

Physics Education

Laboratory

Lecture 19 - 27.11.2025

Learning Disorder in Physics Learning

Valentina Bologna and Francesco Longo

<https://www.youtube.com/watch?v=9Wb7vS3k2Lc>

COME PUÒ ESSERE COSÌ DIFFICILE?

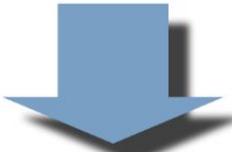
<https://www.youtube.com/watch?v=l8EUzZIVPco>

How difficult can this be?

FACULTY AWARENESS

Faculty members can be made aware of the characteristics of specific learning disabilities. Such awareness thus provides a theoretical frame of reference that makes it possible to know at least in general terms the most characteristic learning problems of students with Learning disabilities. In parallel, pathways can be activated to investigate well-being and difficulties of students already enrolled in university courses.

...becoming an inclusive University...



...enacting faculty's reflection...



PROFESSIONAL DEVELOPMENT



VADEMECUM FOR PHYSICS TEACHING



TUTORING

4
TRANSFORM



SUPPORTING

...promoting students' wellness...

The links are not correct ...

PROFESSIONAL DEVELOPMENT



<https://drive.google.com/file/d/1oU6VutHdr2DkxuiqZXIfMEdM3btrJJLS/view?usp=sharing>



<https://drive.google.com/file/d/132aDY145xS4N-Q28z6T2OqTOBGjEpeTJ/view?usp=sharing>

Video prepared for faculty's professional development (Italian language)



UNIVERSITÀ
DEGLI STUDI
DI TRIESTE

Disturbi specifici dell'Apprendimento (DSA)



Dott.ssa Isabella Lonciari
Dirigente psicologo
IRCCS Burlo Garofolo, Trieste



ISTITUTO DI RICOVERO E CURA
A CARATTERE SCIENTIFICO
Burlo Garofolo di Trieste





UNIVERSITÀ
DEGLI STUDI
DI TRIESTE

Lo studente con diagnosi di DSA (Disturbi specifici dell'apprendimento) all'Università



Indicazioni per favorire la frequenza ai corsi
e le procedure d'esame

The links are not correct ...

TUTORING



<https://drive.google.com/file/d/1S2IDPrmFDN9MNT3ev3pyUNdVHVAcLA2E/view?usp=sharing>



<https://drive.google.com/file/d/1PDBMCJr1KJ1VJpYOShFRFC0ZclC-ZwyZ/view?usp=sharing>

**Video prepared for encouraging students with Learning Disabilities through peers experiences
(Italian language)**

<https://drive.google.com/file/d/1Ih4B0SqmQcP0Zyf4Yb7Bt3f7lu4f39H/view>



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DI TRIESTE

Essere studente universitario con DSA

Una testimonianza





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DI TRIESTE

Essere studente universitario con DSA

Una testimonianza



<https://drive.google.com/file/d/1eGoyNXDT1FxG2OgD0c9D8S1f4KctyILZ/view?usp=sharing>

Guide for supporting students with learning disabilities (Italian language)

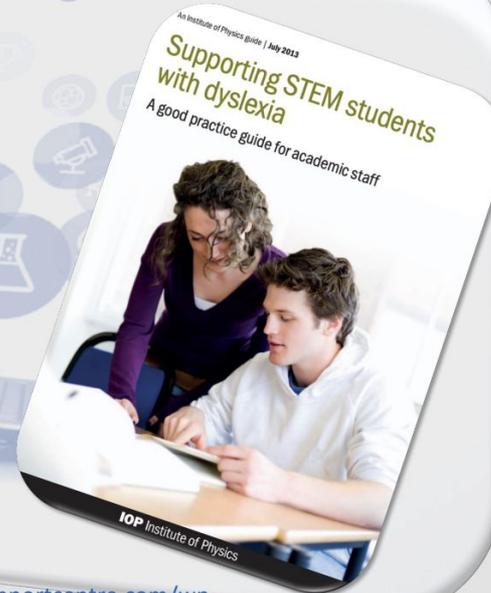


**Studenti con diagnosi di DSA
(Disturbi Specifici dell'Apprendimento)
all'Università**

**Indicazioni per favorire
la frequenza ai corsi e le procedure d'esame**



**Translating and
adapting to Italian
context the guide for
Academic Staff**



<http://www.learningsupportcentre.com/wp-content/uploads/2014/10/Supporting-dyslexia-in-STEM.pdf>

Supporting STEM students with dyslexia

A good practice guide for academic staff



<https://learningsupportcentre.com/content/uploads/2024/10/Supporting-dyslexia-in-STEM.pdf>

Physics Education Laboratory Lecture 20 Content Knowledge for Electromagnetism

Francesco Longo - 01/12/25



<https://youtu.be/10jRTmaozl0>

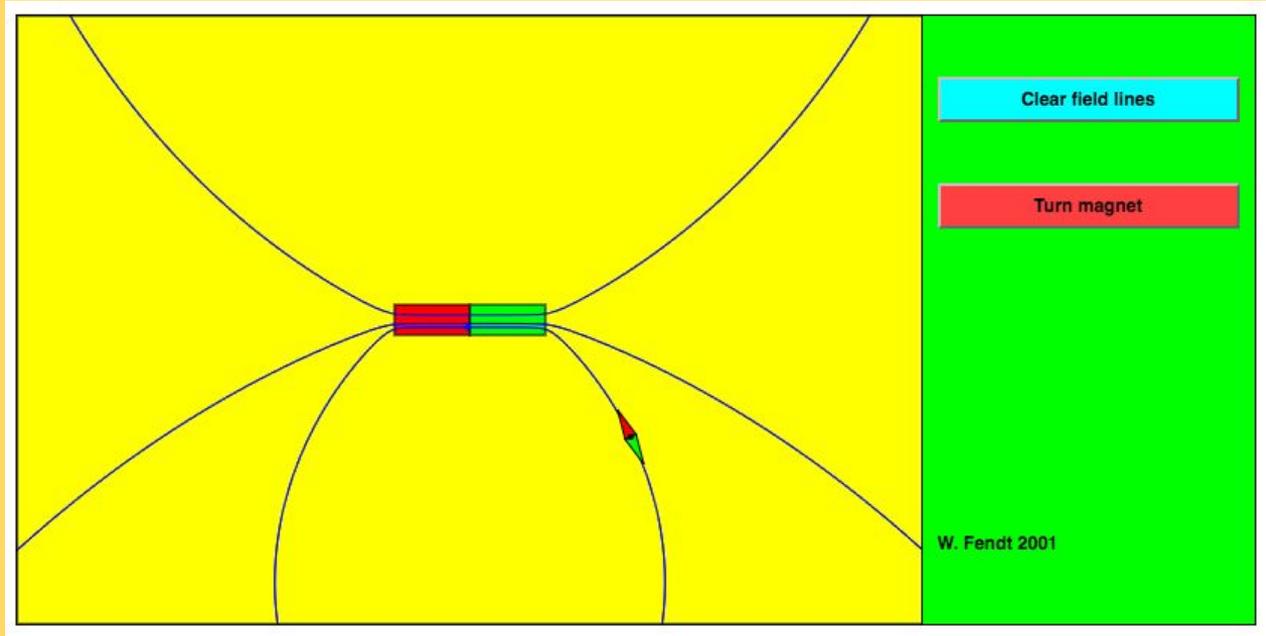
- PROBLEM SOLVING ?

Electricity and Magnetism Conceptual Assessment (EMCA)

<https://drive.google.com/file/d/1pG16k-lvDqwohShthWi8MpTn9tK2D8NZ/view?usp=sharing>

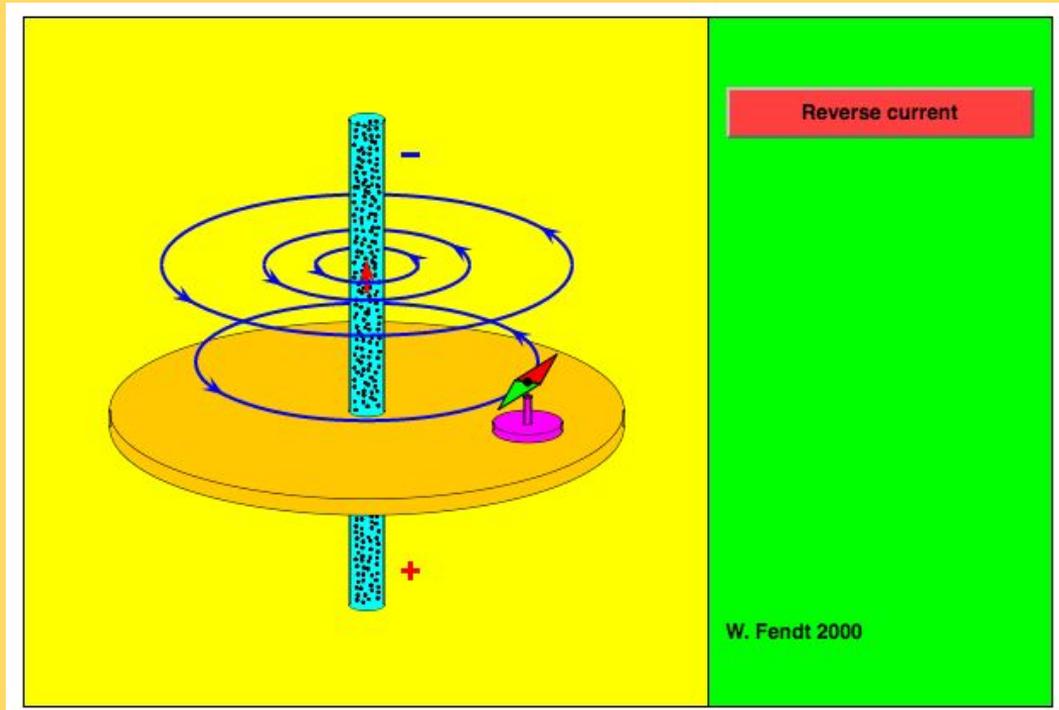
The conceptual representation
using computer based simulations
- inquiry based approach
(Inquiry-based learning with
Interactive Simulation)

Magnetic Field of a Bar Magnet



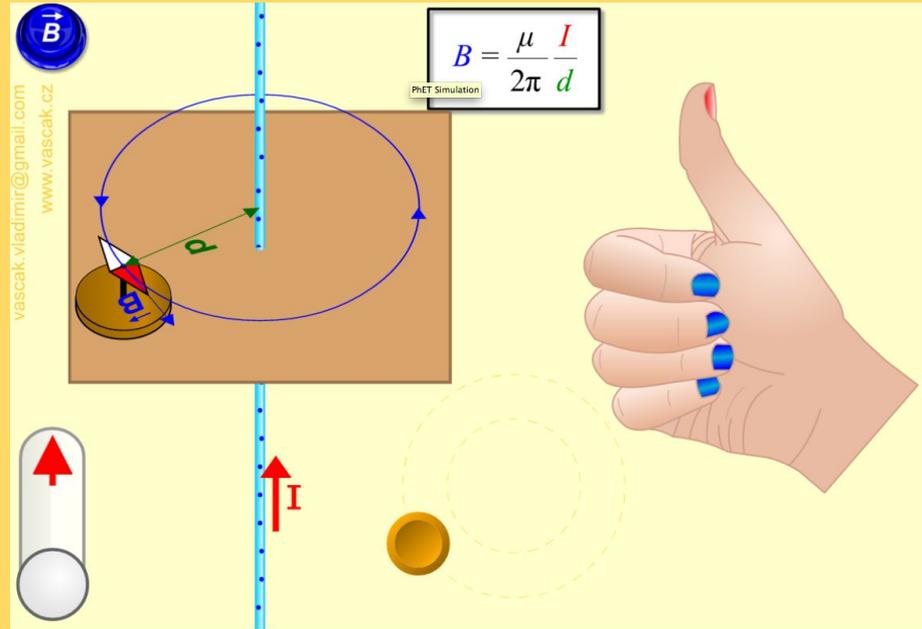
https://www.walter-fendt.de/html5/phen/magneticfieldbar_en.htm

Magnetic Field of a Straight Current-Carrying Wire



https://www.walter-fendt.de/html5/phen/magneticfieldwire_en.htm

Magnetic Field of a Straight Current-Carrying Wire



https://www.vascak.cz/data/android/physicsatschool/template.php?s=mag_vodic&l=en

FISICA A SCUOLA:

<https://www.vascak.cz/?id=22&language=it>
[#kapitola9](#)

The conceptual representation
using computer based simulations
- inquiry based approach
(Inquiry-based learning with
Interactive Simulation)

Materials for Physics education



[SIMULATIONS](#) [TEACHING](#) [RESEARCH](#) [ACCESSIBILITY](#) [DONATE](#)  

PhET's COVID-19 resources: [remote learning tips](#), [HTML5 prototype sims](#), and [browser-compatible Java sims](#).
Help us keep students learning. [Donate Now](#)



806 million simulations delivered

<https://phet.colorado.edu/>

Materials for Physics education

The screenshot displays the PhET website's search results for 'Physics'. The page features a navigation bar with 'SIMULATIONS', 'TEACHING', 'RESEARCH', and 'ACCESSIBILITY'. A sidebar on the left contains a filter menu with the following options:

- Physics
 - Motion
 - Sound & Waves
 - Work, Energy & Power
 - Heat & Thermo
 - Quantum Phenomena
 - Light & Radiation
 - Electricity, Magnets & Circuits
- Chemistry
 - General Chemistry
 - Quantum Chemistry
- Math
 - Math Concepts
 - Math Applications
- Earth Science
- Biology

Below the filter menu are sections for 'GRADE LEVEL', 'COMPATIBILITY', 'ACCESSIBILITY', and 'LOCALE', each with a '+' sign. A 'Clear Filters' button is located at the bottom of the sidebar.

The main content area shows '106 Results' for 'Physics'. A grid of 12 simulation thumbnails is displayed, each with a title and a small icon:

- Alpha Decay
- Atomic Interactions
- Balancing Act
- Balloons & Buoyancy
- Balloons and Static Electricity
- Band Structure
- Battery Voltage
- Battery-Resistor Circuit
- Bending Light
- Beta Decay
- Blackbody Spectrum
- Build an Atom

<https://phet.colorado.edu/>

Materials for Physics education



<https://phet.colorado.edu/en/teaching-resources/tipsForUsingPhet>

What Levels of Guidance Promote Engaged Exploration with Interactive Simulations?

https://phet.colorado.edu/publications/PERC_Interview_Guidance.pdf

(Adams et al. 2008)

Materials for Physics education



Using [PhET Interactive Simulations](#) in College Lecture

Ideas for engaging students through inquiry in lecture settings

University of Colorado's PhET Project has developed over 100 interactive simulations for teaching and learning science. These simulations provide animated, interactive, and game-like environments which enable scientist-like exploration. They emphasize the connections between real life phenomena and the underlying science, make the invisible visible (e.g. atoms, molecules, electrons, photons), and include the visual models that experts use to aid their thinking. **More, including examples, at phet.colorado.edu**

Visual Aids and Demos

By using sims as an animated illustration, instructors find that it is easier to communicate effectively with their students. The sims **show dynamic processes** and these can be **slowed down, sped up, or paused**, depending on the concept being shown; the **invisible is made visible**; and **multiple representations are linked**. Finally, the sims are **easily adjusted** by the instructor during the discussion. These features often make sims more effective for learning and more practical to use than static drawings or live demos.

Student-driven Discussions

PhET is designed to help students develop science inquiry skills by exploring cause-and-effect relationships. Instructors can facilitate **whole-class inquiry** by creating a scenario in the simulation, and asking students to predict the effect of manipulating variables. In such classrooms, students often spontaneously ask **many more, and deeper questions**. It is common for students to ask a **series of "what-if" questions** and direct the teachers' use of the sim.

The [Radio Waves](#) sim helps faculty **communicate ideas** about: creating electromagnetic waves, oscillating electric field strength, and the speed of light.



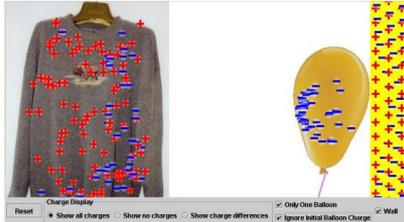
Materials for Physics education

Student-driven Discussions



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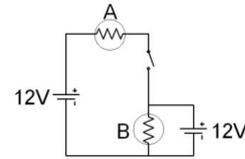
A short demo of charge transfer and polarization with [Balloons and Buoyancy](#) generates a series of student questions:



Students say:
*If you rub the sweater on the balloon (rather than balloon on sweater) will electrons transfer the other way?
Can you polarize something where the protons move?
Are there any situations in which the +’s move?*

An in-class question at right resulted in a class-led “what if” exploration with the [Circuit Construction Kit](#). (Only 25% correctly answer D)

The light bulbs in the circuit are identical. When the switch is closed,



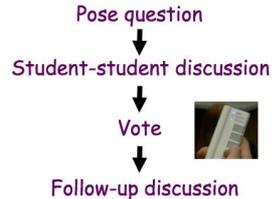
- A: bulb A glows, and bulb B changes brightness
- B: bulb A glows, and bulb B stays the same
- C: bulb A does not glow, and bulb B changes brightness
- D: bulb A does not glow, and bulb B stays the same

Students say:
*I don’t get it. It’s a closed circuit.
Can you explain one more time why Bulb A doesn’t light ?
What if that battery is increased in voltage?
(Instructors says “let’s try it. Which way will current flow?”)
What happens to Bulb B current? Does it get brighter?
What happens if you flip one (of the batteries) over?*

Materials for Physics education

Concept or “Clicker” Questions

Concept tests give students an opportunity to discuss and make sense of concepts related to the simulation.



Strategies for Writing Questions*

1. Predict an outcome of an “experiment” with the simulation (e.g., what will happen if? Which change in the sim setup would result in the desired behavior?)
2. Rank cases (e.g. which bulb will be brightest).
3. Compare contrasting cases (e.g., two different waves)
4. Interpret different representations (e.g. graphs, pictures, vectors).
5. Connect to real-world applications

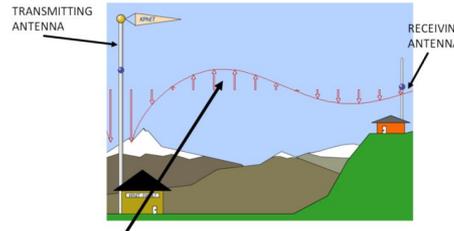
*adapted from Beatty et al., AJP, 2006

Interactive Lecture Demos (ILDs)*

ILDs increase student learning from demos by having students actively identify expectations, and resolve

Instructor probes common student difficulty and then helps students visualize speed of light with the [Radio Waves](#) sim.

How do you measure the propagation speed of the wave (signal)?



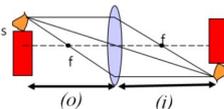
The speed of the wave (signal) is measured as...

- a. how fast this peak moves towards antenna.
- b. how fast this peak moves up and down.
- c. both a or b

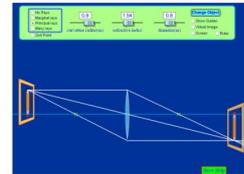
What will happen to image if we increase focal length of lens?

(Keeping the object distance fixed)

- a. Image is same size, same place
- b. Image is same size and further from lens
- c. Image is bigger and further from lens
- d. Image is smaller and closer to lens



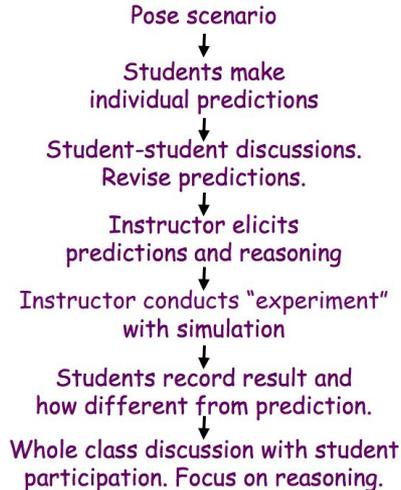
After peer discussion and voting, instructor elicits student reasoning and then settles debate by “doing the experiment” with PhET’s [Geometric Optics](#) simulation.



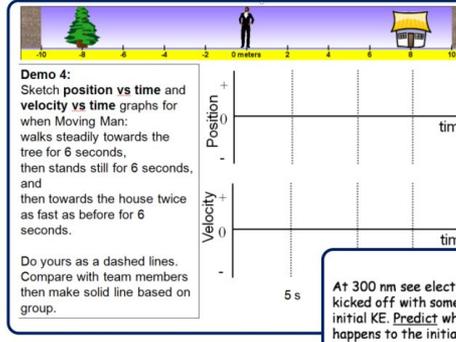
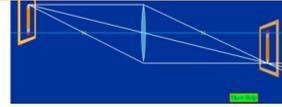
Materials for Physics education

Interactive Lecture Demos (ILDs)*

ILD's increase student learning from demos by having students actively identify expectations, and resolve any inconsistencies.

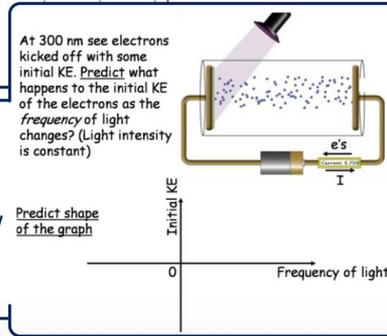


settles debate by "doing the experiment" with PhET's [Geometric Optics](#) simulation.



Question elicits students ideas about graphs. [Sim](#) then allows instructor to dynamically generate graph, and play back motion during further discussions

Many students will predict a linear graph starting at origin. The [sim](#) "experiment" dramatically shows that below a certain frequency, no electrons are kicked off even at high intensities.



*see Sokoloff and Thornton, *Physics Teacher*, 35, 340-346 (1997)

Magnets-Introduction (Inquiry Based) ★

 [Introductio to Magnets Faraday Electromagne Lab CQ.pptx](#) - 186 kB

 [Lesson plan intro to magnets.docx](#) - 19 kB

 [Clicker questions faraday Introductio to Magnets.PDF](#) - 357 kB

 [Lesson plan intro to magnets.pdf](#) - 123 kB

 [Student directions for intro to magnets.pdf](#) - 119 kB

 [Student directions for intro to magnets.DOC](#) - 27 kB

[Download](#) all files as a compressed .zip

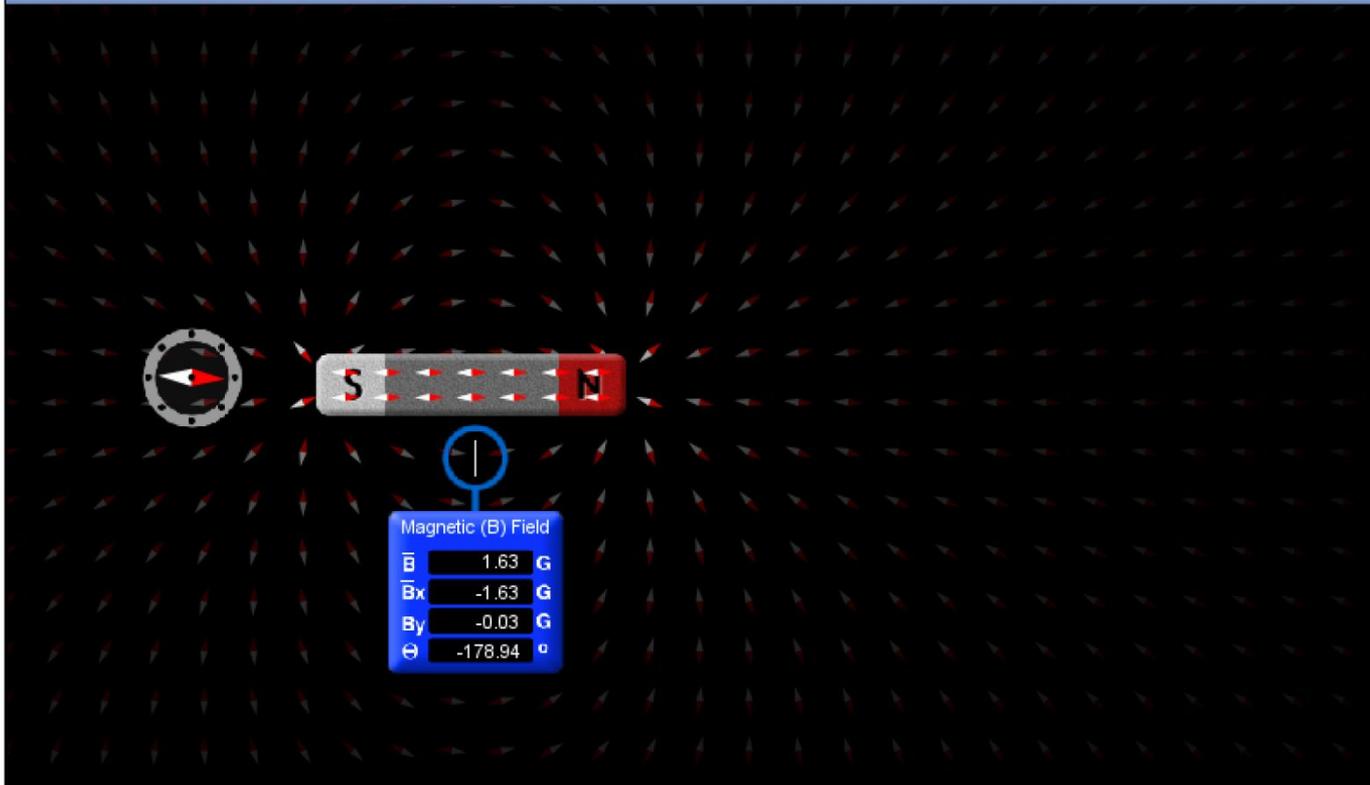
Magnets and Electromagnets



<https://phet.colorado.edu/en/simulation/legacy/magnets-and-electromagnets>

Bar Magnet

Electromagnet



Bar Magnet

Strength: 37 %



Flip Polarity

 See Inside Magnet Show Field Show Compass Show Field Meter Show planet Earth

Reset All

LET'S TRY NOW ...

Behind the curtains ...

- EXPLORING the SIMULATION
- <https://phet.colorado.edu/en/simulations/faraday>
- EXPLORING STUDENTS' SHEETS
- <https://phet.colorado.edu/en/contributions/view/2827>
- FOLLOWING the INSTRUCTIONS
- <https://phet.colorado.edu/en/teaching-resources/activity-guide>

Physics Education Laboratory

Inquiry Based - Simulations

Lecture 20 – 01.12.2024

26th Multimedia in Physics Teaching and Learning



7-9 September, 2023

Comparing Simulations to Improve Physics Students' Education

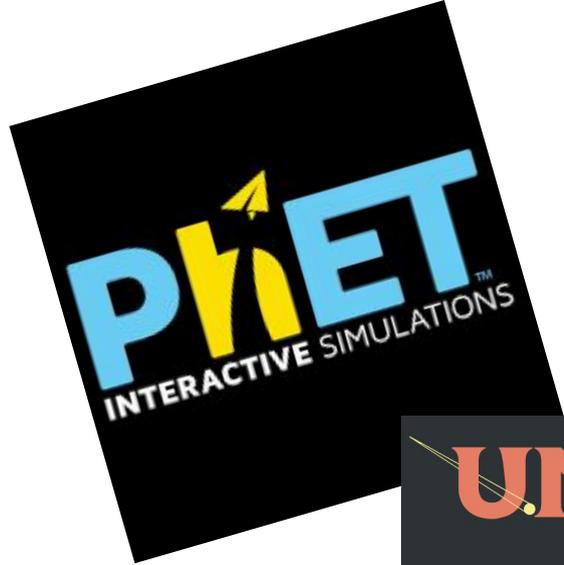
Valentina BOLOGNA*, Paul KOENIG **, Francesco LONGO*



* Physics Department, University of Trieste (Italy), valentina.bologna@units.it

** Physics Department, University of Vienna (Austria)



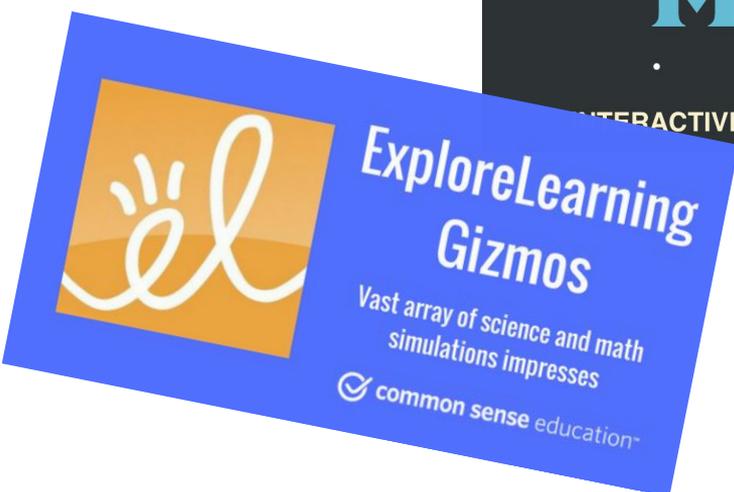


Tutorial Interactives Review Session Calculator Pad Minds On Physics

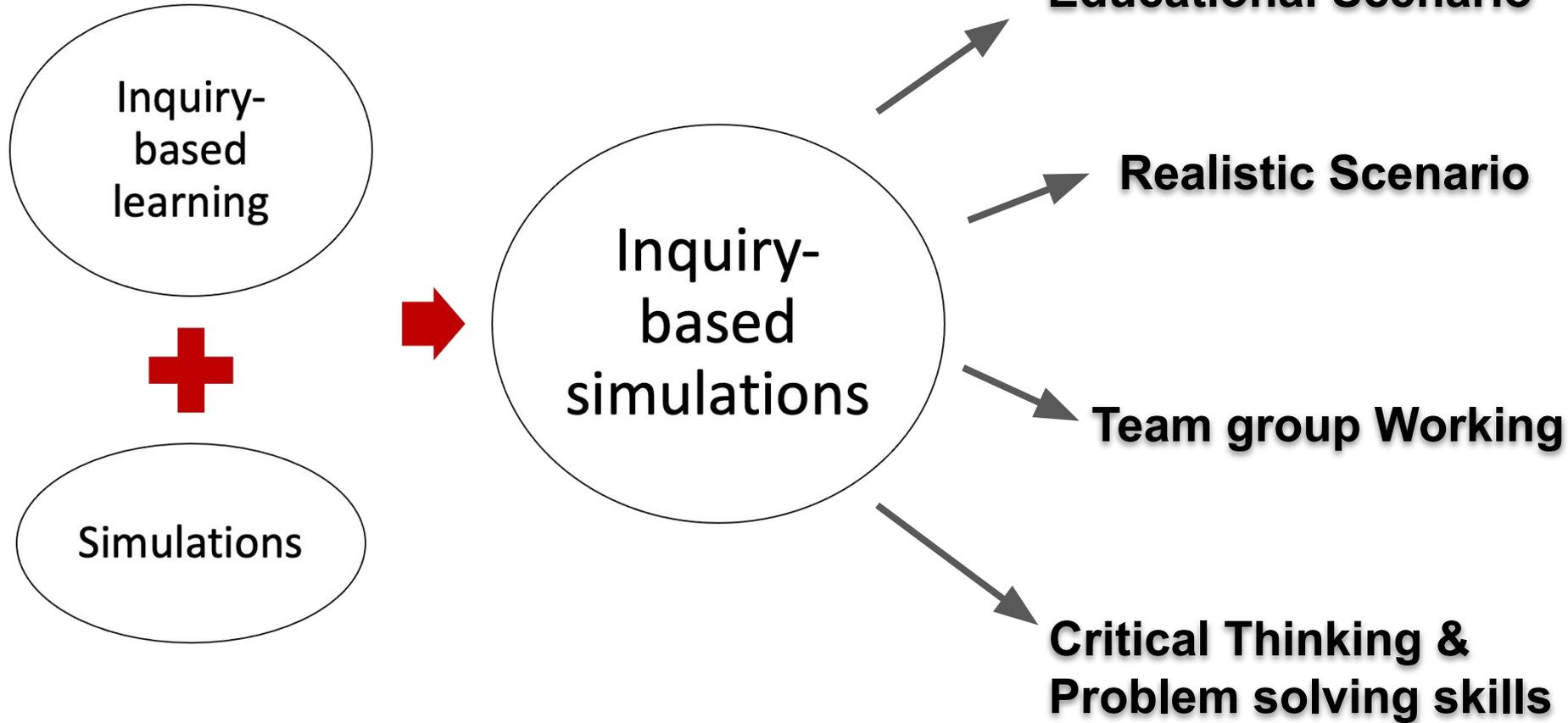
THE PHYSICS CLASSROOM

Laboratory Reasoning Center Toolkits Social Media

www.physicsclassroom.com



THEORETICAL FRAMEWORK



**Practical
Application**

**Engagement
and Motivation**

**Transferable
Skills**

FACTORS IN INQUIRY-BASED SIMULATIONS

WHAT IS AUTHENTIC INQUIRY?

“Authentic scientific inquiry refers to the research that scientists actually carry out. Authentic scientific inquiry is a complex activity, employing expensive equipment, elaborate procedures and theories, highly specialized expertise, and advanced techniques for data analysis and modeling.”

(Chinn & Malhorta, 2002)

“The cognitive models that underlie authentic experiments are fundamentally different from the cognitive models that underlie simple experiments, and the differences in models help account for why there are differences in cognitive processes and epistemology”

(Chinn & Malhorta, 2002)

SIMPLE ILLUSTRATIONS

SIMPLE OBSERVATIONS

SIMPLE EXPERIMENTS

**Increasing of Cognitive
Processes Activated in
Reasoning Tasks**

AUTHENTIC INQUIRY EXPERIMENTS

First research question:

**To what extent inquiry-based
simulations resemble
AUTHENTIC SCIENTIFIC INQUIRY?**



Analysis of selected inquiry-based simulations focusing on cognitive processes activated, according to the cognitive models defined by Chinn & Malhorta (2002)

METHOD: COMPARATIVE RESEARCH DESIGN

Focus on six of the fundamental cognitive processes that scientists engage when they conduct research and concerning aspects which profile their reasoning process

Comparison of simulations for different PHYSICS TOPICS considering two different standpoints:

- 1) GENERAL SIMULATION OVERVIEW
- 2) TEACHING/LEARNING MATERIAL

ASPECTS OF SCIENTIFIC COGNITIVE PROCESSES



Generating a research question



Designing a study to address the research question



Making observations



Explaining results



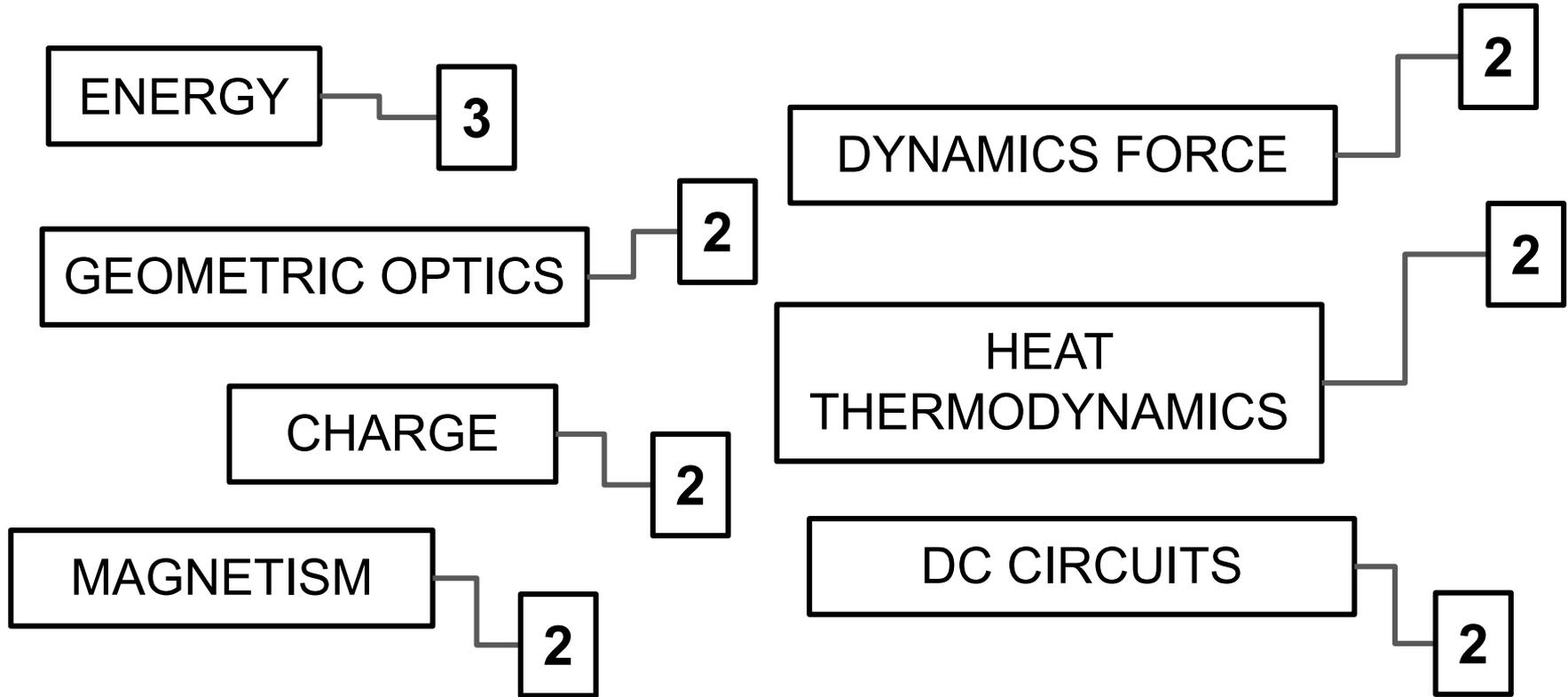
Developing theories



Studying others' research

**LEVEL / TYPE
OF INQUIRY**

SAMPLE: TOPICS & SIMULATIONS



7 TOPICS and 15 SIMULATIONS

COMPARED SIMULATIONS AND DATA COLLECTION

Cognitive Process	Authentic Inquiry	Energy Skate Park (PHET)	Kinetic Energy (physicclassroom)	Fan Cart Physics (ExploreLearning Gizmos)
Generating research questions	Scientists generate their own research questions	Research questions already given	Research questions already given	Research questions already given
Designing studies	Scientists select and even invent variables to investigate. There are many possible variables	Variables given, students are free to choose from them	Variables given, students are free to choose from them	Variables given, students are free to choose from them
Selecting variables	Scientists invent complex procedures to address questions of interest. Scientists often devise analog models to address the research question.	It is possible to create complex procedures on a simple level, with the Mode "Playground"	Students follow instructions given by the simulation	Students follow instructions given by the simulation
Planning procedures	Scientists often employ multiple controls. It can be difficult to determine what the controls should be or how to set them up.	Students can choose out of multiple variables to determine and work freely with gravity	Students can choose what variables to control but are limited to the variables given by the simulation.	Students can choose what variables to control but are limited to the variables given by the simulation.
Controlling variables	Scientists typically incorporate multiple measures of independent, intermediate and dependent variables.	Students can choose and work with multiple measures and take data out of a Bar and Pie Chart.	Students can work with multiple measures by selecting them.	Students can work with multiple measures given by adjusting the moving objects with weights and boosters.
Planning measures	Scientists employ elaborate techniques to guard against observer bias.	Observer bias does not play a role	Observer bias does not play a role	Observer bias does not play a role
Making observations	Observations are often repeatedly transformed into other data formats.	Observations can only be pairwise transformed into other Simulations, out of the same category	Observations cannot be transformed	Observations can only be pairwise transformed into other Simulations out of the same category.
Explaining results/Transforming observation	Scientists constantly question whether their own results and others' results are correct or artefacts of experimental flaws.	Experimental flaws are mostly ruled out in these computer simulations	Experimental flaws are mostly ruled out in these computer simulations.	Experimental flaws are mostly ruled out in these computer simulations.
Finding flaws				



Authentic inquiry	4 points
Simple experiments	3 points
Simple observations	2 points
Simple illustrations	1 point
Not inquiry based	0 points

**FOR EACH STANDPOINT
FOR EACH TOPIC**

DATA ANALYSIS OF COMPARED SIMULATIONS

EXAMPLE BY ENERGY TOPIC

Mean value of cognitive processes involved

	Authentic inquiry	4 points
	Simple experiments	3 points
	Simple observations	2 points
	Simple illustrations	1 point
	Not inquiry based	0 points



Simulation
mean value:

2.14 ± 0.23

READING SCALE

Teaching/learning
material mean value:

1.21 ± 0.57

How close simulations gets to authentic inquiry

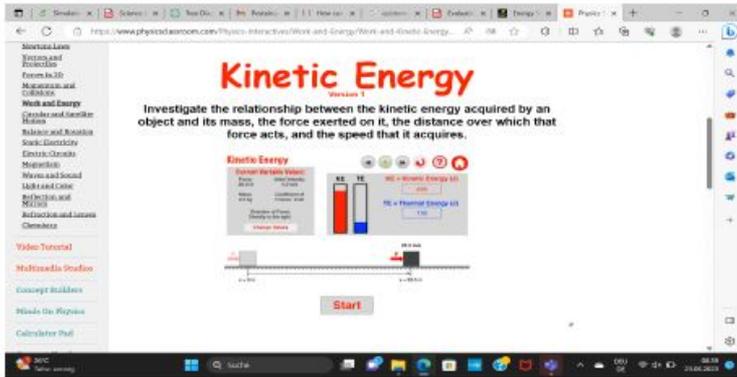
Main results:

SIMULATIONS OVERVIEW FEATURES

1.29 ± 0.57



2.21 ± 0.27

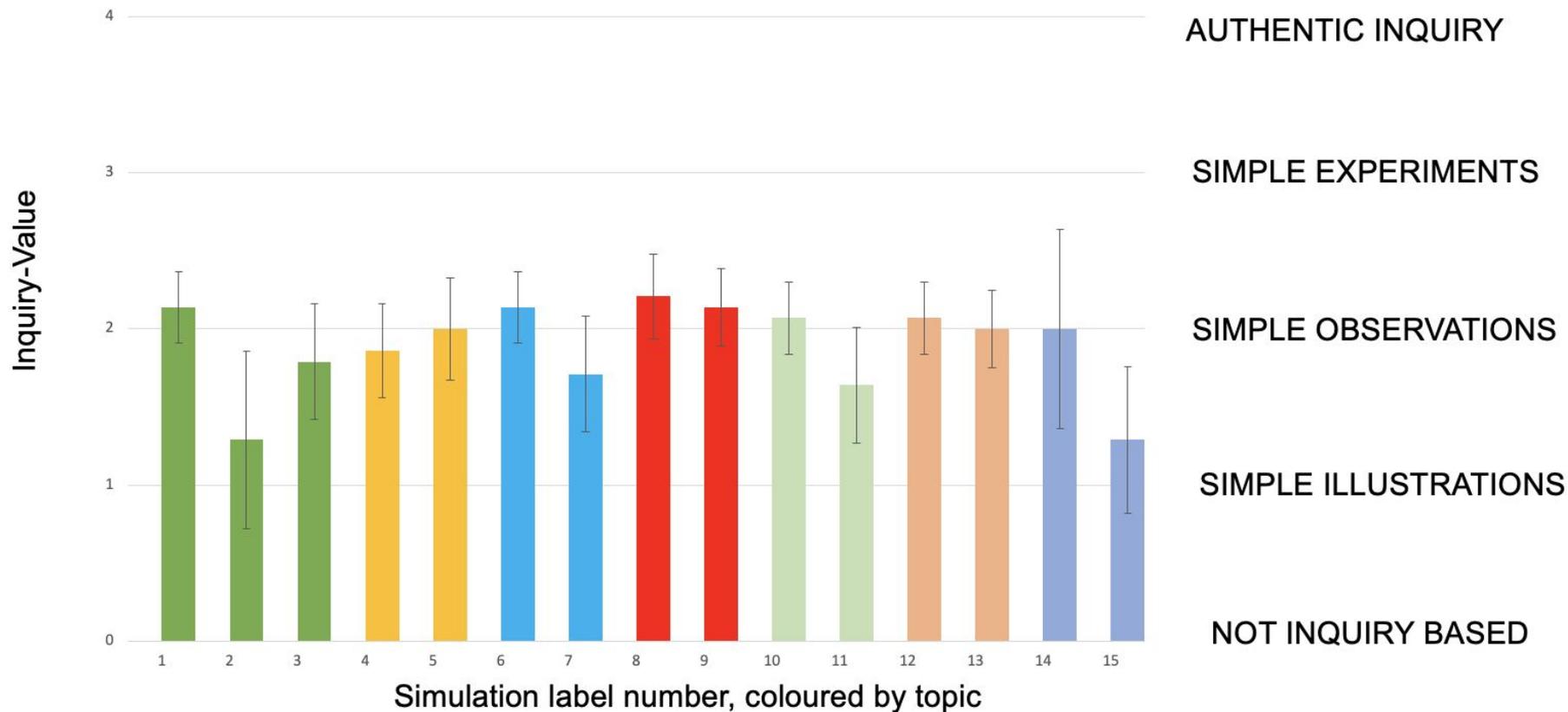


SIMPLE ILLUSTRATION



SIMPLE OBSERVATION

MEAN VALUE OF COGNITIVE PROCESSES FOR SIMULATION OVERVIEW



ENERGY

DYNAMICS FORCE

GEOMETRIC OPTICS

HEAT THERMODYNAMICS

CHARGE

DC CIRCUITS

MAGNETISM

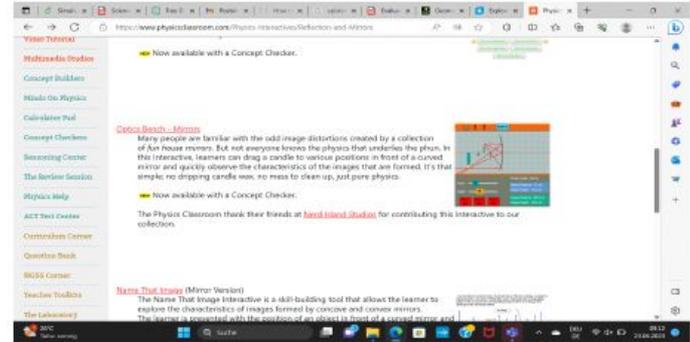
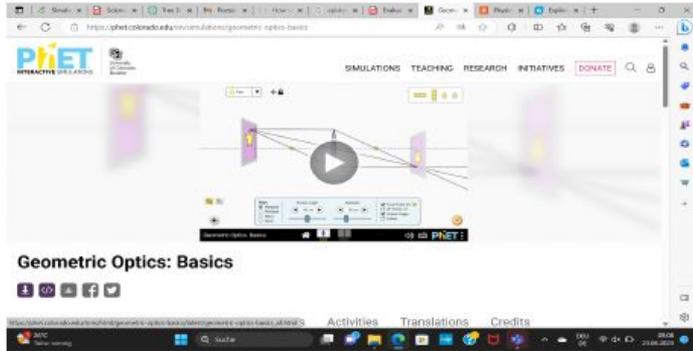
Main results:

TEACHING/LEARNING MATERIALS

1 ± 0.64



2.5 ± 0.37



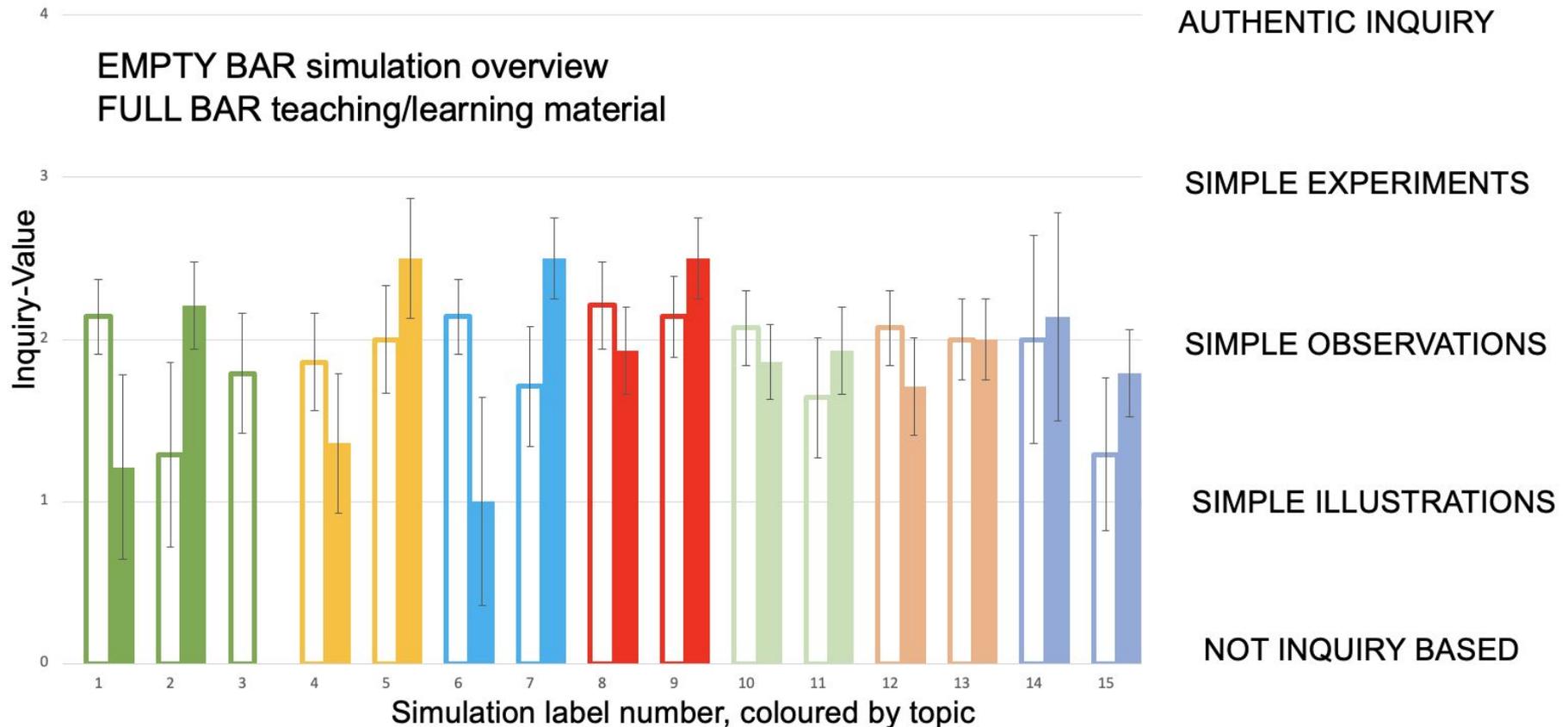
SIMPLE ILLUSTRATIONS



SIMPLE OBSERVATION
towards

SIMPLE EXPERIMENTS

MEAN VALUE OF COGNITIVE PROCESSES ACTIVATED FOR BOTH



ENERGY

DYNAMICS FORCE

GEOMETRIC OPTICS

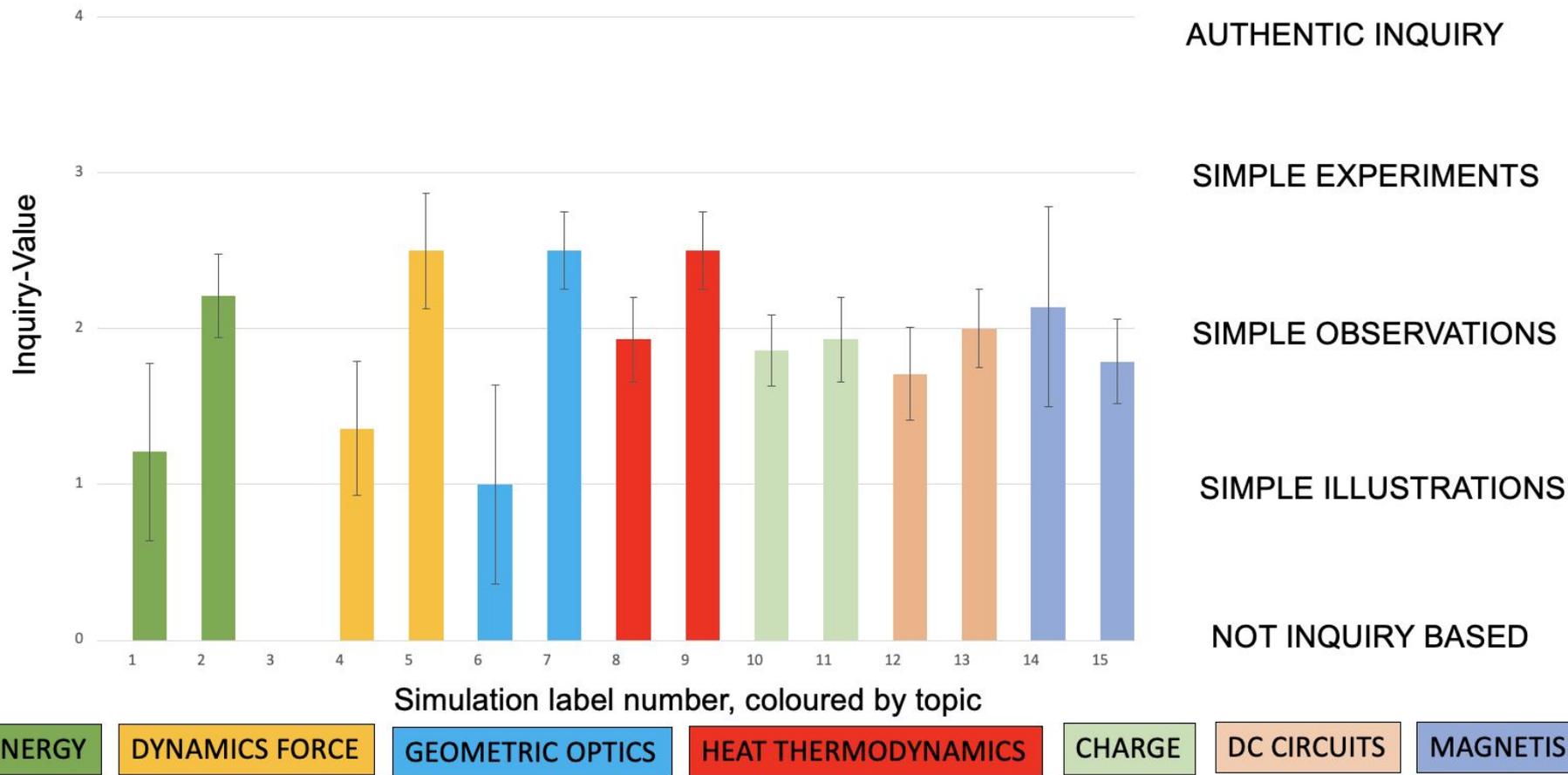
HEAT THERMODYNAMICS

CHARGE

DC CIRCUITS

MAGNETISM

MEAN VALUE OF COGNITIVE PROCESSES FOR TEACHING/LEARNING MATERIALS



Discussion

We analysed some inquiry-based simulations using the lens of focusing on the cognitive processes activated in their use through the Chinn & Malhorta reference framework (2002) by the definition of authentic inquiry.

We basically found that most of the simulations analysed in different physical topics promote a cognitive processes of inquiry that appears mostly similar to those concerned simple observations. This happens both in a general simulation overview and in the teaching/learning materials investigated.

Implications

FOR RESEARCHERS

When building NEW INQUIRY-BASED SIMULATIONS researchers could take support by analysing their products with the lens of cognitive processes activate in order to improve their simulations toward a more authentic inquiry environment

Implications

FOR PHYSICS TEACHERS

When selecting which simulations adopt in their classroom activities try to explore which level/type of inquiry is activated using the teaching/learning materials available.

Create/design NEW TEACHING/LEARNING MATERIALS which let students engage in cognitive processes of **authentic inquiry**

Second research question:

How could we prepare teaching/learning materials for inquiry-based simulations which resemble AUTHENTIC SCIENTIFIC INQUIRY?



Using the framework of the ISLE - INVESTIGATIVE SCIENCE LEARNING ENVIRONMENT (Etkina et al. 2019) which is an example of authentic inquiry-based approach (Brookes et al, 2020)

METHOD

Start from the analysis conducted

For each topic, select the simulation analysed with the higher mean value in the inquiry level performed from the point of view of the cognitive processes activated

Create/design NEW teaching/learning materials which empower an ISLE - process

Administer the teaching/learning materials to a group of in-service physics teachers (training workshop)

RESULTS

We prepared the teaching/learning materials in order to obtain the highest possible level of inquiry (MORE AUTHENTIC AS POSSIBLE) analysing them with the lens of the cognitive processes activated.

2.86 ± 0.53

SIMPLE EXPERIMENTS

**27% PERCENTAGE OF MEAN
IMPROVEMENT IN NEW MATERIALS**

Conclusions

It is possible to create/design inquiry-based simulations and their teaching/learning materials in order their use enact and mirror an experience of **authentic scientific inquiry**.

Create/design materials in the **framework of the ISLE** approach and process is a possible way activating learners' cognitive processes as the ones of scientists in their reasoning tasks.

Laboratory

Simulating ISLE

Investigative Science Learning Environment, using Computer Simulations

Paul König

Università degli studi di Trieste

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Introduction

- Brief overview of the ISLE approach
 - ① Inquiry-Based Learning: Active investigation, hands-on experimentation, critical thinking.
 - ② Authentic Science Practices: Real-world experiences, questioning, experimentation, data analysis, evidence-based conclusions.
 - ③ Collaboration and Reflection: Group work, idea sharing, reflection, teamwork, scientific process.
- Importance of science education
 - ① Scientific Literacy: Promotes critical thinking, evidence-based reasoning (Inductive Reasoning, Deductive Reasoning, Abductive Reasoning), and informed decision-making.
 - ② STEM Workforce and Innovation: Prepares future scientists, engineers, and fosters creativity for solving complex challenges.

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What is ISLE in computer simulations?

- Definition and principles of ISLE in computer simulations
 - ① Interactive Simulations: Utilizes computer simulations to engage students in hands-on exploration of scientific concepts.
 - ② Realistic Scenarios: Presents authentic scenarios and challenges within the simulations, providing students with a practical understanding of scientific principles and their applications.
- Comparison with traditional teaching methods
 - ① Active Learning (Student centred): ISLE encourages active engagement, while traditional methods often involve passive learning (Teacher centred).
 - ② Student-Centered Approach: ISLE prioritizes student involvement, whereas traditional methods tend to be teacher-centered.
 - ③ ISLE provides real world experiences, traditional methods mostly more theoretical
- Benefits of ISLE for students and teachers with focus on computer simulations

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Computer Simulations

- Definition of computer simulations:
Interactive digital tools for virtual scientific exploration and experimentation.
- Advantages of computer simulations:
 - ① Safe and controlled environment
 - ② Flexibility and repeatability
 - ③ Access to real-world scenarios
- Disadvantages of computer simulations:
 - ① Lack of real world physical interaction
 - ② Simplified representations, since one can only see the models but not the assumptions behind the simulation.
 - ③ Potential need of conceptual change
- Examples of ISLE based computer simulations
 - ① PHET
 - ② physicsclassroom

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Analysis Method

- Explanation of the analysis method used in the study
 - ① Analysis based on article: "Epistemologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks" (Clark A. Chinn and Betina A. Malhotra)
 - ② Comparison between cognitive processes and epistemologically.
- Data collection and processing techniques
 - ① Data collection through a comparison between different providers of simulations of the same physical phenomenon
- Limitations and potential biases
 - ① Only limited resources, therefore only 2–3 providers got analysed
 - ② Even though, using the article named above, the analysing process was as objective as possible, it is still nearly impossible to find a way to analyse simulations and their level of inquiry completely objective

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Doing the Investigation

- Please find groups of 2–3 people.
- Every group gets a different physical phenomenon.



Exercise sheets