A moment-by-moment analysis of a successful case of students generating and running a model of permanent magnetism

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Abstract

Within PER, case studies of successful physics learning are important for many reasons, including because they provide insight into curricular development. Additionally, from a theoretical perspective, examples of successful learning as demonstrated through microgenetic analyses of moment-by-moment shifting priorities of intuitions, can also contribute to the Knowledge in Pieces (KiP) framework by providing empirical evidence for the KiP learning mechanism. Here we present a moment-by-moment analysis of a case of successful learning in which we see how intuitions about translational symmetry, scaling symmetry, and how magnets work, i.e. they have opposite poles that attract or repel, are raised and lowered as students develop and run a model of permanent magnetism that is substantively similar to the canonical model.

Introduction

- Analysis of successful physics learning is important in PER
  - Provides insights into the ways learning unfolds
  - Influences curricular innovation (e.g., diSessa, 2014; Burdle & Wilhelm, 2020)
- Focus on learning difficulties and deficits is common in PER (e.g., Li & Singh, 2016; Pollock, 2009)
  - Research shows these deficits persist despite high-quality instruction (e.g., Ambrose, Heron, Vokos, & McDermott, 1999, Dermott & Shaffer, 1992)
- Focusing on a successful pathway of learning allows us to unpack a learning mechanism
  - Provides insight into what students are capable of
  - Suggests ways to scaffold future curricular innovation (Hammer & Elby, 2003)

Theoretical Framework

- Knowledge in Pieces (KiP): Leaners can access pieces of knowledge, or knowledge resources, that they use when making sense of new phenomena (diSessa, 2018).
- Learning is defined as changes in the activation of knowledge pieces as they can be triggered across contexts, also known as conceptual change (diSessa & Sherin).
- Within this theory is a focus on learning mechanisms (triggering of knowledge pieces), but often they have been backgrounded in the empirical research, rather than emphasized in the analysis and results.
- Analyses of how knowledge resources are raised and lowered can provide insights about how students develop understandings for themselves.

Relevant Intuitive Knowledge Resources

Intuitive resource	Definition
Translational symmetry	Things here are the same as things there
Scaling symmetry	Things stay the same after changing size
Magnets are dipoles	Magnets have 2 opposite poles
Opposites attract	Opposite poles of a magnet attract each other

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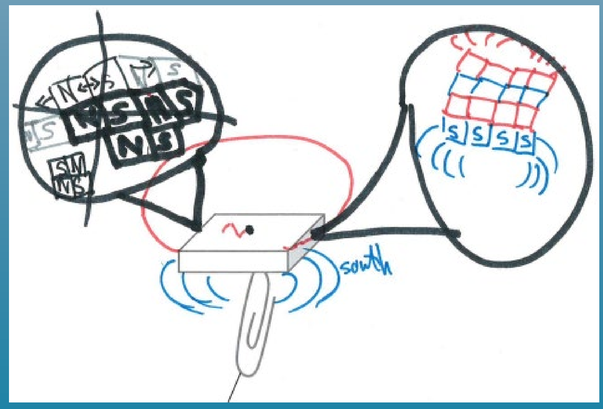
Methods

We conducted interviews of middle-grade students in small groups of 2-3 using an interview protocol based on a lesson on modeling magnetism (Braden, Barth-Cohen, Gailey, & Young, 2021).
The interviews involved 3 phases.

I. The students interacted with magnetic stations designed to elicit specific knowledge pieces necessary for constructing a model of magnetism.
II. The students drew models, focusing on the macroscopic and microscopic elements of the model, and what is happening inside and around the magnets.
III. The students were asked to explain and run their model.

During the interviews, the students were also asked probing questions with the intent of nudging them towards a more canonical model.

We analyzed the data through an iterative process of transcribing and coding the data. We identified knowledge resources using heuristics based on the properties of intuitive knowledge resources (Barth-Cohen, Swanson, & Arnell, 2023). For example, intuitive resources often arise from embodied experiences. Therefore, one heuristic we used is the principle of the body, in which learners will express intuitive resources through non-verbal means.



Vignette 1: Drawing the Model

Oscar and Clarisa began generating their model of magnetism by trying to put together dipole particles.

- Likely Oscar used intuitions about translational symmetry when he stacked the particles in a way that would create a permanent magnet. "So they're all stuck together in a line."
- This quote was immediately followed by "no wait, cuz then the souths are touching" indicating that intuitions about how magnets stick together were raised at that moment.

In this segment, they raised intuitions about how magnetic particles have two poles, how those poles stick together, and about translational symmetry.

Vignette 2: Running the Model

Oscar and Clarisa reason with the model they had previously constructed to determine if it produces a magnet.

- They observed that if the particles are stacked N-S, S-N, they would not get a magnet, suggesting they were using intuitions about how magnets have 2 poles.
- They extended their N-S N-S particles to create a stack of 4 particles, which likely used intuitions about translational symmetry.
- They verified that if they broke that model in half, "You would still get a south side and a north side" (Oscar). This may indicate they were using resources about how things stay the same when scaled.
- When asked about the other model, Oscar explained "yeah then if you broke it that wouldn't work," suggesting intuitions about scaling were in primacy.
- The students likely were using resources related to magnets having 2 poles when Clarisa answered that the north pole would be at both the top and the bottom for that model.

In this segment, they used intuitions about magnets having 2 poles, translational symmetry and scaling symmetry to ultimately create a canonical model of magnetism.