Mapping Conceptual Understanding of Experts, Teachers, and Students through Conceptual Metaphor Theory

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Abstract: This study investigates conceptual understanding of quantum physics across expertise levels using conceptual metaphor theory. Interviews and focus groups with experts, teachers, and students revealed distinct metaphorical patterns. Experts exhibited complex, interconnected metaphors, while novices displayed fragmented and limited mappings. These findings demonstrate the role of metaphor in making meaning of abstract scientific concepts and offer insights into the development of expertise in quantum physics. By understanding the role of conceptual metaphors in learning and reasoning, we can develop more effective pedagogical approaches that foster deeper understanding and critical thinking skills.

Conceptual understanding, an elusive cognitive construct, manifests itself in our seemingly natural ability to apply knowledge and articulate related concepts (Vosniadou, 2013) and is instigated by diverse stimuli, including questions, experiments, and situational contexts (diSessa, 2014). This study explores conceptual understanding of quantum physics across a spectrum of expertise, employing conceptual metaphor theory (Lakoff & Johnson, 2008) as a framework for analysis.

Conceptual Metaphor Theory

Conceptual metaphor theory proposes that we comprehend abstract concepts (target domains) by mapping them onto more concrete or familiar ones (source domains) (Lakoff & Johnson, 1980, 1999; Lakoff, 2006; Sullivan, 2017). This mapping process allows us to leverage our embodied experiences and existing knowledge to make sense of the unfamiliar. This theory is particularly relevant for understanding abstract domains that defy direct sensory experience, such as quantum mechanics, with its counterintuitive principles and departure from classical physics principles. Its concepts, like superposition and entanglement, are difficult to visualize and reconcile with everyday experiences. Therefore, this research focuses on quantum physics as the domain of study, investigating how individuals with varying levels of expertise employ conceptual metaphors to understand its complex ideas.

Methodology

The research involved conducting interviews and focus groups with three distinct groups: quantum physics experts (researchers and professors), high school physics teachers, and high school physics students. These groups represent a continuum of expertise, allowing for a comparative analysis of their conceptual understanding. The interviews and focus groups were designed to elicit participants' explanations and interpretations of key quantum physics concepts. Transcripts were then analyzed to identify recurring metaphorical mappings by identifying source domains used to describe target domains within quantum physics (e.g., describing electrons as "clouds" or quantum states as "waves"). The identified metaphors were then mapped to visualize each individual's conceptual understanding.

Findings and Discussion

The findings reveal distinct patterns in the metaphorical mappings across the expertise continuum. Experts demonstrated more complex and interconnected metaphorical structures. They possessed a wider repertoire of metaphors and exhibited a greater degree of integration between these metaphors. Their mappings often involved multiple source domains contributing to a richer understanding of a single target domain. While there was overlap in the metaphors used by different experts, individual variations were also observed, suggesting unique conceptualizations within the expert community. This implies that while there is a shared understanding within the expert community, their individual experiences and research specializations lead to a different network of metaphorical mappings.

In contrast, novices exhibited more fragmented and less developed metaphorical mappings. They had access to fewer conceptual metaphors, and these metaphors were often isolated and lacked interconnectivity, implying a less nuanced and less integrated understanding of quantum physics concepts. Unlike experts who used integrated networks of metaphors, novices often relied on more literal metaphorical mappings. On the other hand, teachers exhibited some of the complexity of expert mappings but also showed some of the limitations of the student mappings, reflecting their limited experience with the abstract domain. By mapping the metaphors used by individuals with varying levels of expertise, we gain insights into the development of conceptual understanding and the challenges associated with learning abstract concepts. Also these maps demonstrate that simple one-to-one mappings that are often used as illustrations in Conceptual Metaphor Theory are not typical – conceptual understanding is instead a complex blended network of conceptual metaphors. Finally, as educators we can used these maps to develop more effective pedagogical approaches that foster deeper understanding of abstract concepts.

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