26th Multimedia in Physics Teaching and Learning

MPTL

7-9 September, 2023

Comparing Simulations to Improve Physics Students’ Education

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PhET INTERACTIVE SIMULATIONS

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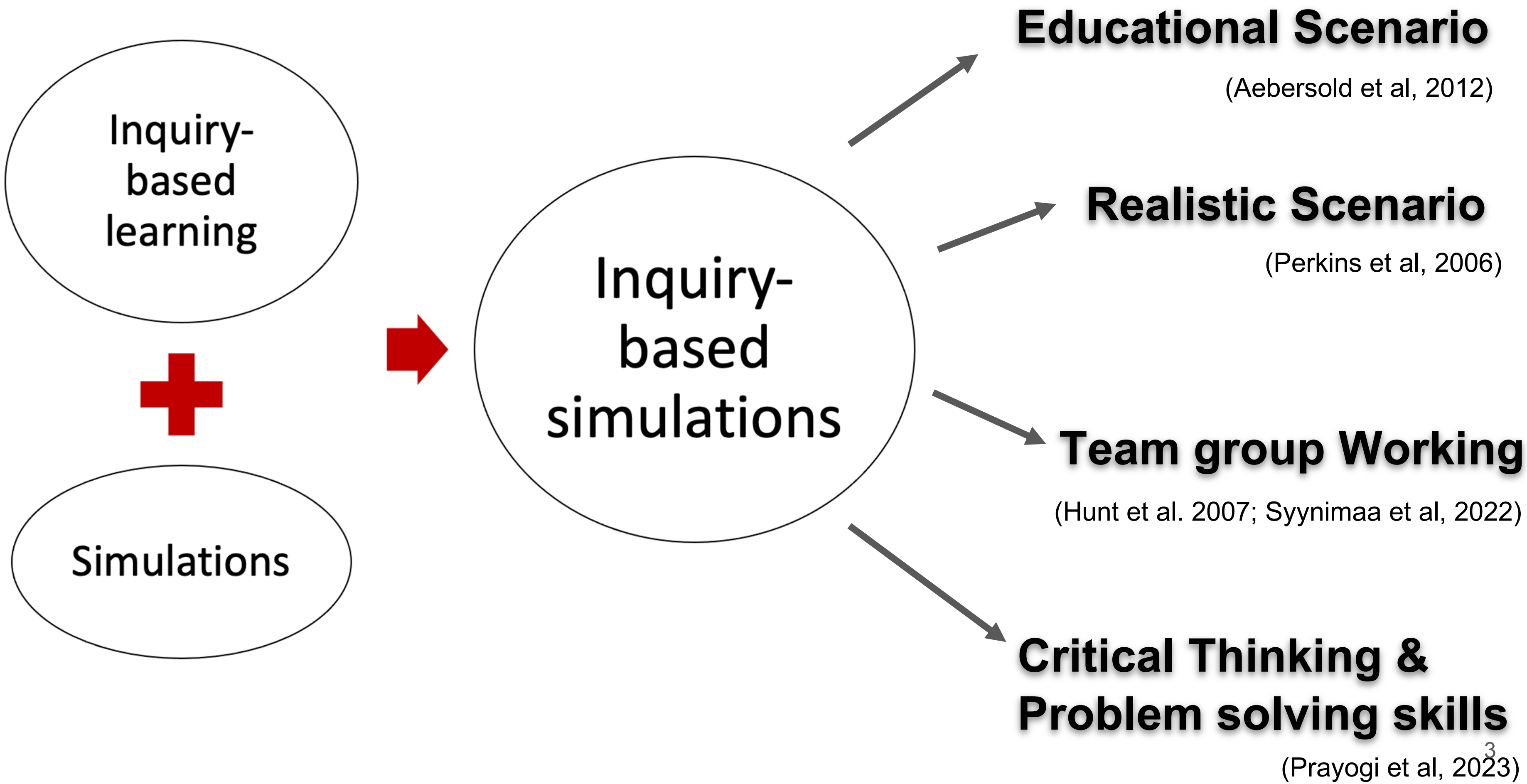
THEORETICAL FRAMEWORK



Practical Application

Engagement and Motivation

Transferable Skills

COMPONENTS 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

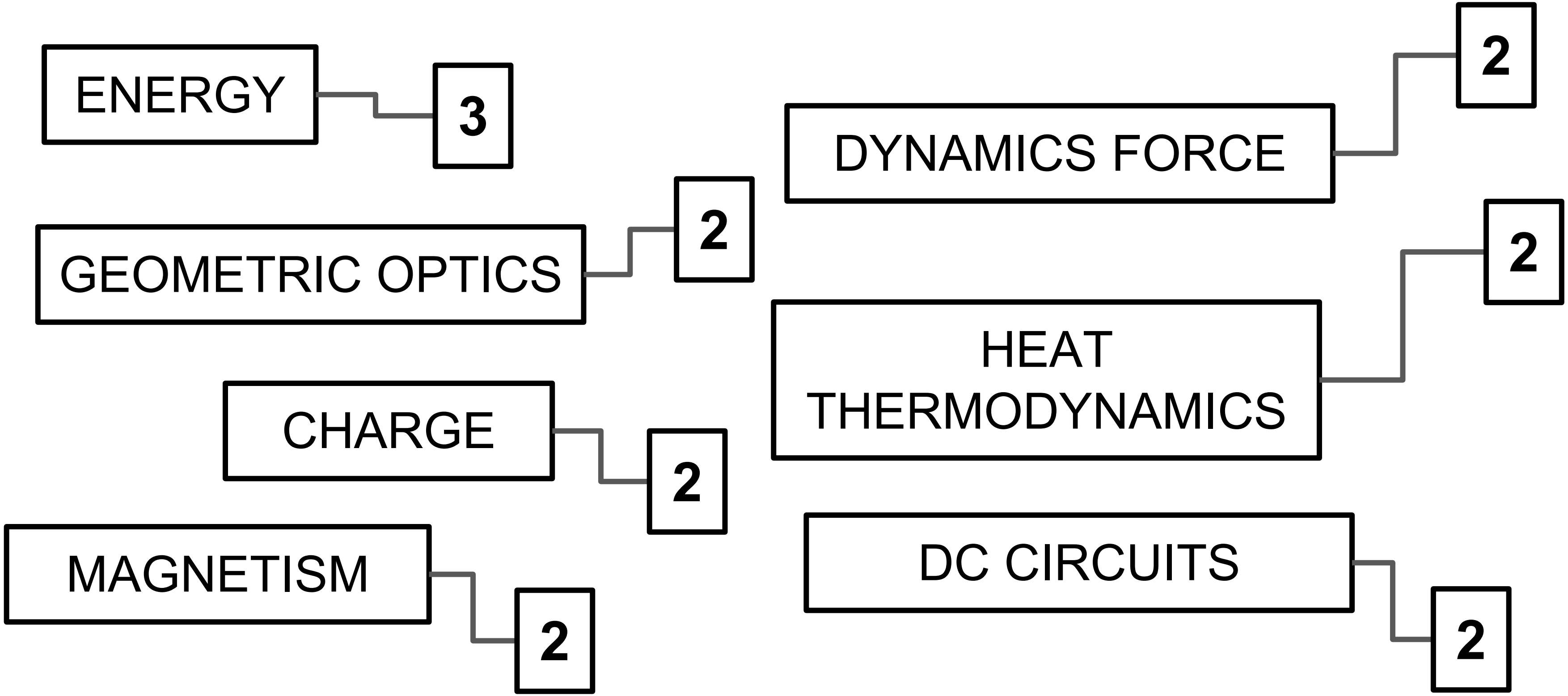
ASPECTS OF SCIENTIFIC COGNITIVE PROCESSES

- 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

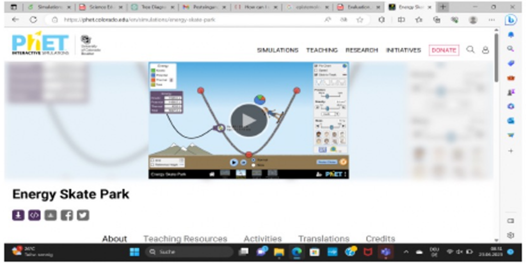
DATA ANALYSIS OF COMPARED SIMULATIONS

Mean value of cognitive processes involved

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

READING SCALE

EXAMPLE BY ENERGY TOPIC



Simulation mean value: 2.14 ± 0.23

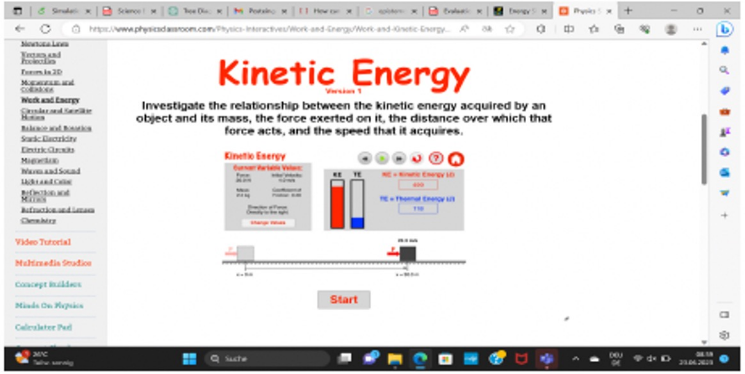
Teaching/learning material mean value: 1.21 ± 0.57

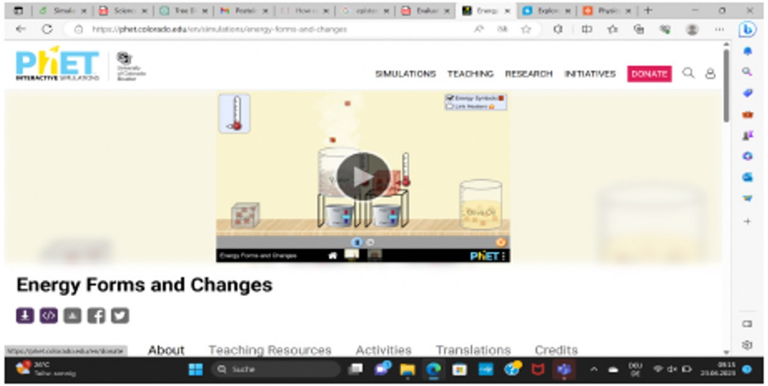
How close simulations gets to authentic inquiry

Main results:

SIMULATIONS OVERVIEW FEATURES

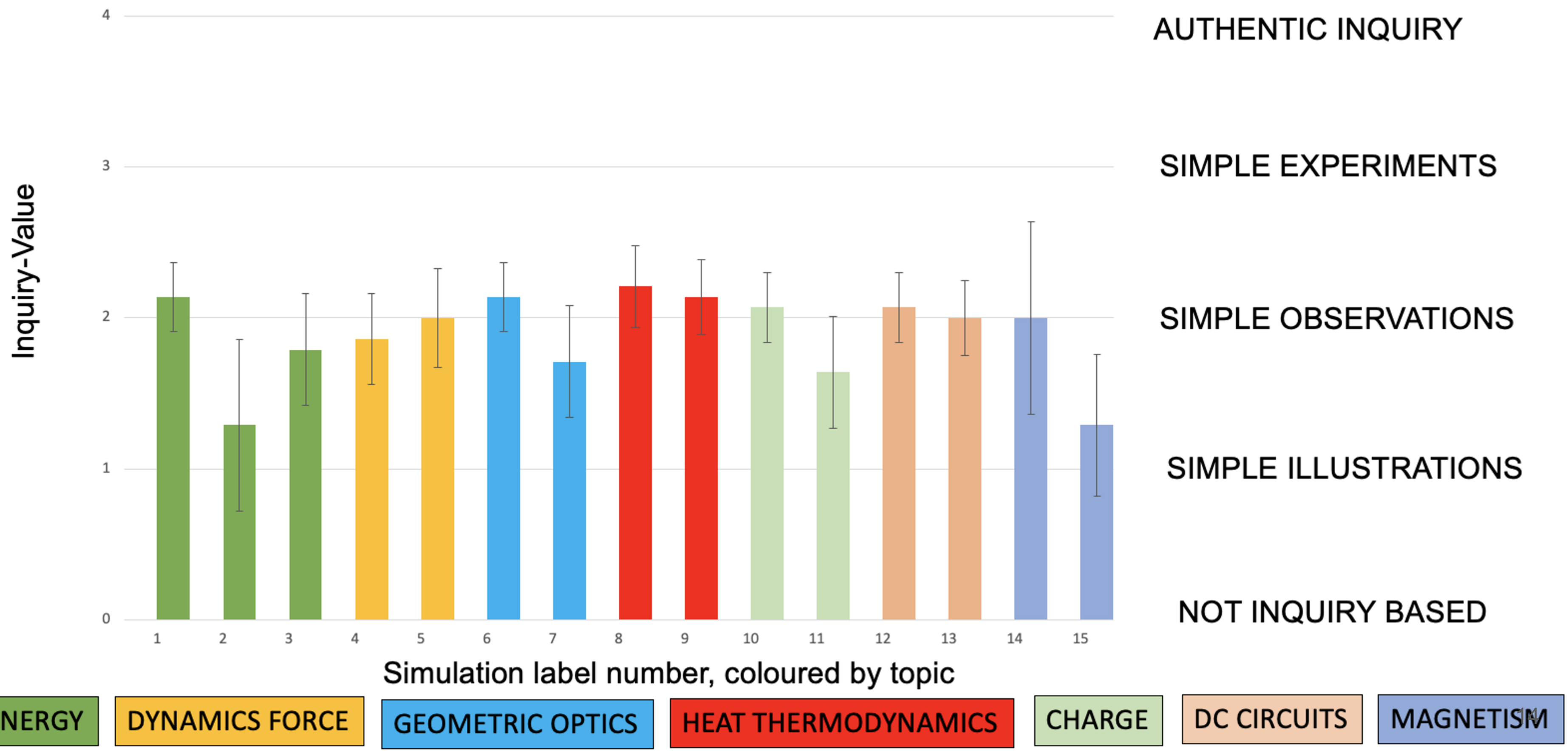
1.29 ± 0.57 ⟷ 2.21 ± 0.27





SIMPLE ILLUSTRATION ⟷ SIMPLE OBSERVATION

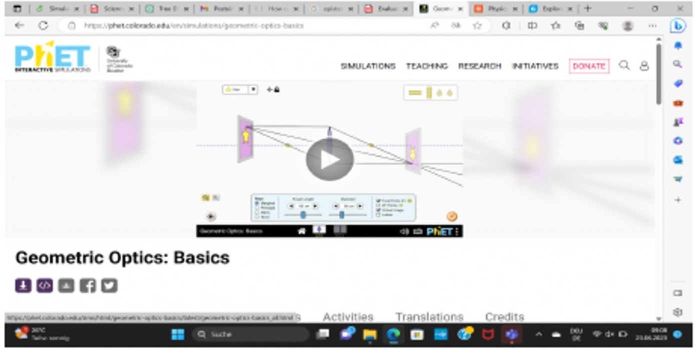
MEAN VALUE OF COGNITIVE PROCESSES FOR SIMULATION OVERVIEW

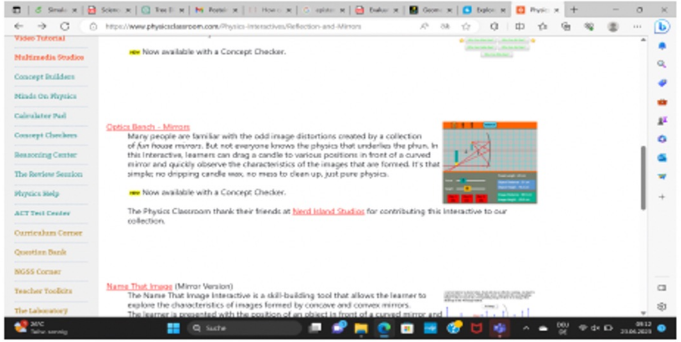


Main results:

TEACHING/LEARNING MATERIALS

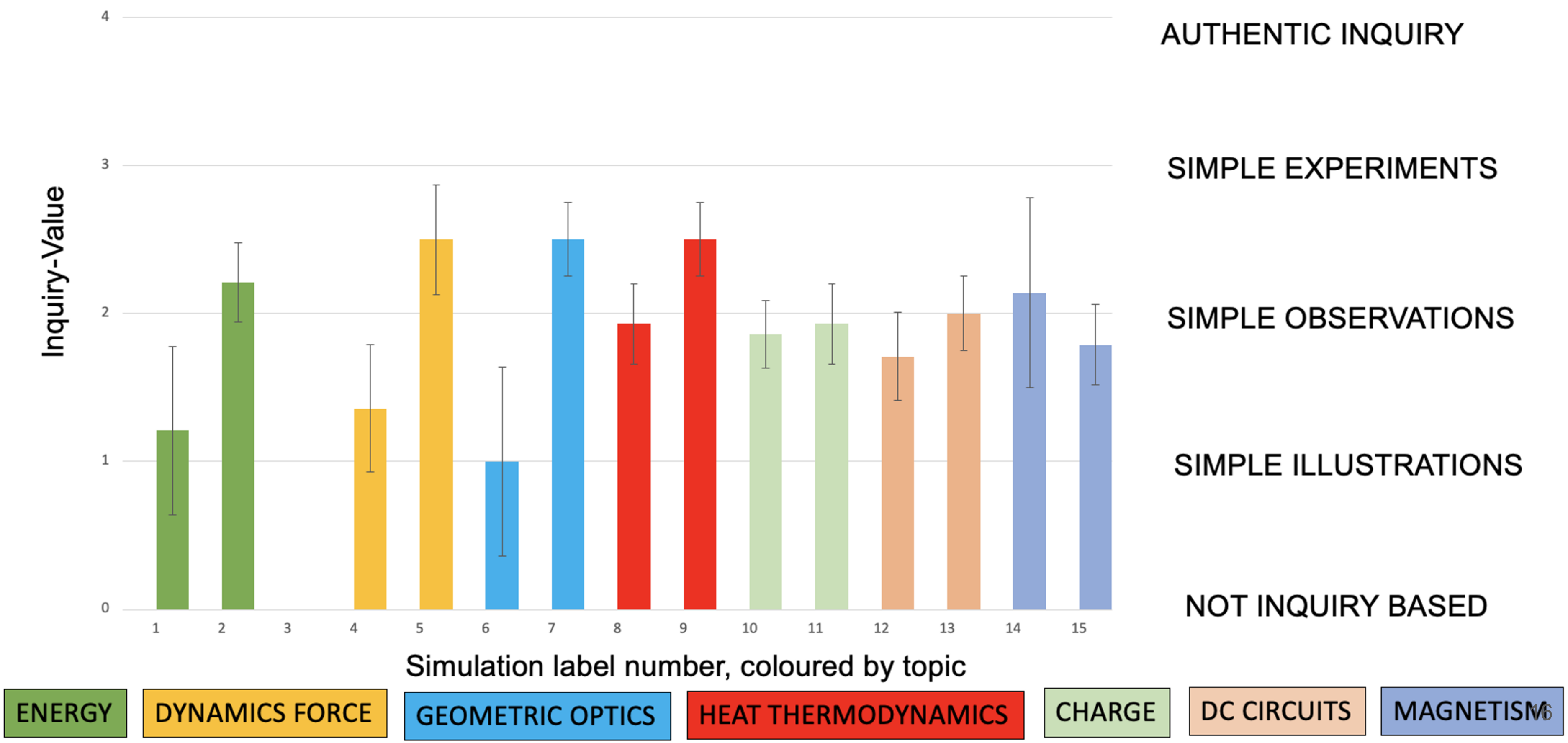
1 ± 0.64 ⟷ 2.5 ± 0.37



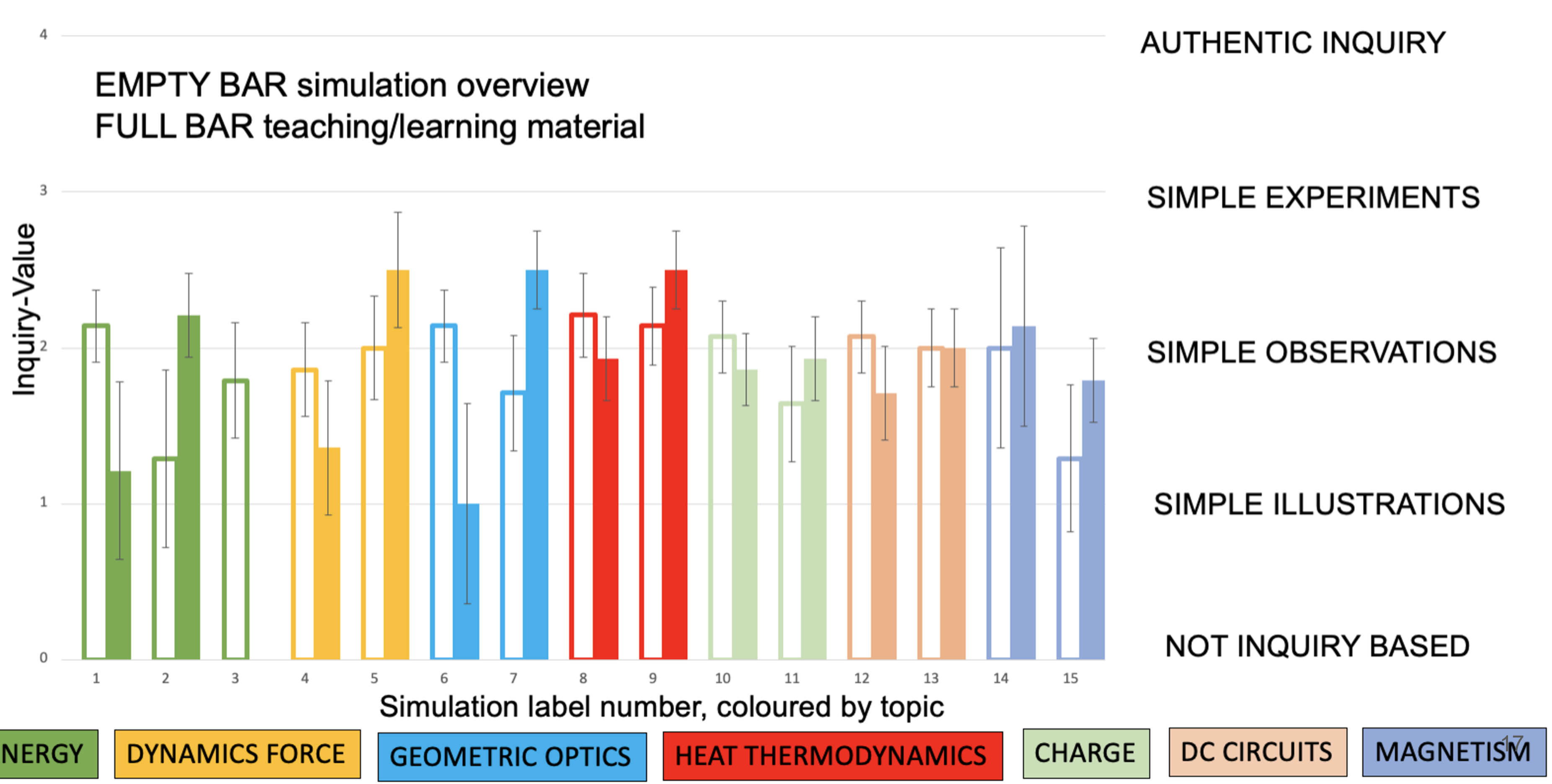


SIMPLE ILLUSTRATIONS ⟷ SIMPLE OBSERVATION **towards** SIMPLE EXPERIMENTS

MEAN VALUE OF COGNITIVE PROCESSES FOR TEACHING/LEARNING MATERIALS



MEAN VALUE OF COGNITIVE PROCESSES ACTIVATED FOR BOTH



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.

$$2.86 \pm 0.53$$

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.

References

Katherine Perkins et al. “PhET: Interactive simulations for teaching and learning physics”. In: The physics teacher 44.1 (2006), pp. 18–23

Michelle Aebersold, Dana Tschannen, and Melissa Bathish. “Innovative simulation strategies in education”. In: Nursing research and practice 2012 (2012)

Elizabeth A Hunt et al. “Simulation: translation to improved team performance”. In: Anesthesiology clinics 25.2 (2007), pp. 301–319.

E. Etkina, D. T. Brookes and G. Planinsic, “Investigative Science Learning Environment: When learning physics mirrors doing physics”, Institute of Physics, Concise Publishing; Morgan and Claypool Publishers (2019)

Clark A Chinn and Betina A Malhotra. “Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks”. In: Science education 86.2 (2002), pp. 175–218.

David T. Brookes, Eugenia Ektina, and Gorazd Planinsic. “Implementing an epistemologically authentic approach to student-centered inquiry learning”. In: Physical Review Physics Education Research 16.2 (2020), p. 020148.