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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 48(0)

Authors

Aguilar, Omar

Aguirre, Anthony

Publication Date

2026

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How are scientific concepts birthed? Typing rules of concept formation in theoretical physics reasoning

Omar Aguilar (omalagui@ucsc.edu)[1] **& Anthony Aguirre**[1]
[1]Department of Physics, University of California, Santa Cruz

Abstract

This work aims to formalize some of the ways scientific concepts are formed in the process of theoretical physics discovery. Since this may at first seem like a task beyond the scope of the exact sciences, we begin by presenting arguments for why scientific concept formation can be formalized. Then, we introduce type theory as a natural framework for this formalization. We formalize what we call "ways of discovering new concepts" including property preservation and concept change, as cognitive typing rules. Next, we apply these cognitive typing rules to a case study of conceptual discovery in the history of physics: Einstein's conceptual path to the relativity of time. Then, we recast what a physicist might informally call "ways of discovering new scientific concepts" as compositional typing rules built from cognitive typing rules—thus formalizing them as scientific discovery mechanisms. Lastly, we computationally model the type-theoretic reconstruction as a program synthesis task.

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