Introduction

- Making sense of very abstract physics concepts can be difficult for students. The electromagnetic wave is a very abstract concept bearing little resemblance to anything we experience in the real world.
- Research question: How can students make sense of very abstract concepts in physics?
- Hypothesis: There are varying levels of abstraction. Simpler levels can be used to scaffold understanding of higher levels.
- This paper explores a model of learning where students begin by making simple analogies with low levels of abstraction. Simple analogies form an analogical scaffolding that students use to build more complex analogies.
- This model is based on a cognitive theory of analogy.
- We conducted interviews with students using the PhET computer simulations to provide grounding for our model.

Example of Analogical Mapping: The Planetary Model of the Atom

- The Physics Education Technology (PhET) project is a suite of computer simulations designed to be fun, interactive, and help students connect physics topics with everyday experiences.
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The PhET Computer Simulations

- The PhET project is a suite of computer simulations designed to be fun, interactive, and help students connect physics to everyday experiences.
- Designed to be fun, interactive, and help students connect physics to the real world.

Analogical Scaffolding

- In our model of learning, students progress from a low level of abstraction to a more abstract level.
- This forms a scaffolding, helping the student to build understanding of a concept requiring a high level of abstraction.

Mapping Sound Waves to Water Waves

- The representation of sound in the Sound Waves simulation resembles ripples in water.
- The picture in the center bridges the water wave to the concept of pressure.

Mapping Sound Waves to Radio Waves

- The Sound Waves simulation becomes the source of an analogical mapping to Radio Waves.
- Concepts that are understood for sound map to concepts for radio.

The Ordering of Analogies

- Below is a pictorial representation how analogies are linked together:
- Analogical links are indicated by arrows.
- Some students used a jump rope analogy for Radio Waves.
- The jump rope analogy led to wrong ideas about sound (indicated by broken links, see next section on student interviews).

Sound Waves precedes Radio Waves

1. Sound Waves references water waves
2. Water is analogy for Sound Waves
3. Radio references Sound Waves
4. Sound Waves is analogy for Radio

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Student Interviews

- Think aloud interviews were conducted with five students using PhET simulations.
- Three students used Sound Waves preceding Radio Waves (S-R).
- For the other two students, the order was reversed (R-S).

Peaks and Troughs in Sound Waves

- Karen (S-R) interpreted the dark and light areas in the wave as peaks and troughs.
- "The amplitude is, uh, how loud it is...uh I see. And it's just, I think that's how, how big the waves are, or a little amplitude is little waves... Yeah, you can barely see um. Those are really really big, like really deep and really...high.

Water Waves - Pressure Analogy

- Gary (S-R) described a water wave to pressure analogy.
- "Like, it's not just a wave. At least, I remember from playing with the simulation, the air pressure changes the whole way and I guess it would make sense, if you think, thinking about the whole, like, distance based I guess...I guess if you say like this, wave...the wave it does come down and up, but you have to think of it differently. It's the pressure that's taking those highs and lows, instead of actually a wave."

Sound - Radio Waves Analogy

- Karen (S-R) describing radio waves:
- "They act the same as sound waves, just you can't hear them because the frequency is too low, or on the radio waves, I think."
- After using the Radio Waves simulation, Karen was asked how sound was related to radio waves:
- "Well, it's not really moving air...I think of compression of air...when I think of sound...but here I just...kind of, like things like electrons moving through the air...but that doesn't make any sense because...since electrons are creating it, it can't be electrons."

A Jump Rope Analogy

- Susan (R-S) used Radio Waves before Sound Waves. She makes use of a jump rope analogy.
- "The amplitude stays the same on this half but at the beginning it's varied. And I'm, kind of, not real sure why that is. Just because, unless it needs, like, kind of a high beginning amplitude or something...like when you do with a jump rope or something, you need, like, a big shock to start off the wave."
- Susan also used the jump rope analogy to explain how one electron's motion related to the other electron in Radio Waves.
- "I guess it makes it look like this electron and this one are a little bit more related because they're, they're on the same line that's kind of...like they're connected to the same jump rope."

Conclusions

- We have developed a model of student learning where simple, concrete analogies are used to scaffold understanding of more complex, abstract analogies.
- This model is based on a cognitive theory of analogy, and also on student interviews.
- Student interviews provided evidence in support of our model.