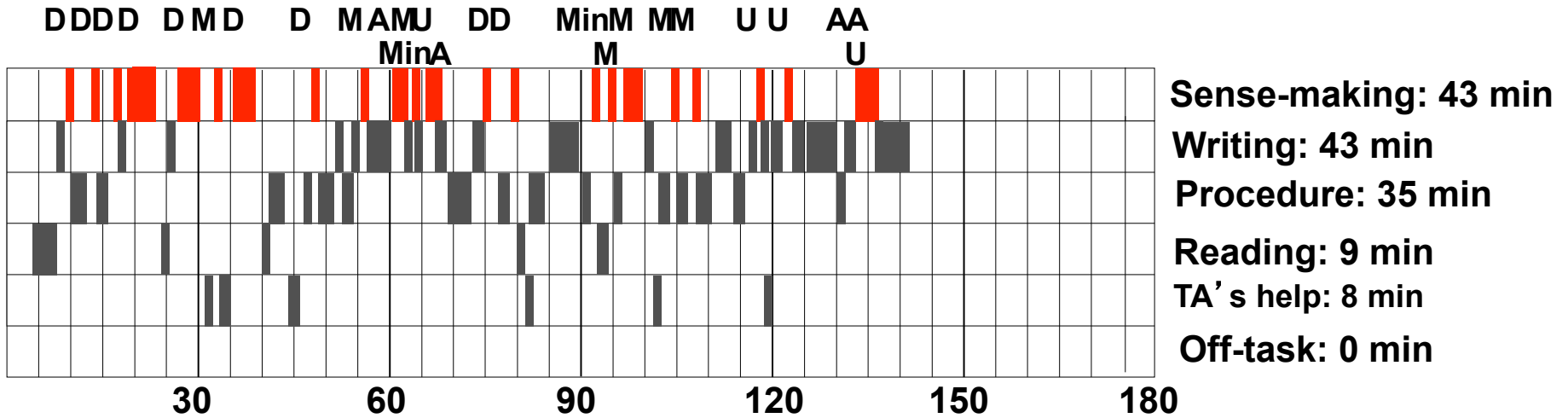


Sense-making week by week

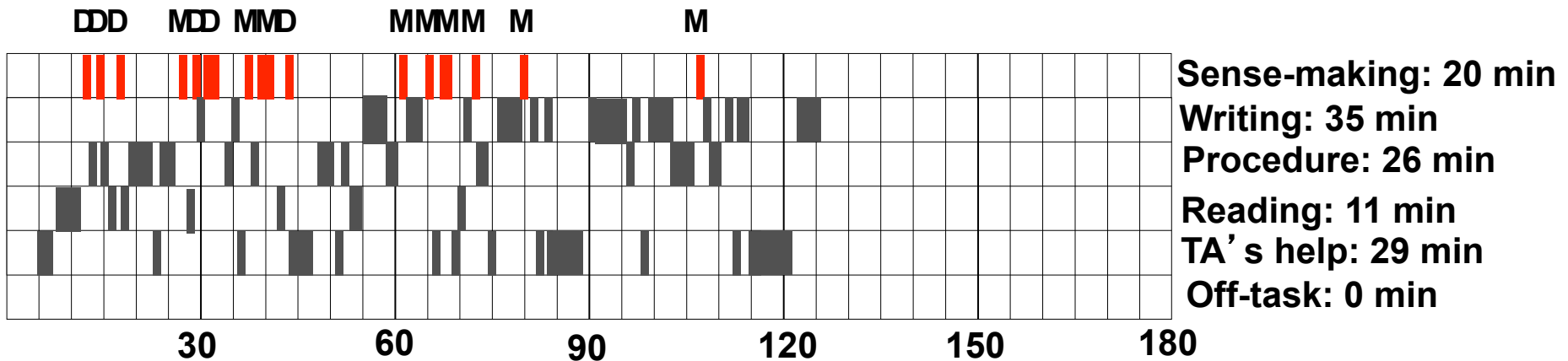


Students' activities during physics "transfer" lab

ISLE Group

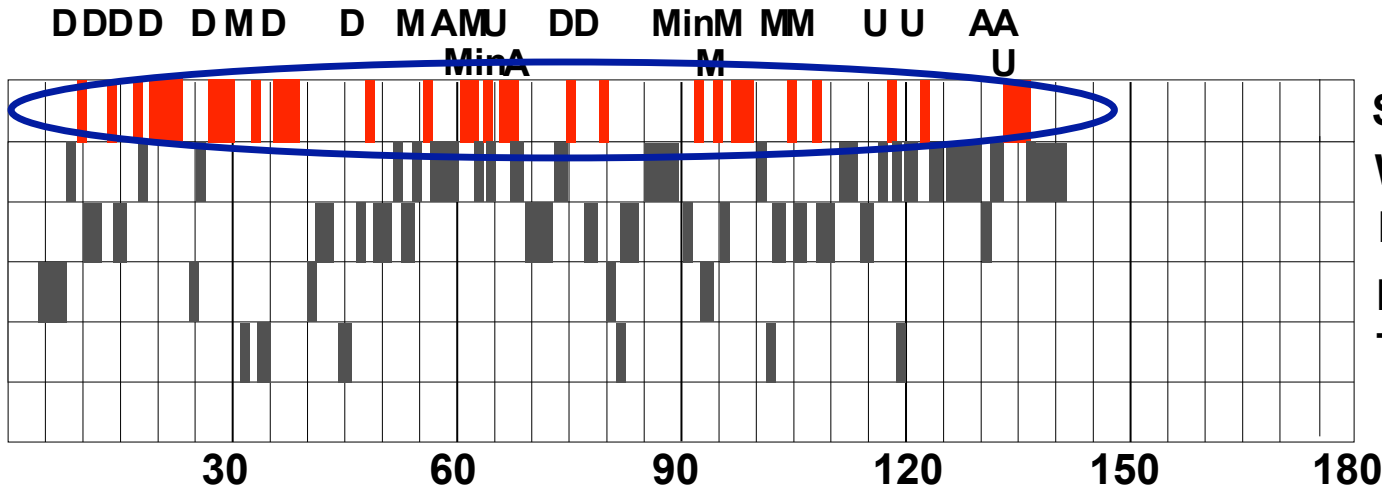


Non-ISLE Group



Students' activities during physics "transfer" lab

ISLE Group



Sense-making: 43 min

Writing: 43 min

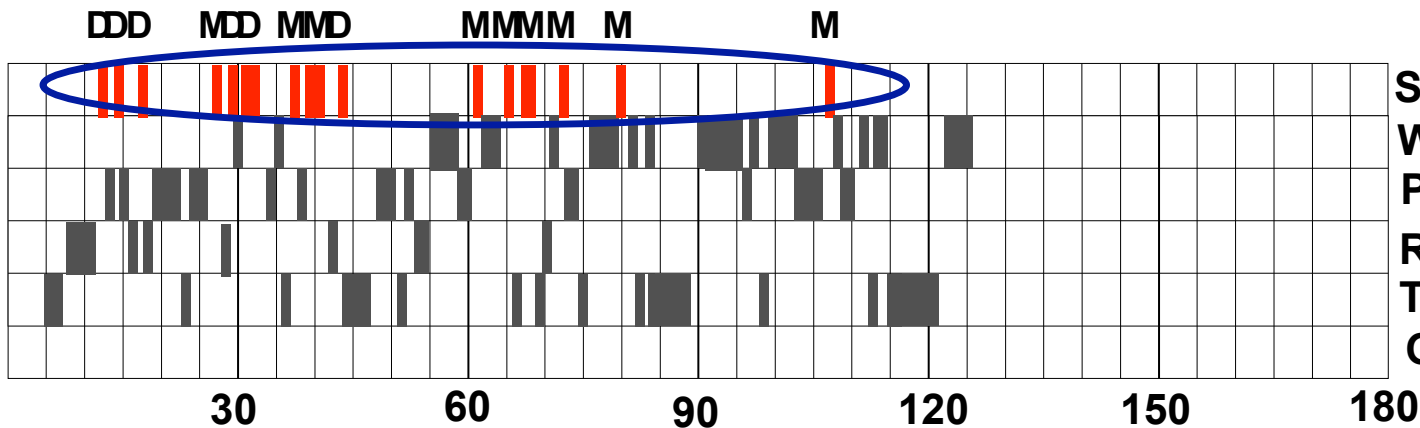
Procedure: 35 min

Reading: 9 min

TA's help: 8 min

Off-task: 0 min

Non-ISLE Group



Sense-making: 20 min

Writing: 35 min

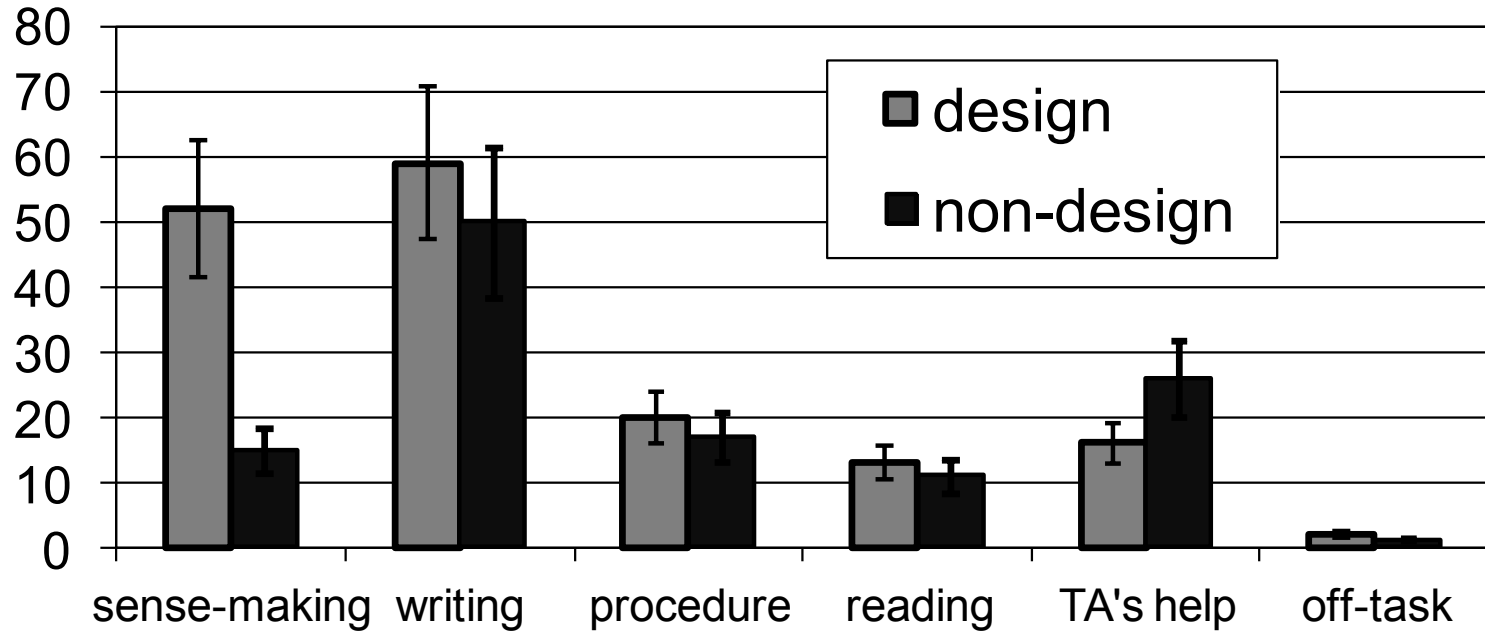
Procedure: 26 min

Reading: 11 min

TA's help: 29 min

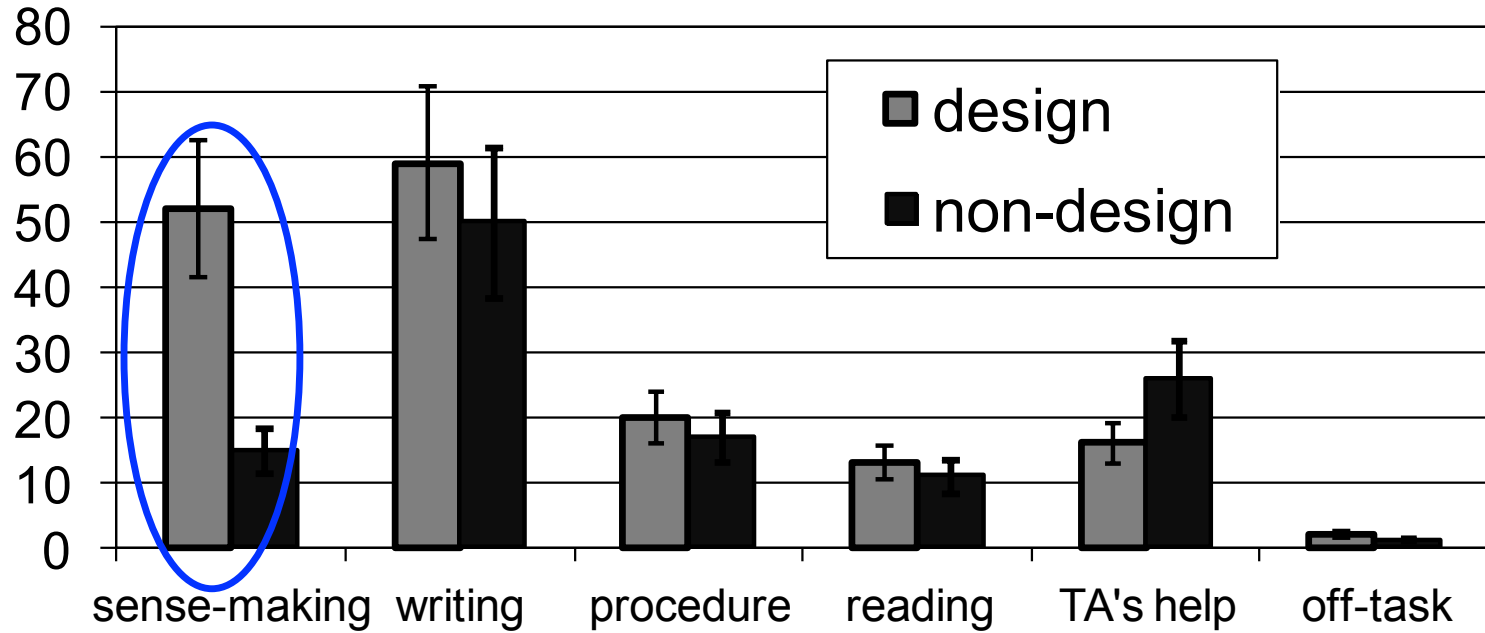
Off-task: 0 min

Time spent on lab activities



	ISLE	Non-ISLE	p - level of significance
Total time	162±17min	120±25min	0.0375
Sense-making	52±10min	15±5min	0.0007

Time spent on lab activities

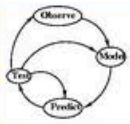


	ISLE	Non-ISLE	p - level of significance
Total time	162±17min	120±25min	0.0375
Sense-making	52±10min	15±5min	0.0007

Physics Teaching Technology Resource

Users

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Introduction

This is a long introduction for physics teachers and those interested in [Prof. Etkina's](#) teaching methods.

Information

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site



Motion

Learning cycles on the subject of Kinematics.



Newton

Learning cycles on Newton's Laws

AS SPORE
inner

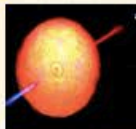


Circular and Rotational Motion

Learning cycles on circular and motion and motion with rotation in it

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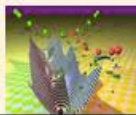


Energy

Learning cycles on work and energy.

Latest update

Updated
on 2012-
13:22:13



Harmonic Motion and Waves

Learning cycles on simple harmonic motion, travelling and standing waves

<https://sites.google.com/site/scientificabilities/>

Scientific Abilities

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Introduction

Instructor site access: If you are an educator and would like access to additional instructor resources you can request it by email. Please include your name and affiliation along with the email address you'd like the invitation sent to (this works best if the email address is associated with a Google account). *If you had instructor-level access on the previous version of this site you still need to request access to this site.*

Introduction to Scientific Abilities

Welcome to the website of the Rutgers Physics and Astronomy Education Research group dedicated to "Scientific Abilities". This project was originally sponsored by the National Science Foundation program "Assessing Student Achievement" (NSF-ASA) but over the years it became a self-sustaining project and now Scientific Abilities are a component of ISLE philosophy. Many people contributed to this project over the years. The list of names is very long and includes: Eugenia Etkina, Alan Van Heuvelen, Suzanne Brahmia, David Brookes, Michael Gentile, Anna Karelina, Michael Lawrence, Marina Milner-Bolotin, Sahana Murthy, Maria Ruibal-Villasenor, Aaron Warren, Xueli Zou.

Scientific abilities are "habits of mind" of scientists and engineers, things that they do on a regular basis in their work. But as these things are not automated and always require deep thinking and self-evaluation, we do not call them science skills, We call them scientific abilities. Next Generation Science Standards and new AP Physics courses use the term "science practices". There is a lot of overlap in all of those, but



Physics Union Mathematics

PUM is a physics/physical science curriculum that strongly links middle and high school physics curricula and builds on the intrinsic mathematical reasoning to develop and strengthen students' mathematical concepts at the pre-algebra, algebra and algebra 2 levels. *PUM* curriculum consists of logically connected modules that allow students to build their conceptual understanding of physics concepts, develop relevant mathematical reasoning and simultaneously learn how to think like scientists. The following modules are developed and are available upon request:

- Physics I (these can be used in middle school physical science courses, high school physical science courses, and high school conceptual physics courses): Motion; Forces, Energy, Matter.
- Physics II: (can be used in all high school physics courses including AP B): Kinematics, Dynamics, Momentum, Energy, Electrostatic Forces, Electric Fields, DC circuits (circular motion, geometrical optics and magnetism are under development).

PUM modules contain lesson activities, homework questions, daily quiz questions and final tests. They use simple equipment that any school is likely to have. In case of the lack of needed equipment, Rutgers has a small lending library. The modules work with any textbook and can be implemented "as is" or used to supplement any materials that the teacher already uses. Each module contains about 20-25 lessons.

To obtain the password to download the *PUM* modules, please contact E. Etkina at eugenia.etkina@gsc.rutgers.edu

In *PUM*

- Students learn physics by engaging in practices similar to that of physicists constructing and

PUM Events

Monday, July 7

9:00am PUM Worksho

Tuesday, July 8

9:00am PUM Worksho

Wednesday, July 9

9:00am PUM Worksho

Thursday, July 10

9:00am PUM Worksho

Friday, July 11

9:00am PUM Worksho

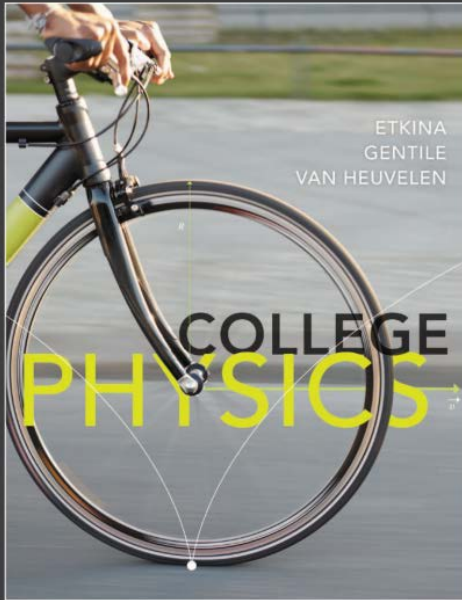
Sunday, July 27



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GENTILE
VAN HEUVELEN

COLLEGE
PHYSICS

Active Learning Guide



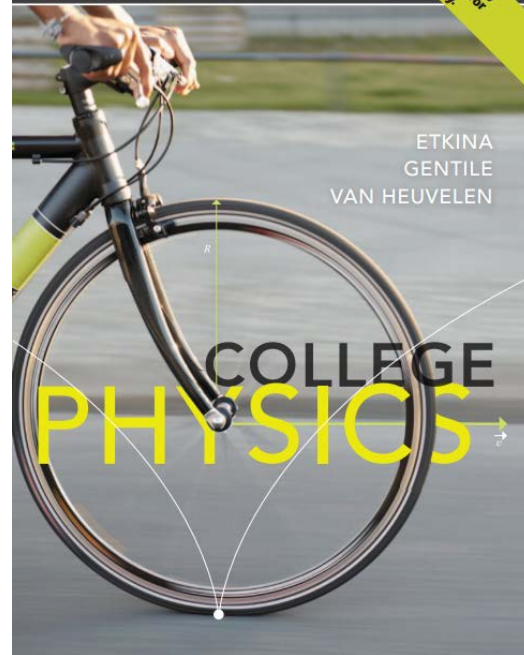
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INSTRUCTOR'S GUIDE
Etkina Brookes Van Heuvelen

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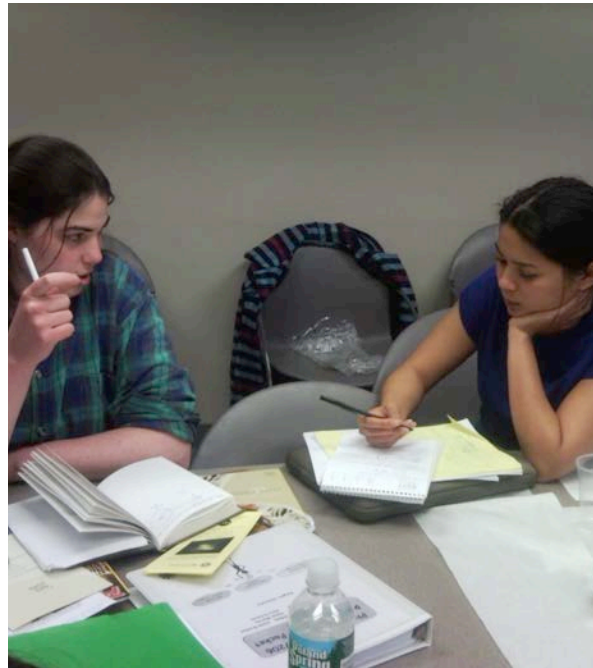
Rutgers Physics Teacher preparation program



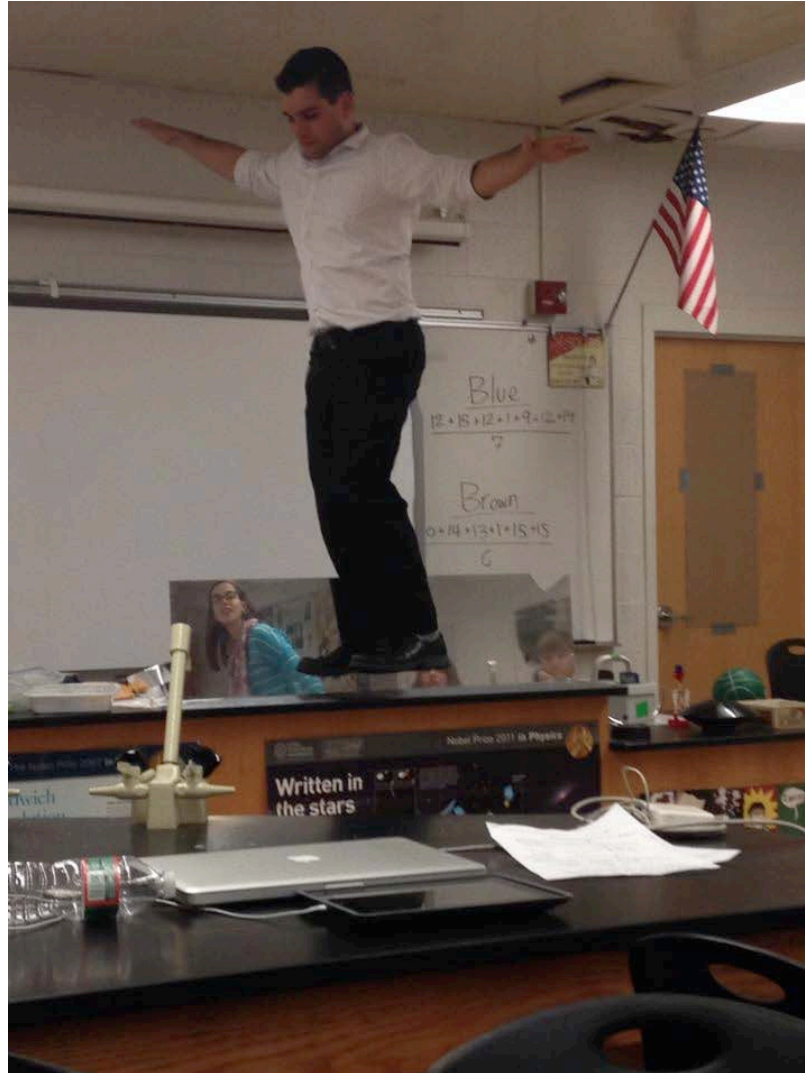
Since 2002 it prepared over 90 physics teachers.

ISLE is the framework for all coursework in the program.

Graduates of the program take ISLE to new levels.



Matt Blackman, graduate of 2010, Ridge HS, NJ



Makes ISLE-oriented physics teaching
computer games



UNIVERSE & MORE

Graphing Game

Electric Space Battle

Wave Superposition

Worksheets

Einstein Dollars™

Click to activate the physics.

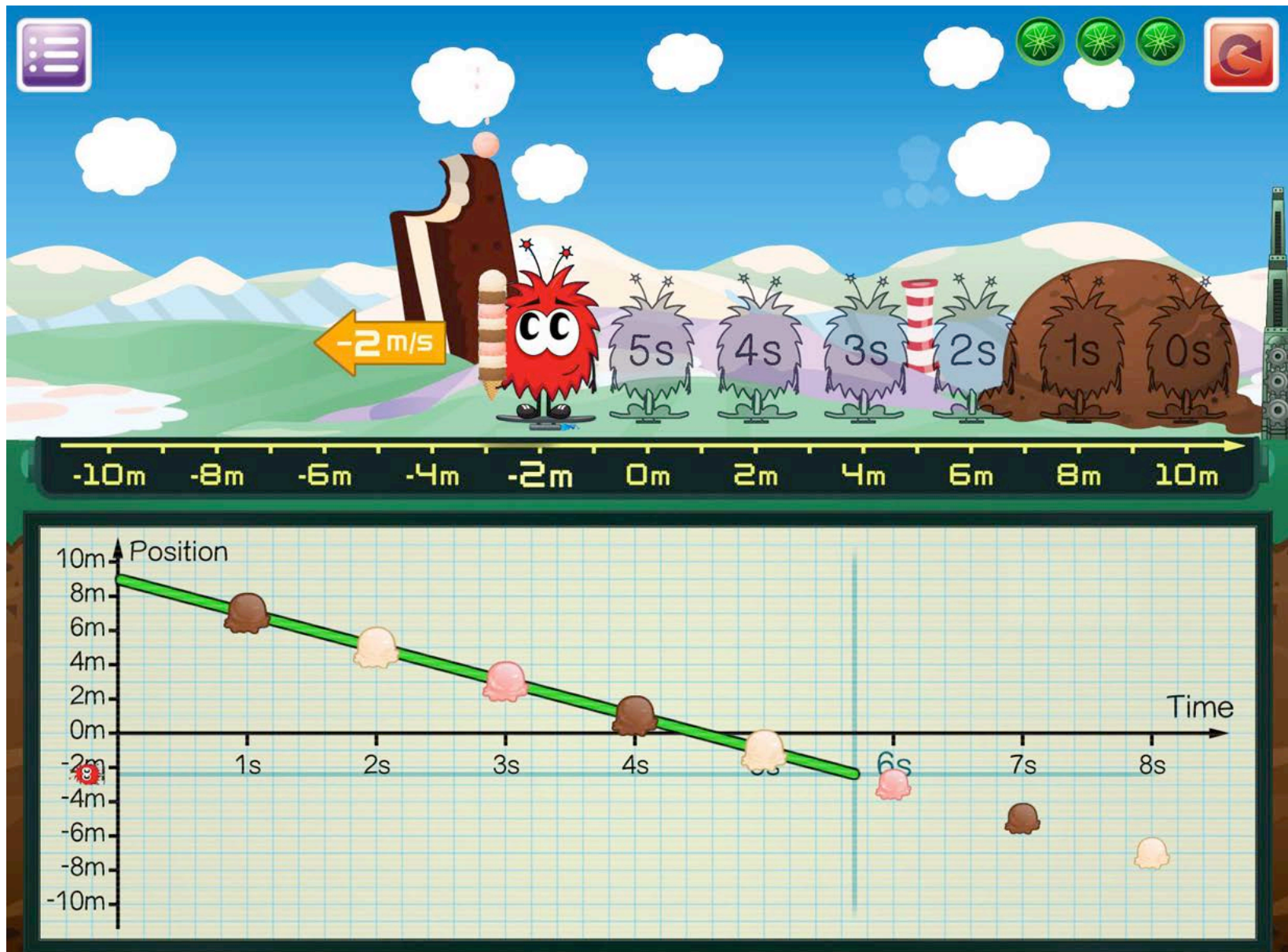


<http://www.theuniverseandmore.com>

One of them is below,
over 2 million people played it



Multiple representations in the game



James Flakker, graduate of 2008 Governor Livingston HS, NJ





NASA

Exploration Design Challenge



His students won a competition to perform an experiment on Space Station. They were chosen out of 150 proposals to design an experiment to test the effects of gravity on a system by performing the experiment in space and comparing it to the same experiment done on Earth. They proposed to test the development of mosquitos. Mosquito larvae attach to the surface of the water to feed on bacteria that grows near the surface. Will the larvae be able to develop to the pupae stage when the water is in this free fall environment?

THE FIRST ROCKET CARRYING MOSQUITO EGGS EXPLODED AT LAUNCH. THEY HAD TO MAKE THE WHOLE THING AGAIN!

Their mosquitoes went in space and one egg developed to the stage of pupa!

Honestly, it is not about teaching people how to think like physicists.

It is about teaching people how to think.

And to persist.

A university professor has a chance to teach about 2500 – 5000 students how to think.

A high school teacher - about 3000 people to think.

A teacher educator...

I might reach 250,000.

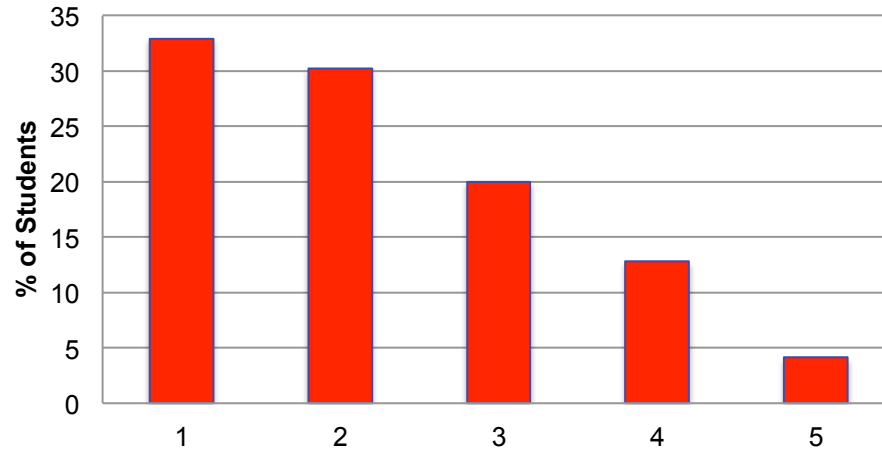
We can really make a change, right?

Thank you

Eugenia.etkina@gse.rutgers.edu

NEW AP Physics Test

National Score Distribution



Matt's Score Distribution

