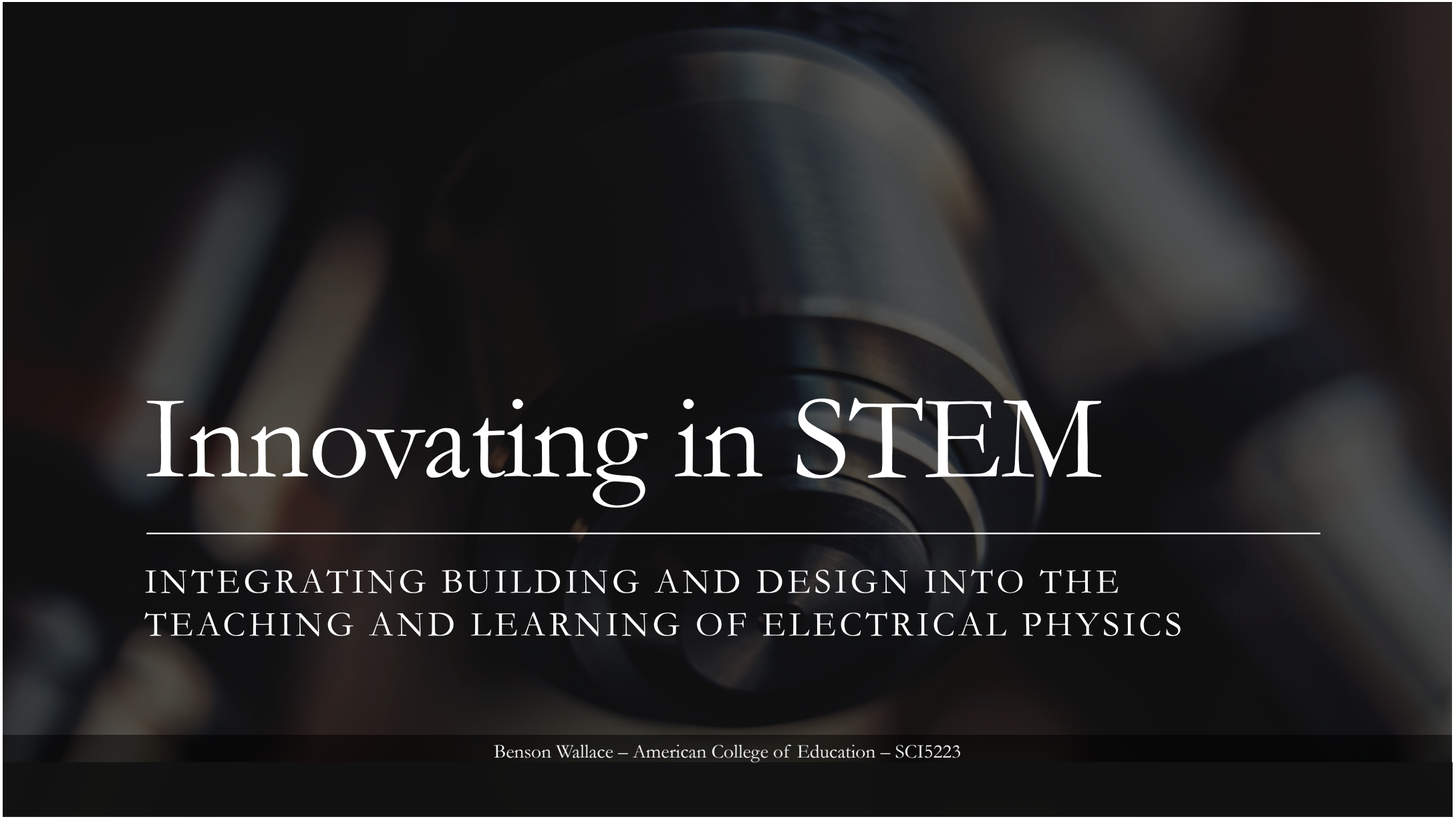


Innovating in STEM

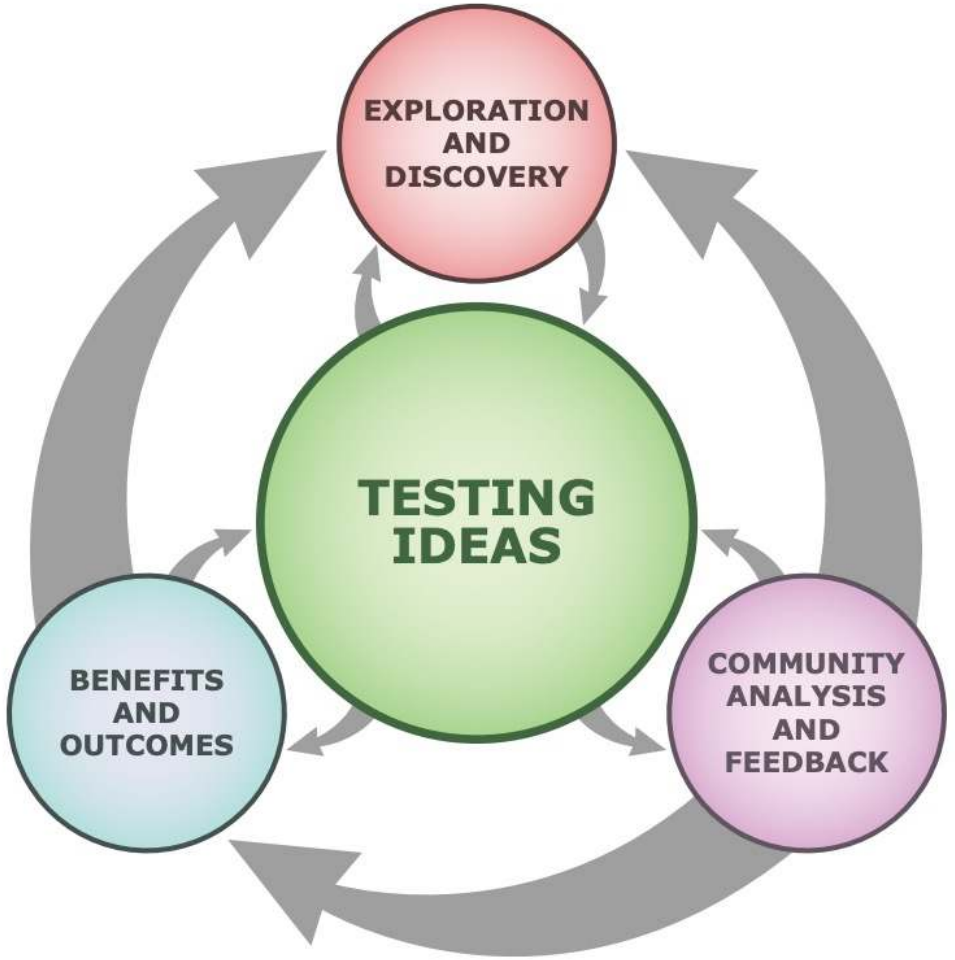
INTEGRATING BUILDING AND DESIGN INTO THE TEACHING AND LEARNING OF ELECTRICAL PHYSICS

Benson Wallace – American College of Education – SCI5223

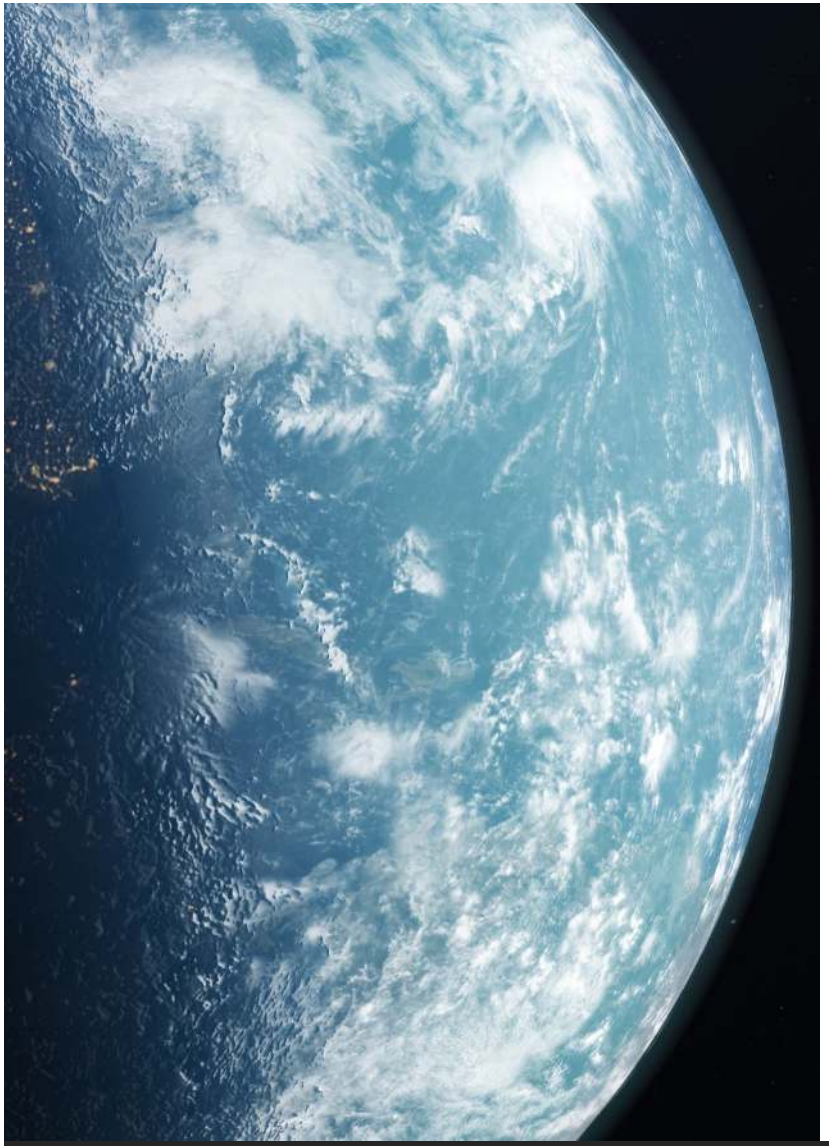
How Science Works

Figure 1

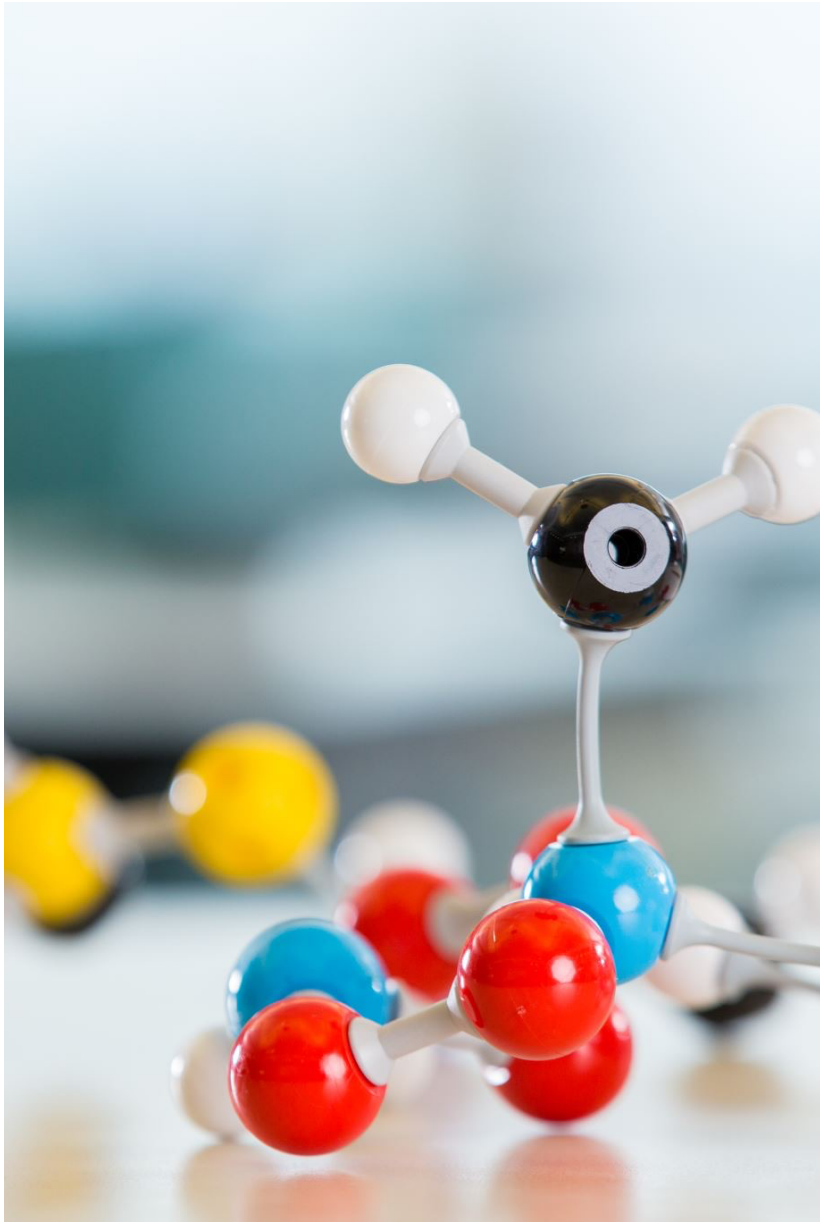
How Science Works Flowchart



Note. Adapted from The University of California Museum of Paleontology



"Physics is the most fundamental of the experimental sciences, as it seeks to explain the universe itself from the very smallest particles to the vast distances between galaxies."
(International Baccalaureate Organization, 2021)



"We're teaching high school science in the wrong order — biology, chemistry and then, for 20 percent of the students, eventually physics. The subjects are unrelated, to be learned and forgotten – in the order taken"

(Leon Lederman, Physicist and Nobel Laureate, as cited in Johnson, 2018)

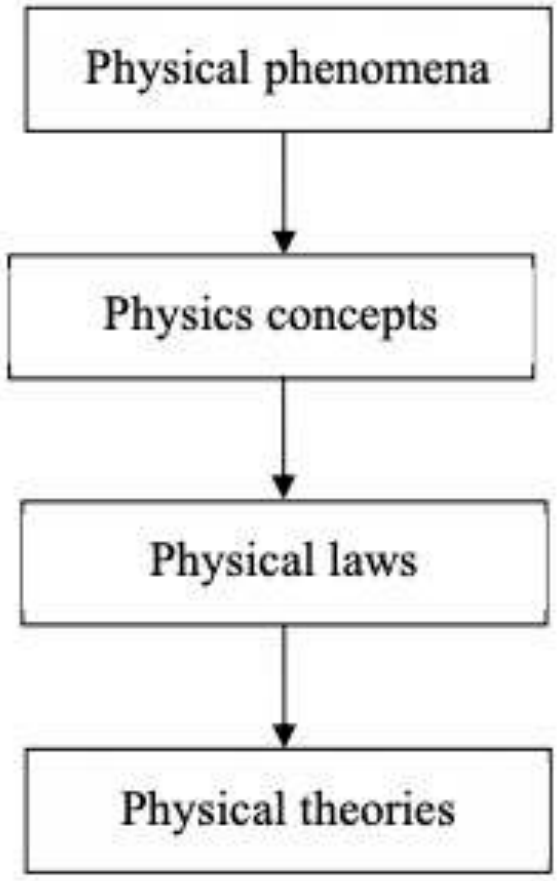
Active Learning vs Traditional Teaching (Marušić & Sliško, 2014)

- "Active Learning" refers to a variety of modern learning frameworks with the common element of students being active participants in the learning process
- In physics teaching, most of these frameworks are based on constructivism
- Despite evidence that active learning leads to better conceptual understanding, many teachers still use the traditional approach of demonstrating the solutions of problems that are likely to be on the final exam to a mostly passive student body
- Resistance to changing this often comes from students as much as teachers

Learning models in physics teaching

Figure 2

The General Structure of Physics Teaching



Note. Adapted from Korsun, 2018

Material models vs thought models (Korsun, 2018)

- Models are approximations of physics phenomena, concepts, laws and theories that are used when the direct study of them would be difficult or impossible
- Many models in physics teaching are based on analogies
- Material models are constructed from physical materials, while thought models are generally diagrams, animations and simulations. For example, a material model of the Large Hadron Collider might comprise two marbles rolling down ramps so that they collide with each other (with a box of sand as the particle detector), while a thought model would be simplified diagram or animation of the process.
- Optimal physics teaching uses a combination of material and thought models

Key competencies of physics teachers (Liu & Sun, 2021)

- Physics literacy
- Education and teaching literacy
- Scientific literacy
- Humanistic literacy
- Information literacy
- Life-long learning ability

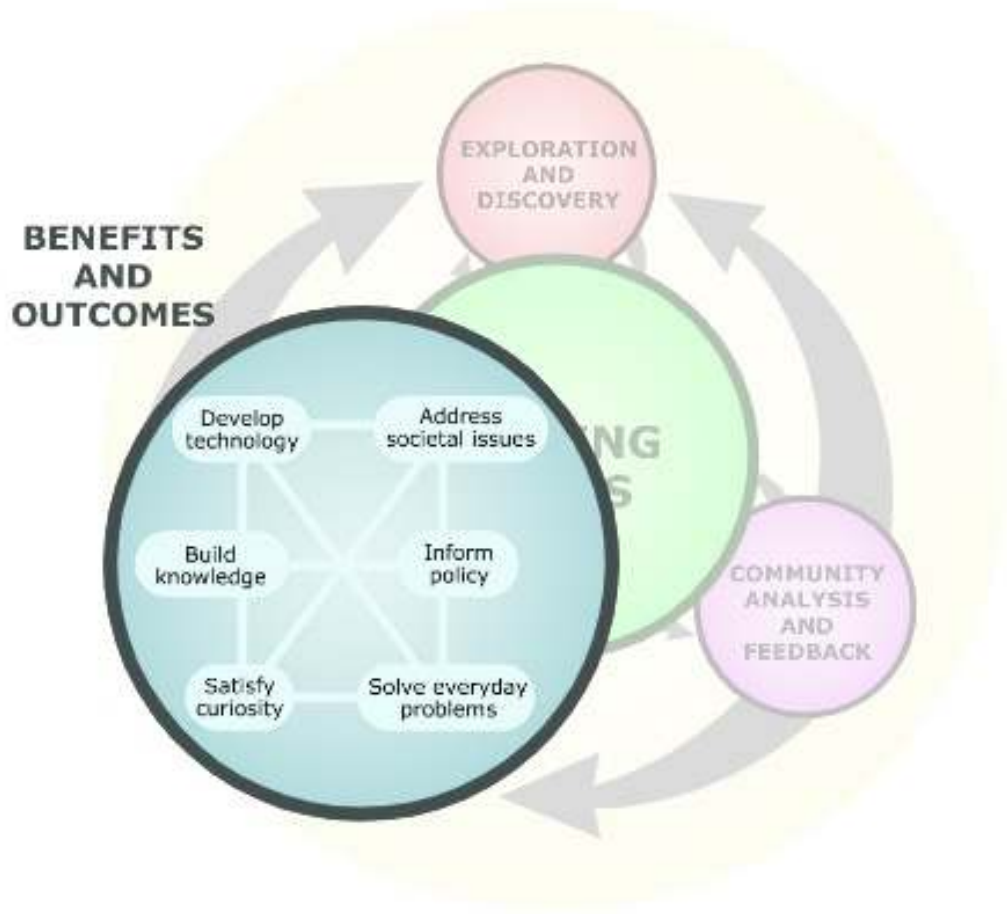
Recent innovations (a.k.a. the rationale for adding building and design to physics)

- The integration of engineering practices into the NGSS (Moye, 2019)
- Systematic Design as a 21st century skill (Cohen et al., 2017)
- National Institute for STEM Education (NISE) Certification Indicators 6 (Response to Failure and Intellectual Risk-Taking, which includes Product Development and Solution Seeking) and 30-31 (Identifying Engineering Problems and the Engineering Design Process) (Accelerate Learning, 2021)

Connecting Design & How Science Works

Figure 3

Benefits and Outcomes of the Scientific Method



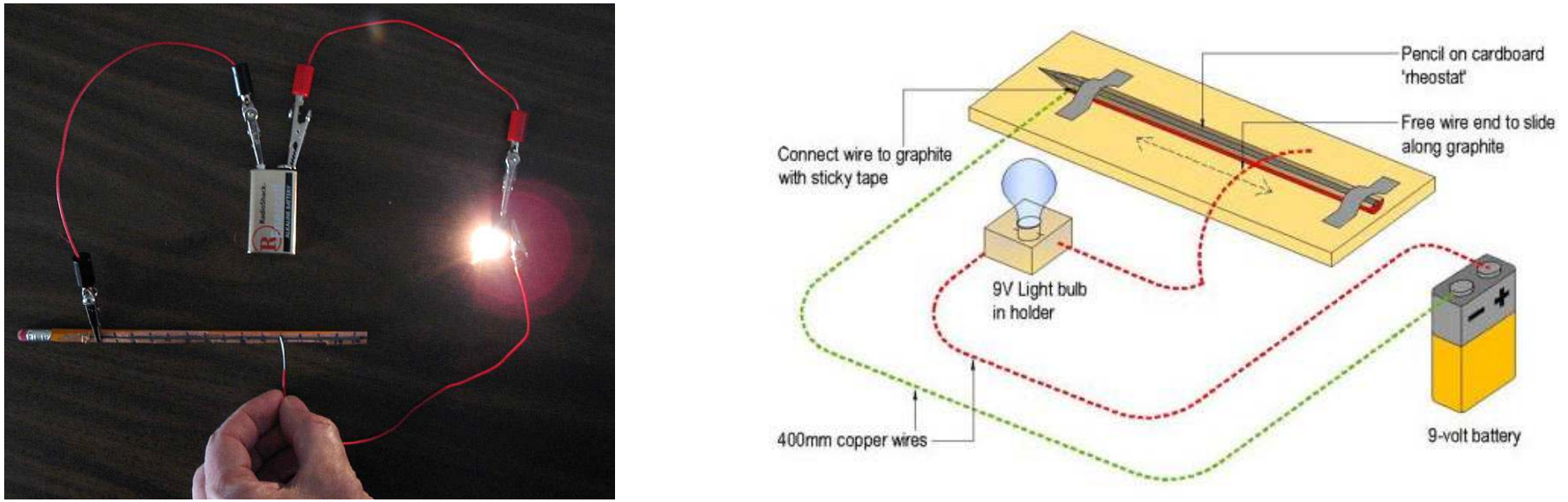
Note. Adapted from University of California Museum of Paleontology

Innovation: from traditional labs to PBL

- Larson (2021) suggests connecting "traditional labs" with a project context
- Almeida and Steinberg (2001) suggest that project-based learning is effective when it is authentic (students produce something of real value), active and applied in a real-world context
- Electrical physics labs are often done simply to verify or illustrate a theoretical concept, but many can easily be turned into short design projects that do not require a large time trade-off

Figure 4

Pencil Dimmer Switch Project Circuit (Left) and Schematic (Right)

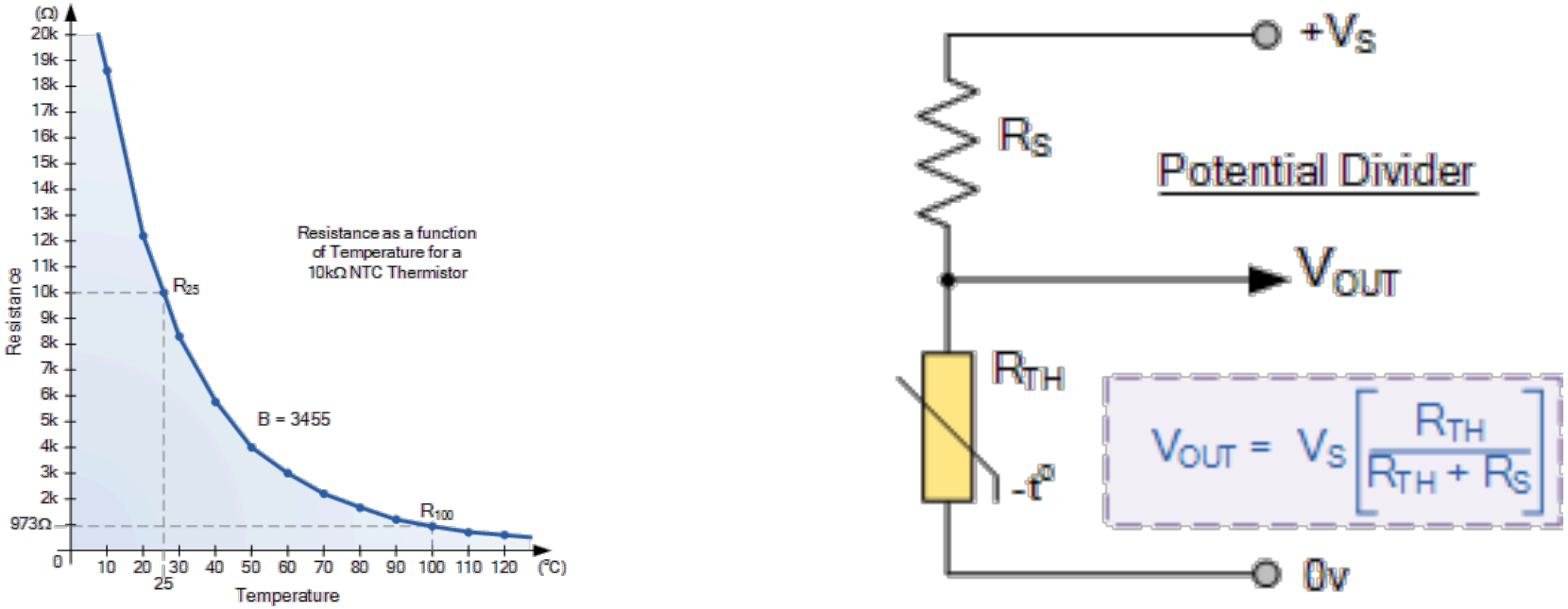


Note. Adapted from Cowen (2011) and Agarwal (2014)

Middle school example

Figure 5

Thermistor Resistance-Temperature Curve (Left) and Temperature Sensor Circuit (Right)

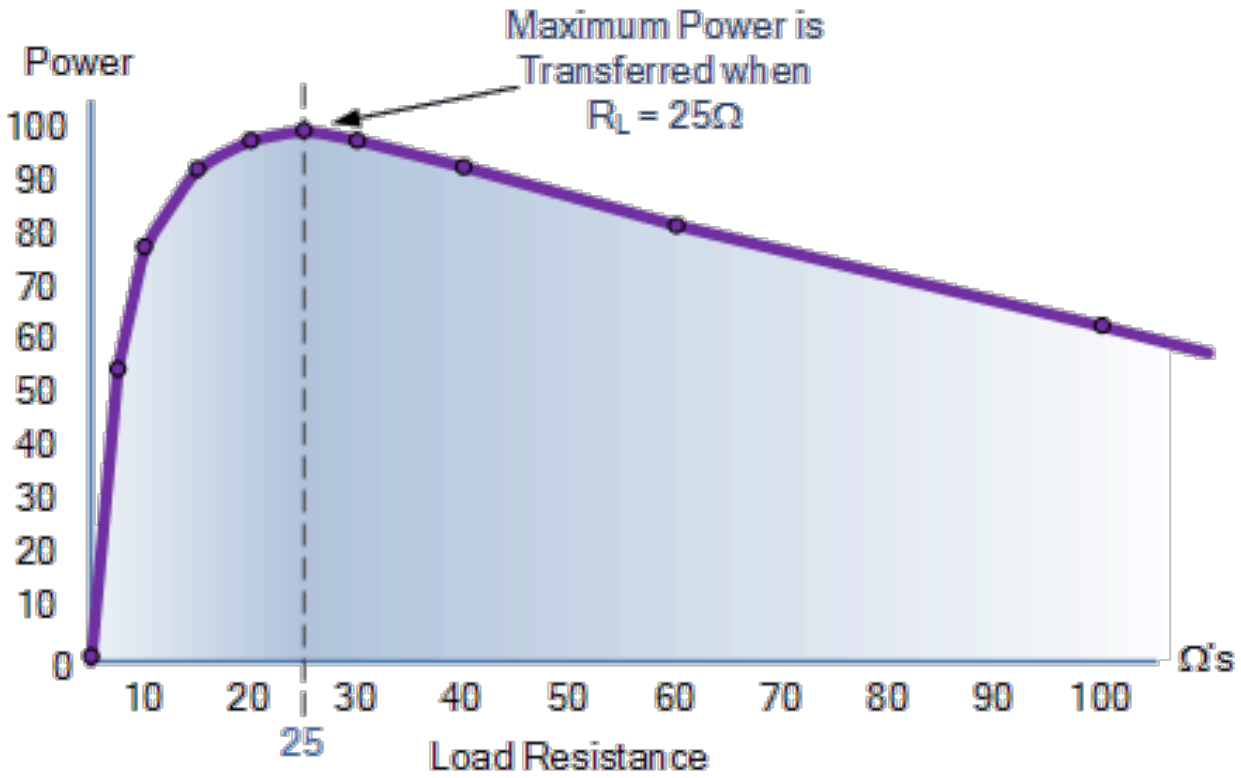


Note. Adapted from Electronics Tutorials, 2021

High school example

Figure 6

Power Delivered to a Circuit as a Function of Load Resistance



Note. Adapted from Electronics Tutorials, 2018

A bridge to mathematics

Mathematical modelling – building bridges between STEM disciplines

- Mathematical modelling is an easy way to achieve context integration within existing school structures (Kurtil and Gurel, 2016)
- In the maximum power transfer example shown, students model the curve as a mathematical function based on the relevant physics principles involved, and then find the maximum value of the function using calculus (or graphing software)

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