Some observations on the use of analogies in teaching of undergraduate physics

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Abstract

We present a summary of work carried out principally as an undergraduate summer project in July – August 2020 to investigate the use of analogies in physics teaching in the undergraduate course at Imperial College London. As a background, we first compare and contrast methods for classification of analogies and provide literature review highlights relevant to practitioners of university level physics education. We follow this with a summary of a study done on the undergraduate course at Imperial involving scrutiny of physics course materials, surveys on the prevalence and efficacy of analogies with staff and students, and interviews with teaching staff.
To conclude we provide advice, guidance and points for consideration for science communicators on best practice for use of analogies in their work.

Classification of analogies

We classified analogies as physical, mathematical, or visual (or a combination).

- **Visual**: the analogy provides a way to picture an abstract concept.
  The expanding universe is like an inflating balloon with dots on the surface.
- **Physical**: the underlying physical principle is the same in each case.
  Resistance in an electrical system is like friction in a mechanical system.
- **Mathematical**: both concepts follow laws or equations which have the same mathematical structure.
  Lorentz transformations of four-vectors are like rotation transformations of three-vectors.

We followed Gentner's 'structure-mapping' model of analogy in which features from the *base domain* are mapped to the *target domain*. Critically, the relations between attributes are mapped, rather than the attributes themselves. For example, the solar system can represent the atom not because electrons are like planets, but because both electrons and planets orbit around a much larger mass (nucleus/Sun), forming a central force system.

Analogies in the physics course at Imperial

The relative frequency of analogy types were examined in three main texts used in the first two years of the physics programme:

- Course notes from lecturers
- *University Physics with Modern Physics (*Young & Freedman)
- *The Feynman Lectures on Physics* (Feynman, Leighton & Sands)

The relative frequencies are shown in Figure 1. In all three texts, the predominant analogy type is physical. Using physical analogies has two notable benefits:

- Encourages students to connect different domains of physics
- Ensures that the base domain is familiar to students

No analogies were a combination of visual and mathematical, nor a combination of all three types of analogy.

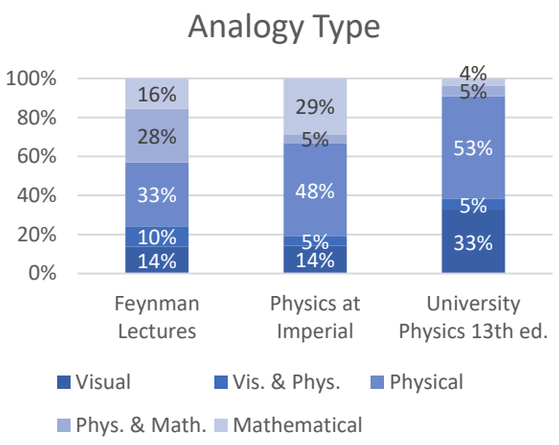

Fig. 1: Relative proportions of analogy types in three main texts used in the first two years of the physics undergraduate programme at Imperial: lecture notes, *University Physics with Modern Physics,* and *Feynman's Lectures on Physics.*

Surveys and interviews with teaching staff and students

Undergraduate physics students and teaching staff were asked to fill out a survey on their opinions of analogies in physics. The surveys were anonymous and voluntary. A total of 154 student responses and 24 staff responses were received.

While staff and students were generally asked different questions, in both surveys respondents were asked about the uses of analogies in physics. Staff were asked to *"Please tick all that apply: In my opinion, analogies in physics can be a useful tool to.."* whereas students were asked "*In my degree, I use analogies to..".* The same options were presented in both surveys. The results are shown in Figure 2.

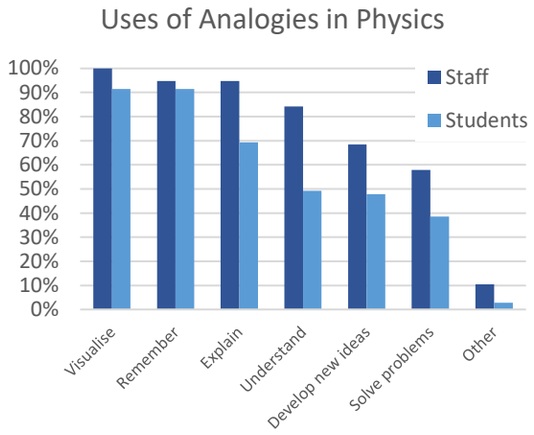

Fig. 2: Staff and student responses about uses of analogies in physics.

Other uses suggested by students include:

- *"To connect methods to the range of phenomena to which they apply"*
- *"To have an intuition for the concept"*

Many students accept that analogies are useful to visualise, understand, and explain. However, compared to staff responses, students do not seem to regard analogies as useful for the more 'active' tasks, such as developing new ideas and solving problems.

Advice and guidance for teaching and learning

How should analogies be used?

Use several analogies
Using several analogies to explain a concept prevents students from being overly reliant on one particular analogy.

Explain the link
Explain why the base concept can be used to explain the target concept.

Highlight limitations and caveats
Highlight any limitations to prevent possible misconceptions about the target concept.

When should analogies be used?

In lectures
Students surveyed prefer analogies to be mentioned in spoken lectures, which allows the lecturer to be explicit about the strengths and weaknesses of the analogy.

In tutorials
Discussion of an analogy's strengths and weaknesses will allow the students to examine their understanding of the concept, with a teacher present to address any misconceptions that may arise from the analogy.

Acknowledgements and references

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