Teaching Physics Metaphorically

Abstract

Physics theories use with both math *and* language. Using structures called theoretical metaphors, they function similar to conceptual metaphors in ordinary language. Conceptual metaphors allow the understanding of one thing in terms of another, and theoretical metaphors allow us to understand reality in terms of math. By mapping concepts—ones we assume to be included in reality—to math, we give the math meaning, interpreting reality in terms of its structure. By mapping different concepts to the exact same math, physicists arrive at completely different interpretations of reality. By more intentionally connecting concepts to math, theoretical metaphors may be able to improve physics education and our understanding of how physics is learned. I propose a study to determine the effectiveness of theoretical metaphors in education.

Introduction

++short discussion on obstacles students encounter when learning physics++

++short explanation of theoretical metaphors, and how they could help students grasp physics theories++

Because, by differentiating concepts from math, they clarify physics theories, theoretical metaphors may be a powerful tool in physics education.

Background

It seems post-structuralism ++reference++ completely destroys the foundation of all science, including physics. Reproducibility is vital to science. All valid experiments must have replicable results that can be consistently interpreted. Interpretation of an experiment is accomplished by using signifiers ++reference++ that refer to certain concepts; signifiers that post-structuralism deconstructs and deems fundamentally unstable. How, then, are scientists to consistently use concepts, if their descriptions for the concepts, the language they use, keeps changing? How can they know that when they say *energy* today it means the same thing it meant over 300 years ago, when a quarantined Isaac formulated Newtonian mechanics ++reference++? *Do* physicists know what they are saying? Yes, because they are not speaking and interpreting within the structure of language alone. By mapping physics concepts, and their signifiers, to math, physics theories *stabilize* the language they rely on.

Math provides physics a stable structure that does not change. Notation can change, but that does not change math's structure. For example, two multiplied by three can be written in many ways: 2 x 3, 2(3), 2 • 3, and there are a few more. Yet, no matter how you choose to write it, two multiplied by three is six, *always*. No amount of time can ever change this fact. No amount of time can ever change the structure of multiplication. Multiplication, as an operation and as a concept, is completely stable, because the structures that define it are completely stable. That is, the structures created by math do not change. Math itself must be stable. This means that any binary oppositions math creates—positive numbers vs negative numbers, large numbers vs small numbers, addition vs subtraction, multiplication vs division, etc.—cannot be deconstructed. Math is stable.

With math, physicists have a stable structure by which to consistently interpret the world. Take, as an example, the concepts of force, mass, and acceleration. In Newtonian mechanics, these are mapped to the equation F = ma. Force is equivalent to mass multiplied by acceleration. This means that a stronger force causes a greater acceleration, and things with more mass are more difficult to accelerate. Suddenly, by being mapped to math, the signifiers *force*, *mass*, and *acceleration* are stabilized, and so are the concepts they signify. If I sat down today to talk to Isaac Newton about politics, art, or history, we would not understand each other very well. If we discussed physics, however, we would have no trouble following each other. We would not get lost in the changing structures of language, because the language of physics is unchanging. The structure of physics is stable, because its theories map language and concepts to math.

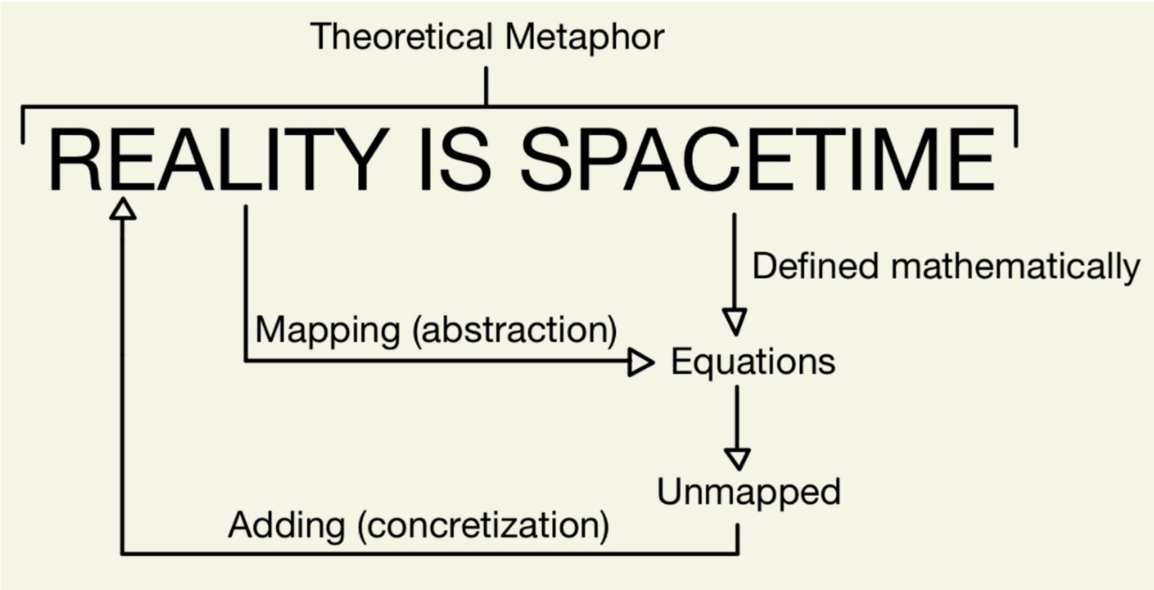
Take any binary opposites ++refernce++ in physics, such as matter and antimatter, and they will be perfectly stable. Matter cannot be shown to be antimatter, nor will antimatter ever be confused as matter. No amount of time will change the meanings of matter as compared to antimatter, because these signifiers are mapped onto math (in this case, the

Dirac equation). By using math, physics theories stabilize the signifiers they use, defying post-structuralism and avoiding deconstruction ++reference++.

Theoretical metaphors can show exactly what a physics theory is saying and what a physics experiment is doing. They show the fundamental connection between language (signifiers) and math in science, and the independence of concepts from the math that they are mapped to. Physics, and all of science, is not math alone. The language is as important as the math, and physics could not exist without it.

The goal of a physical model is to explain reality or phenomena in terms of another thing that has been defined. This sounds like conceptual metaphors. Reality gets mapped to the defined thing the same way that one thing gets mapped to another in conceptual metaphors. All physics theories begin with assumptions about reality. More specifically, each theory assumes that certain concepts exist, and are part of reality. Reality might include concepts like mass, energy, time, space, dark energy, and black holes. In quantum field theory the model is REALITY IS QUANTUM FIELDS (I will use all-caps because, even though this is not a conceptual metaphor, it works the same way). Concepts we assume are part of REALITY–this case includes mass and energy, but not gravity–are mapped to equations defining QUANTUM FIELDS. The math itself does not insist that it is representative of reality. Math does not imply reality. It never says quantum field, electrodynamics, antimatter, etc. The mapping of reality to math, and interpreting what it means, is done by the physicist. This is what Paul Dirac did when he predicted antimatter. ++need reference++ Dirac was working with math and certain assumptions about reality. When the math revealed something new, it was up to him to interpret it and give it meaning. Though the math never spelt out “antimatter,” Dirac realized that is what the math meant within the model he was using to interpret it. Physics gives math life in the same way conceptual metaphors give meaning to abstract concepts. I call these theoretical metaphors. Theoretical metaphors map reality to math, giving it meaning, just as conceptual metaphors map one concept to another.

Thinking of physical models as theoretical metaphors clarifies the role of language in scientific modeling. The theoretical metaphor behind general relativity is REALITY IS SPACETIME. REALITY includes all the concepts that we assume exist. This time it includes things like energy, mass, time, space, gravity, etc. SPACETIME is defined mathematically, and includes a bunch of equations. ++possible reference here++ REALITY is then mapped to SPACETIME, and, upon interpretation, the model spits out predictions: mass is energy, gravity is curved spacetime, etc. This mapping is a process of abstraction. Concepts from REALITY are mapped to abstract equations in SPACETIME. Incredibly, though, we can do inverse mapping. Sometimes there is something new in the equations, something that is not linked to any concept in REALITY. These equations then add concepts to REALITY, a process of concretization. Abstract equations are interpreted as new concepts. In general relativity, there was something new in the equations that was not expected, and there was nothing left in REALITY that could be mapped to it. This abstract variable was concretized as the concept of dark energy. From SPACETIME, dark energy was added to REALITY.



++this looks weird but will become a table++

Domain of REALITY

AbstractionConcretization

Domain of SPACETIME

Gravity

Curved spacetime

Dark Energy

“Λ”

Theoretical metaphors also explain how so many theories can arise from the same math.

Quantum mechanics, for example, has many, many interpretations. Each of these interpretations includes different concepts in REALITY. The pilot wave interpretation assumes that pilot waves are part of REALITY, whereas the Copenhagen interpretation assumes that there is a wavefunction collapse. Experimental physics is the foundation for all this. It suggests, confirms, or denies abstractions and concretizations. It tells whether or not a theoretical metaphor is at all valid.

Physics Misconceptions

++discussion on how students enter the physics classroom using incorrect metaphors++

Proposal

++proposal of study to determine effectiveness of TM's++

References

Lakoff, G., & Johnson, M. (1980). *Metaphors We Live By*. University of Chicago Press.