Physics Education Laboratory

Inquiry Based - Simulations

Lecture 18 – 27.11.2024

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MPTL

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Comparing Simulations to Improve Physics Students’ Education

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PhET
INTERACTIVE SIMULATIONS

Tutorial
Interactives
Review Session
Calculator Pad
Minds On Physics

THE PHYSICS CLASSROOM

Laboratory
Reasoning Center
Toolkits
Social Media

www.physicsclassroom.com

UNIVERSE & MORE

INTERACTIVE PHYSICS RESOURCES

ExploreLearning
Gizmos

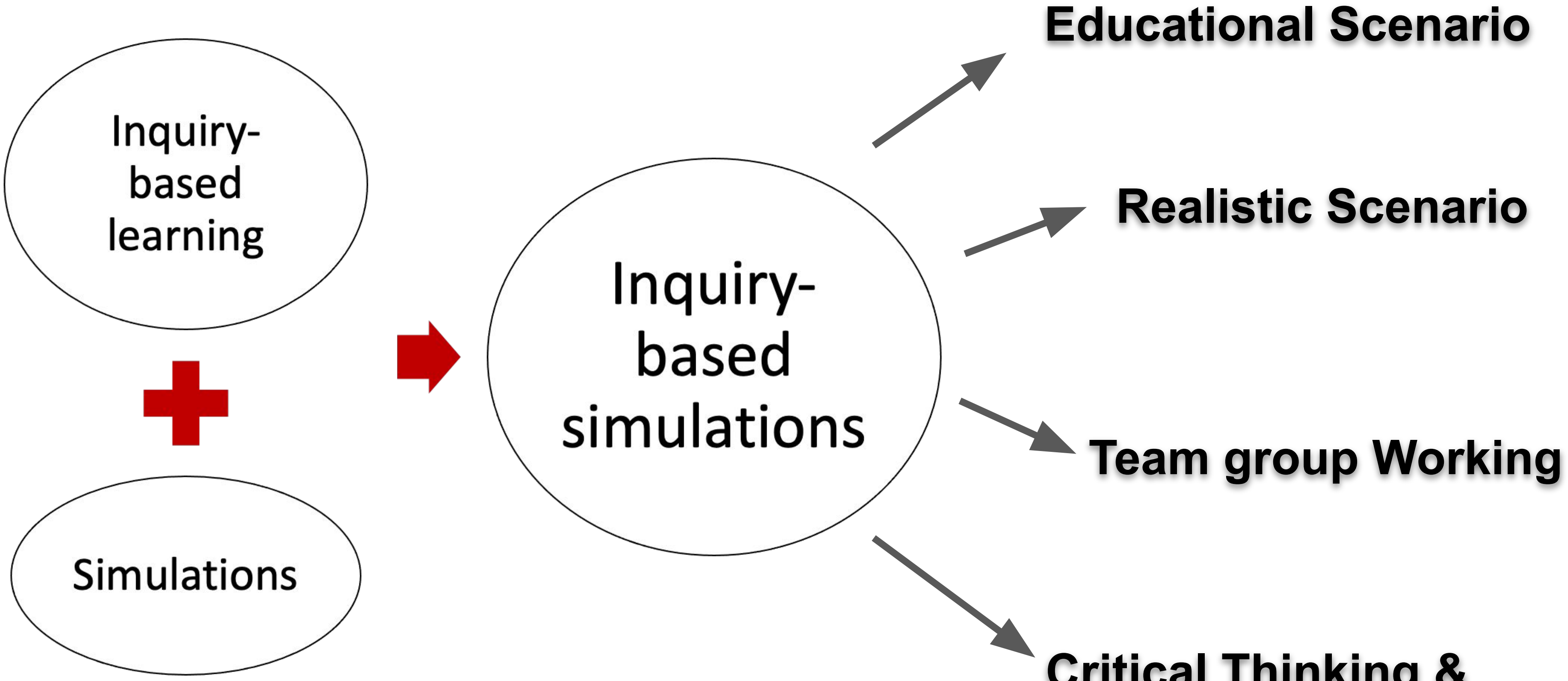
Vast array of science and math simulations impresses

common sense education

Algodoo

myPhysicsLab.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

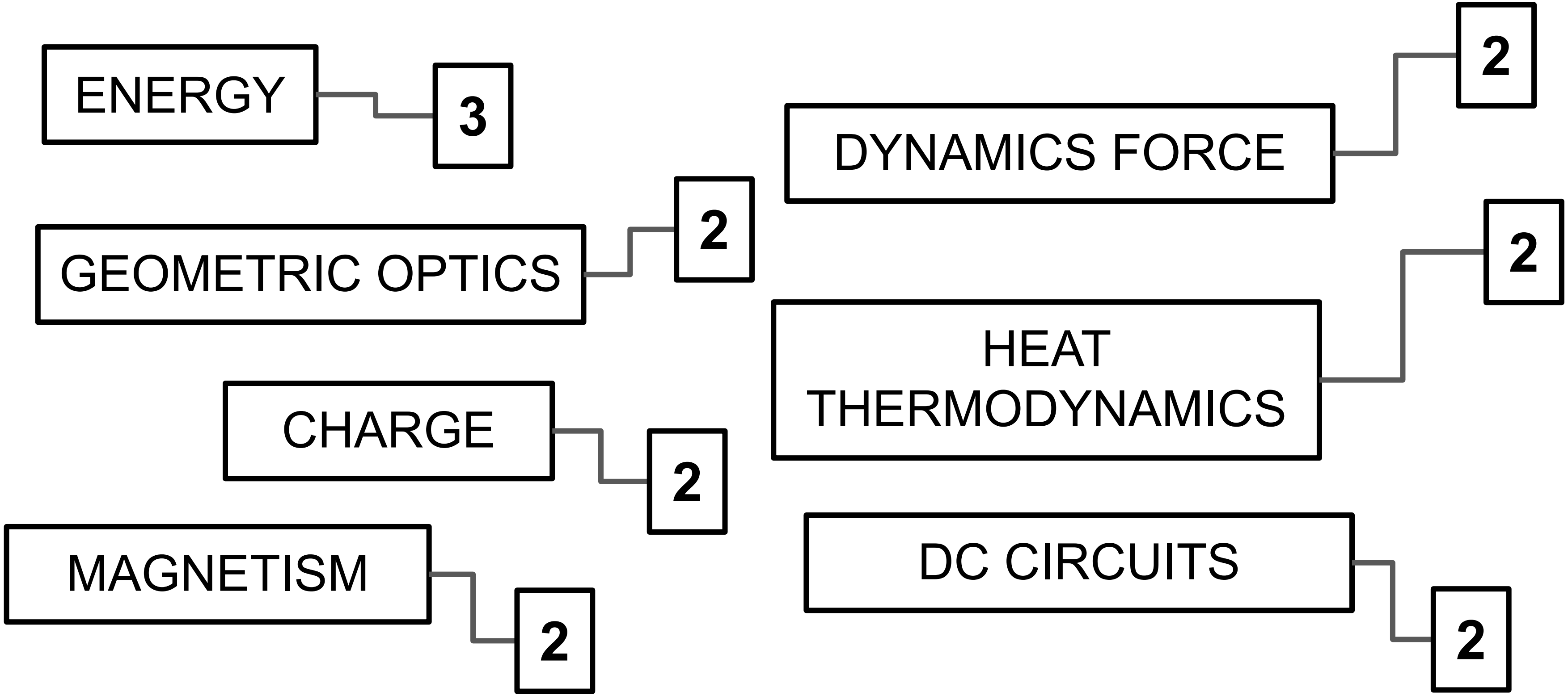
ASPECTS OF SCIENTIFIC COGNITIVE PROCESSES

- 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

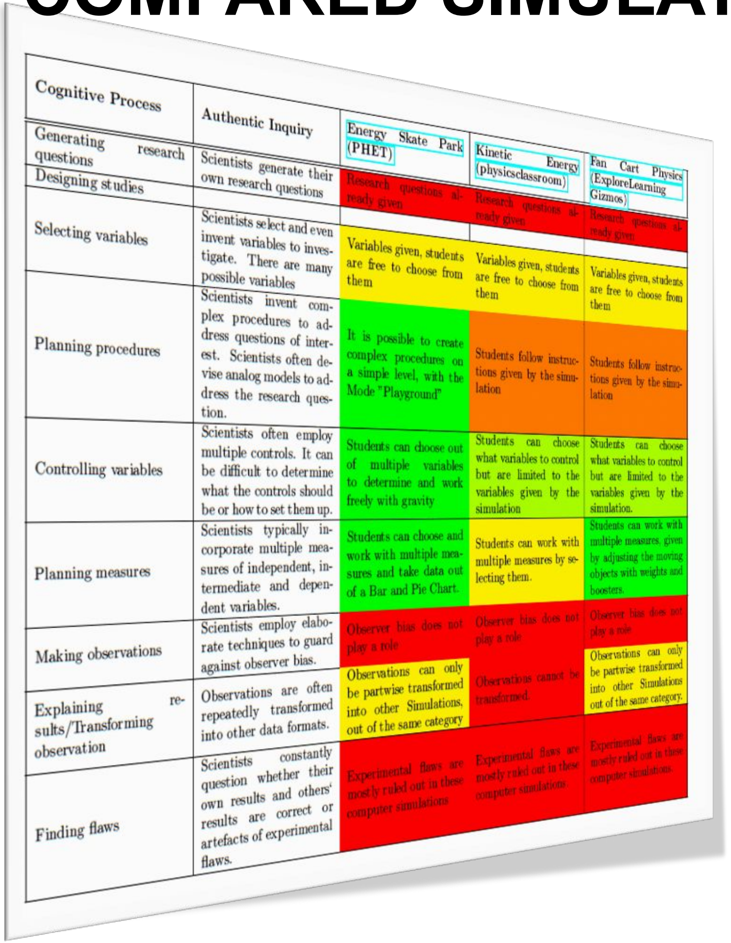
(Chinn & Malhorta, 2002)

SAMPLE: TOPICS & SIMULATIONS



7 TOPICS and 15 SIMULATIONS

COMPARED SIMULATIONS AND DATA COLLECTION



Cognitive Process	Authentic Inquiry	Energy Skate Park (PHET)	Kinetic Energy (physicsclassroom)	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				
Selecting variables	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
Planning procedures	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
Controlling variables	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.
Planning measures	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.
Making observations	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
Explaining results/Transforming observation	Observations are often repeatedly transformed into other data formats.	Observations can only be partwise transformed into other Simulations, out of the same category	Observations cannot be transformed	Observations can only be partwise transformed into other Simulations out of the same category.
Finding flaws	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.

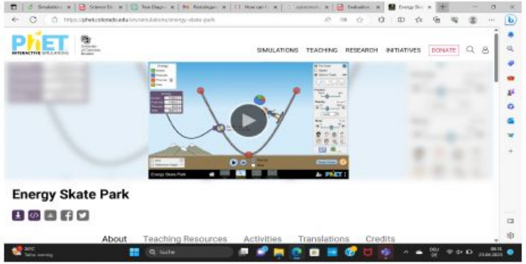
Authentic inquiry	4 points
Simple experiments	3 points
Simple observations	2 points
Simple illustrations	1 point
Not inquiry based	0 points

FOR EACH STANDPOINT
FOR EACH TOPIC

DATA ANALYSIS OF COMPARED SIMULATIONS

Mean value of cognitive processes involved

EXAMPLE BY ENERGY TOPIC



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

READING SCALE

Simulation mean value: 2.14 ± 0.23

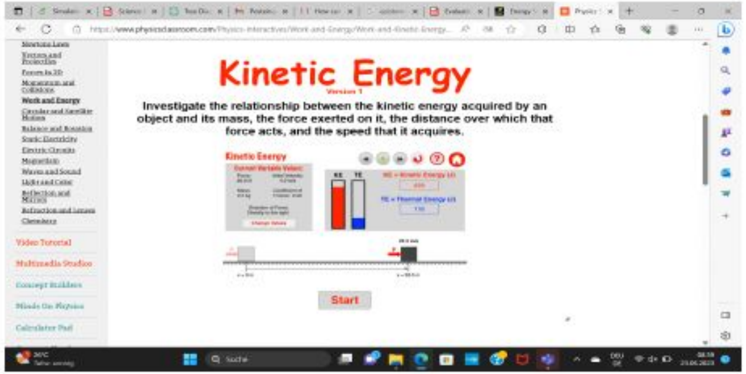
Teaching/learning material mean value: 1.21 ± 0.57

How close simulations gets to authentic inquiry

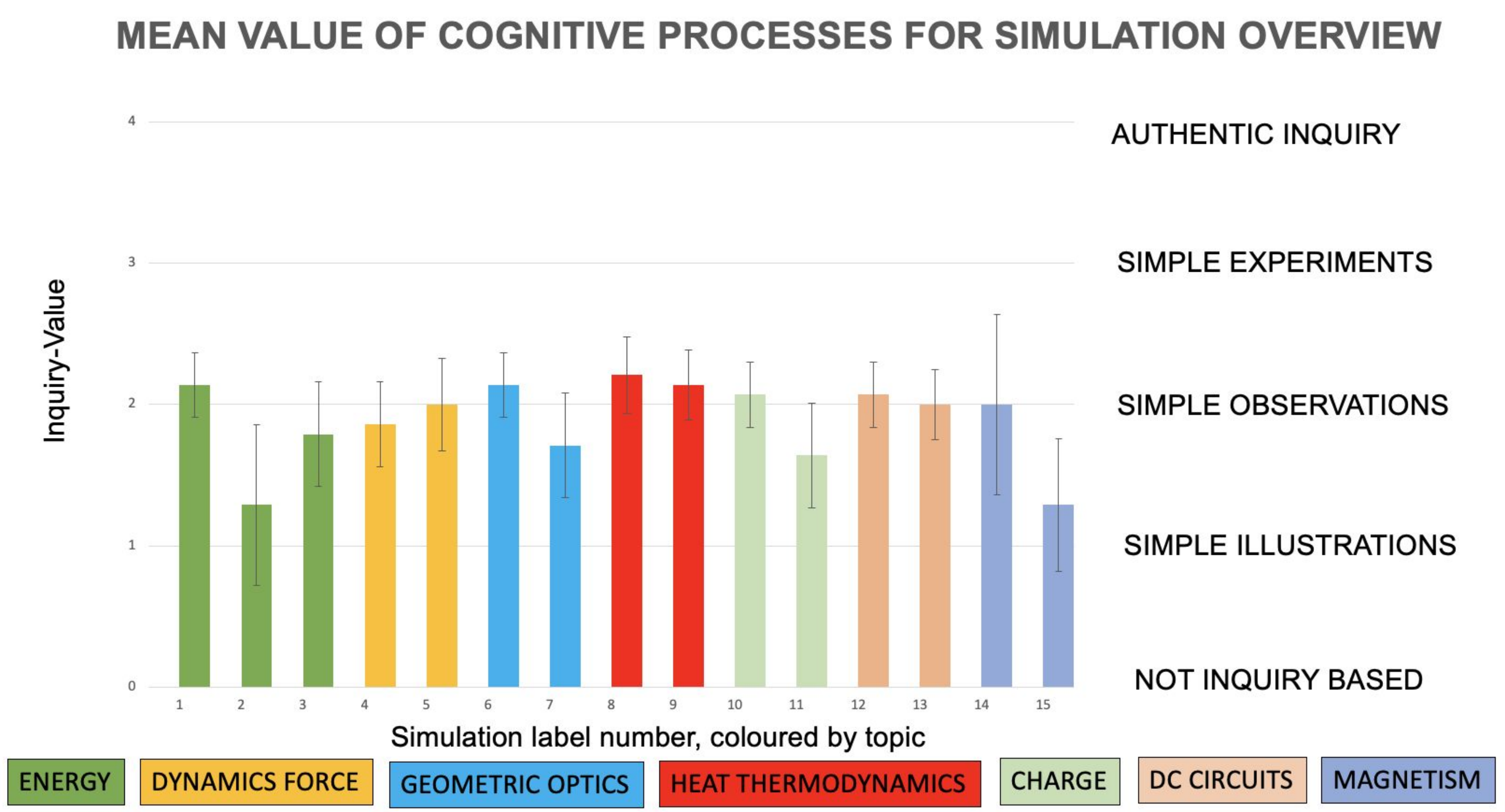
Main results:

SIMULATIONS OVERVIEW FEATURES

1.29 ± 0.57 ↔ 2.21 ± 0.27



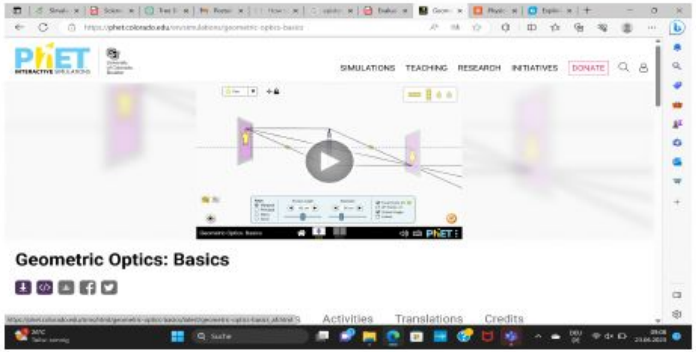
SIMPLE ILLUSTRATION ↔ SIMPLE OBSERVATION


MEAN VALUE OF COGNITIVE PROCESSES FOR SIMULATION OVERVIEW
Inquiry-Value
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
AUTHENTIC INQUIRY
SIMPLE EXPERIMENTS
SIMPLE OBSERVATIONS
SIMPLE ILLUSTRATIONS
NOT INQUIRY BASED
Simulation label number, coloured by topic
ENERGY
DYNAMICS FORCE
GEOMETRIC OPTICS
HEAT THERMODYNAMICS
CHARGE
DC CIRCUITS
MAGNETISM

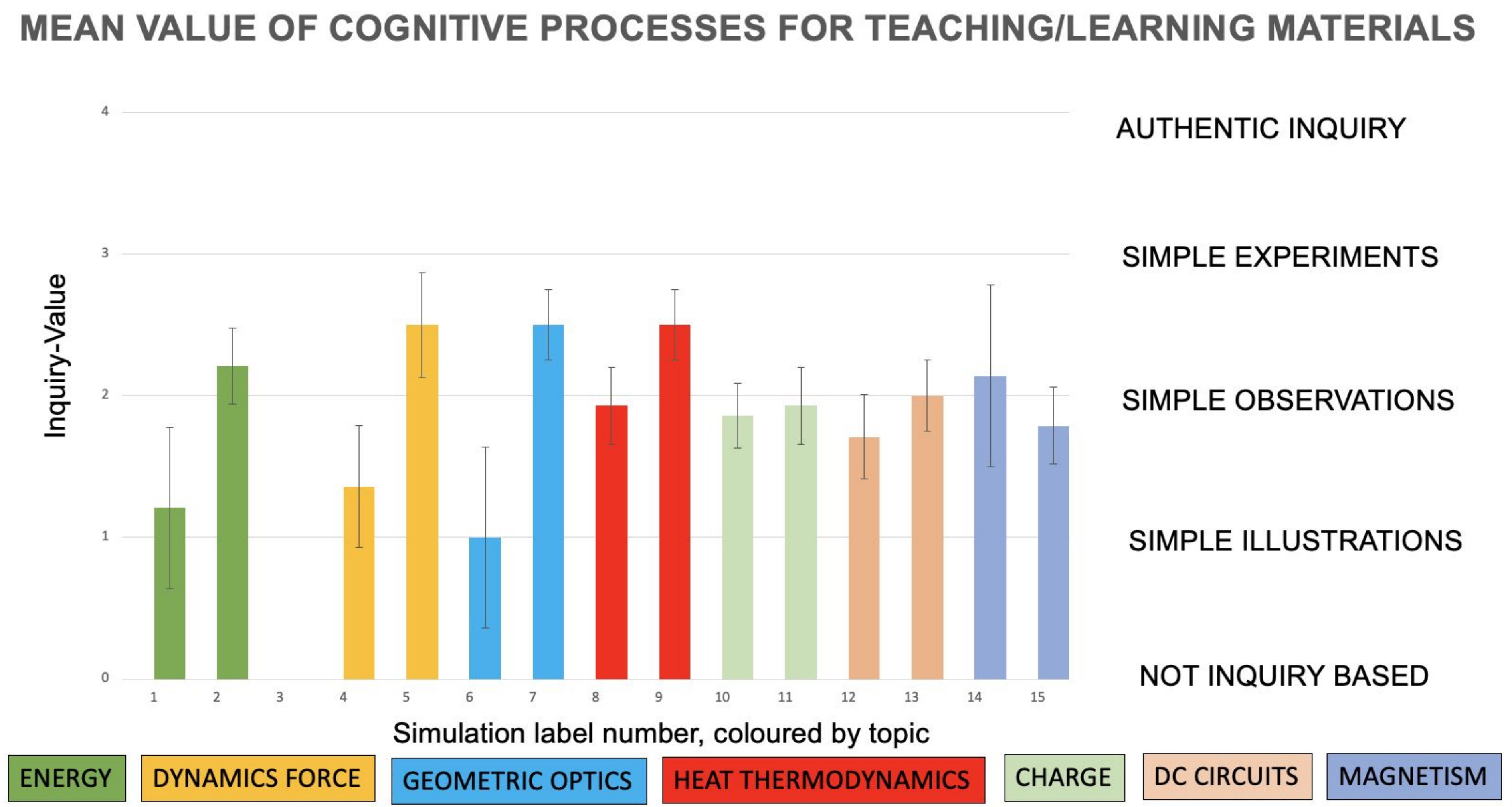
Main results:

TEACHING/LEARNING MATERIALS

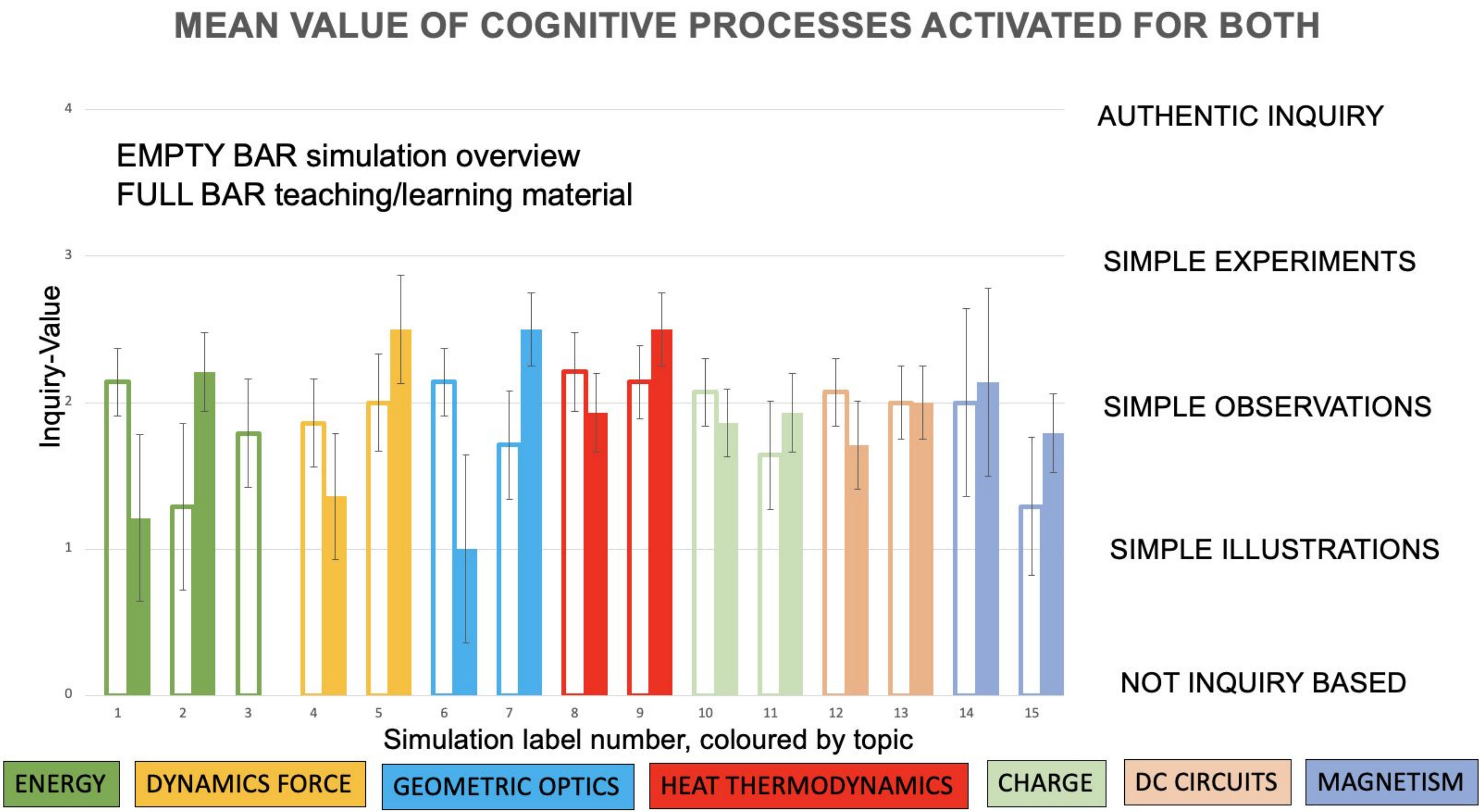
1 ± 0.64 ↔ 2.5 ± 0.37



SIMPLE ILLUSTRATIONS ↔ SIMPLE OBSERVATION **towards** SIMPLE EXPERIMENTS



MEAN VALUE OF COGNITIVE PROCESSES FOR TEACHING/LEARNING MATERIALS
Inquiry-Value
0
1
2
3
4
AUTHENTIC INQUIRY
SIMPLE EXPERIMENTS
SIMPLE OBSERVATIONS
SIMPLE ILLUSTRATIONS
NOT INQUIRY BASED
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Simulation label number, coloured by topic
ENERGY
DYNAMICS FORCE
GEOMETRIC OPTICS
HEAT THERMODYNAMICS
CHARGE
DC CIRCUITS
MAGNETISM


MEAN VALUE OF COGNITIVE PROCESSES ACTIVATED FOR BOTH
EMPTY BAR simulation overview
FULL BAR teaching/learning material
Inquiry-Value
4
3
2
1
0
AUTHENTIC INQUIRY
SIMPLE EXPERIMENTS
SIMPLE OBSERVATIONS
SIMPLE ILLUSTRATIONS
NOT INQUIRY BASED
1
2
3
4
5
6
7
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14
15
Simulation label number, coloured by topic
ENERGY
DYNAMICS FORCE
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DC CIRCUITS
MAGNETISM

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

Universita degli studi di Trieste

June 1, 2023

Laboratory

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.

Laboratory

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

Laboratory

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

Laboratory

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

Laboratory

Doing the Investigation

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

Exercise sheets

Reflections on “Simulating ISLE”

Gruppo 1: Ottica Geometrica. Argomenti complessi. Modello e conoscenze preliminari. Lente convessa / concava.

Gruppo 2: Skate Park. Strumento simulazione potente. Domande spesso ripetitive. Da zero come si costruisce la conoscenza? Idea qualitativa della conservazione energia. Manca l’aspetto matematico

Gruppo 3: Legge di Newton. Domande banali. Dal punto di vista dello studente. Domande facili può aiutare a capire passo dopo passo la costruzione della conoscenza.

Gruppo 4: Faraday. Non tanto le domande. Molte domande ridondanti? Domande deviano dalla risposta. Non richiede la risposta ma la riflessione. Nella simulazione si possono togliere e mettere le linee di campo. Non coerenza nella logica dello sviluppo.