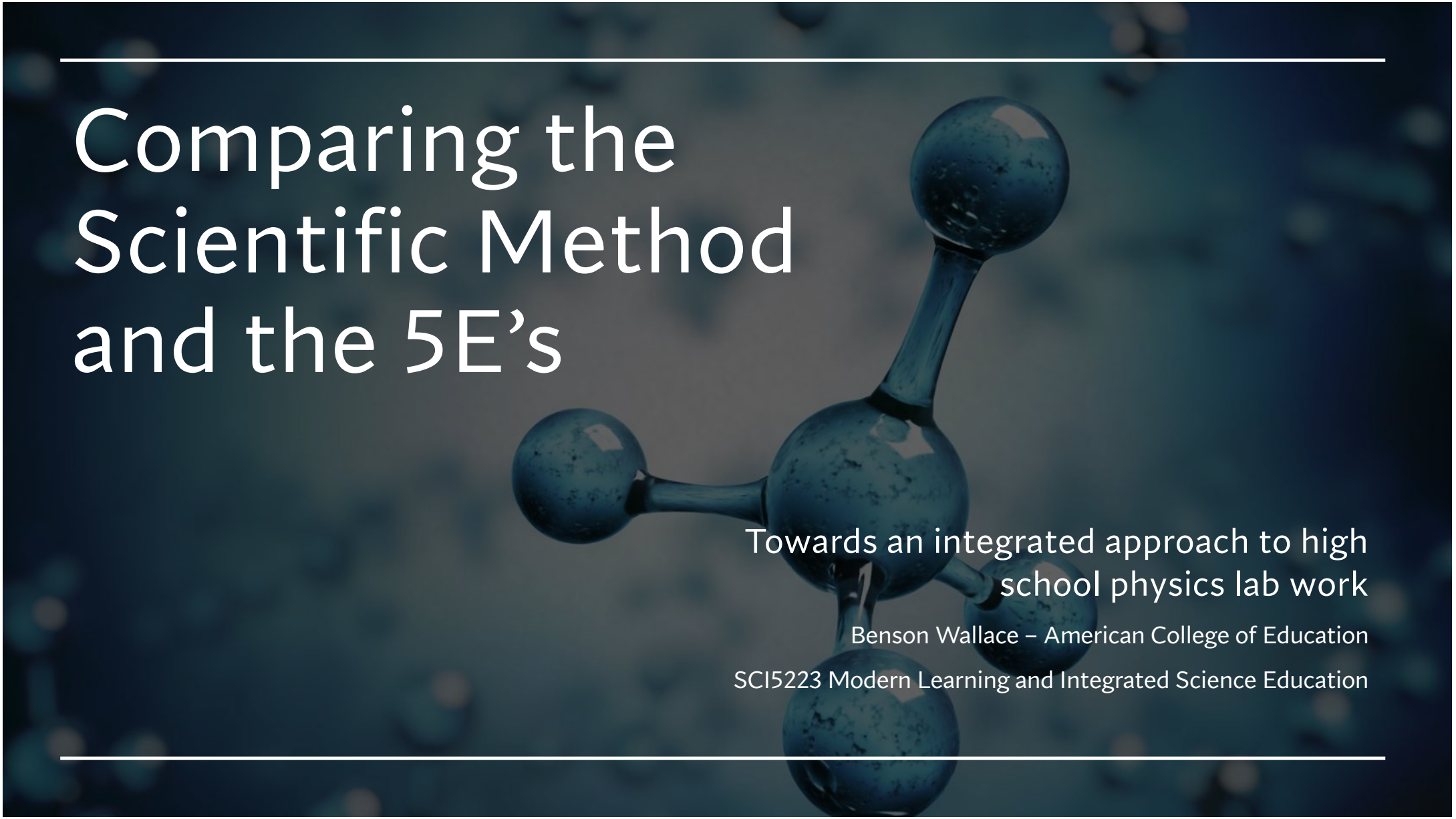

Comparing the Scientific Method and the 5E's

Towards an integrated approach to high school physics lab work

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SCI5223 Modern Learning and Integrated Science Education

The Scientific Method – “the old way”

Cultural “icon” that has been embedded in science education for over 100 years, but promotes “activity without understanding” (Windschitl et al., 2008, p. 942) and associated with “cookbook” laboratory activities (Lonergan et al., 2019)

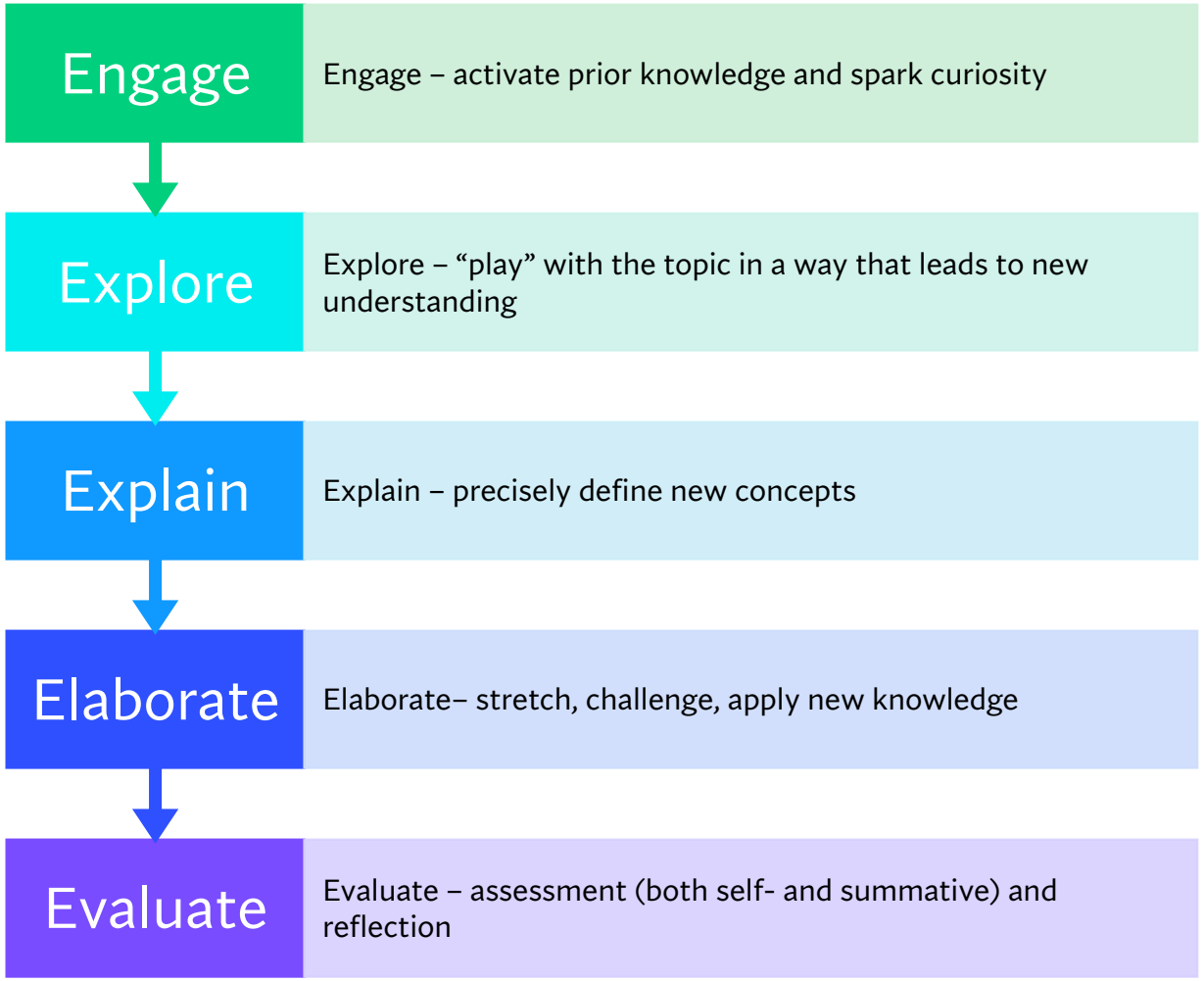
Various versions involving between four and eight steps, with common elements that can be summarised as question, hypothesis, experiment and conclusion (Bobrowsky, 2021, p. 88)

Out with the old, in with the new?

5E Model “should replace presentations on the ‘scientific method’ ” (Bybee, 2019, p. 8)

Real science is not a linear process – many things happen before the traditional scientific method steps (Bobrowsky, 2021)

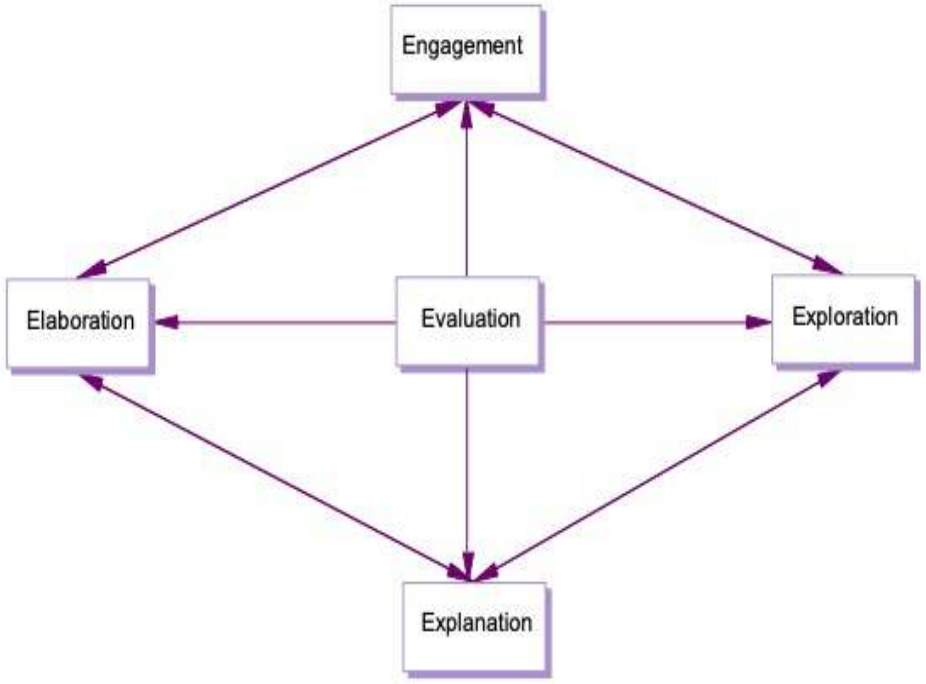
The 5E Model Steps (Bybee, 2019)



Real science is non-linear

Figure 1

Reimagined Representation of the 5E Model



Note. Adapted from Duran and Duran (2004)

The case for the 5E Model in science lessons

- Significantly improved outcomes in a middle school “process of scientific inquiry” unit (Bybee et al., 2006)
- Use with technology can develop 21st century skills (Senan, 2013)
- Inquiry-based by nature; ideal for integrating scientific practices, disciplinary core ideas and cross-cutting concepts (Rodriguez et al., 2019, p. 50)

Can they be integated?

- Many overlapping elements, and the scientific method can be embedded in a 5E lesson cycle (Lesley University, n.d.)
- Real scientific research can be easily adapted into a classroom investigation using the 5E Model (Idsardi et al., 2019)
- Integrating the scientific method and the 5E model might give students a more holistic view of how scientific progress is made

From the scientific method to “the nature of science”?

The 5 main areas of the International Baccalaureate Programme’s “Nature of Science” framework (from InThinking, 2021):

- What is science and the scientific endeavour?
- The understanding of science
- The objectivity of science
- The human face of science
- Scientific literacy and the public understanding of science

Simple Harmonic Motion with the 5E Model

Engage – students are shown several provocative examples of oscillations (for example the Tacoma narrows bridge collapse) and try to suggest explanations for what they are observing based on prior knowledge of forces and motion.

Explore – students are given time to “play” with various spring and masses and asked to investigate the factors that affect amplitude and frequency.

Explain – students develop the equations of simple harmonic motion through guided inquiry and reconcile these with their observations of the physical phenomena observed earlier.

Elaborate – students design and conduct experiments to precisely verify that the effect of one or more of the factors identified has on frequency and/or amplitude. Stronger groups can investigate the effect of damping.

Evaluate – groups present their finding to each other via slide decks and peer feedback is given

Pros and cons

The 5E Model helps learners see the “bigger picture” of all the variables involved in simple harmonic motion and why the topic matters, but...

Less independent learners may struggle to identify appropriate factors during the Explore phase (may need support investigating systematically) and thus may also struggle to design experiments that appropriately separate variables during the Elaborate phase.

Simple Harmonic Motion with the Scientific Method

Question – students observe a teacher demonstration of a spring-mass system and are asked the question “what is the effect of mass on the period of oscillation of a spring-mass system”?

Hypothesis – the teacher leads students in deriving a quantitative hypothesis by starting with the relevant equations of motion: “period of oscillation should be proportional to the square root of mass”.

Experiment – students follow a set of instructions to carry out an experiment to measure how the period of oscillation varies as mass is increased. Students may not be explicitly required to choose control variables or consider an appropriate range of independent variable values.

Conclusion – students process the data and write a lab report, which concludes with a statement about whether the data supports the hypothesis.

Pros and cons

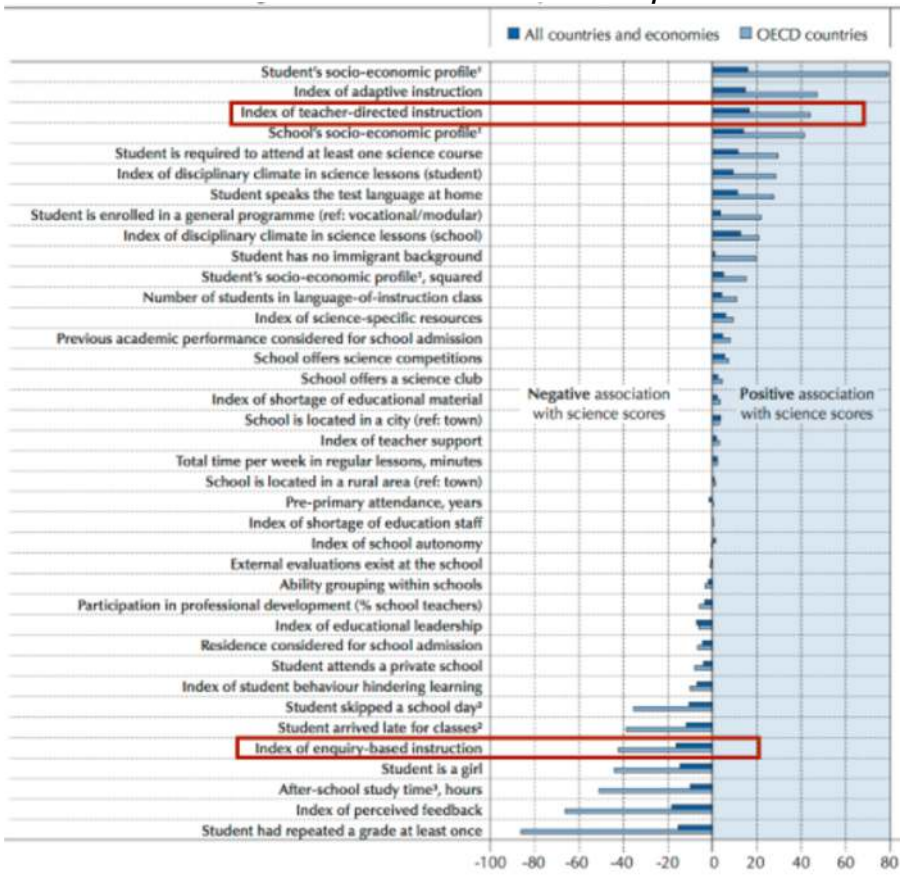
The “traditional science lab” structure provides a reliable process for students to follow and ensures that students can experience success in their data collection, but...

Many students may go through the motions of the task without learning anything about how to generate testable questions or design controlled experiments that answer those questions, and the lab work does not answer the question of why the topic is important.

Is inquiry-based always best?

Figure 2

Factors Associated With Science Performance

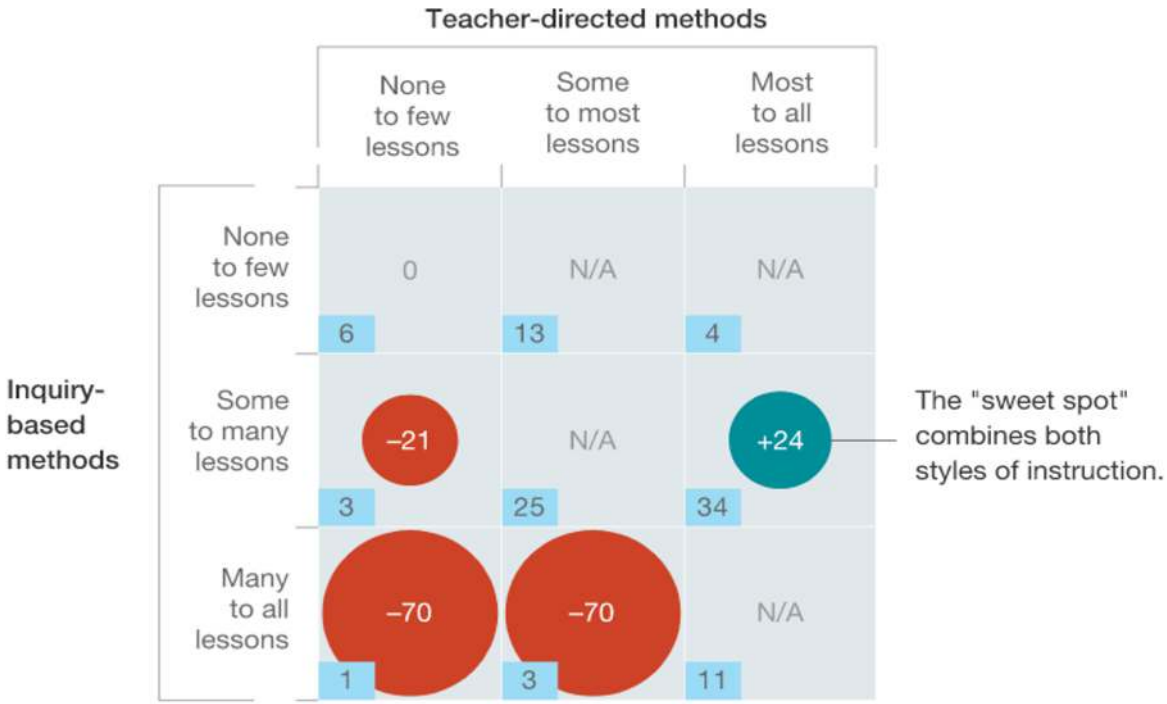


Note. Adapted from The Age of STEM Education (2019)

Cultural Contexts

Figure 3

Impact of Teacher-Directed and Inquiry-Based Instruction on PISA Science Scores



Note. Adapted from McKinsey and Company's *Drivers of student performance: Asia insights* (Chen et al., 2018)

Conclusion

The scientific method can be integrated into the 5E Model to provide students with the rigorous science skills that they need while also developing their awareness of “the nature of science”

The right mix of teacher-directed and inquiry-based instruction will depend on the topic of study and the cultural context of the school and cohort

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