Towards the meta-fundamental: introducing intercontextual invariants

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Abstract

The pursuit of knowledge often leads downwards and outwards: towards the lowest-level phenomenon (fundamental) and the largest number of like-minds (intersubjectivity). According to this view, a scientific phenomenon is reduced to its lowest common denominator, and eventually leads to a consensus-like view. Yet this may not be the only set of paths to and from fundamental knowledge, as this implies an inherently reductionist approach to the creation and exploration of knowledge. In this essay, we will explore how fundamental levels of analysis relate to larger frameworks of knowledge and discovery. Rather than framing the fundamental as a mechanistic necessity or a lower-level enabler of emergence, I propose that an alternative (the nonlinear intercontextual view) leads to a number of important benefits. The proposed viewpoint allows for fundamental components of a body of knowledge to be identified and characterized in a broader historical, intellectual, and mechanistic context. This view can be distinguished from the intersubjective view of knowledge-sharing, which implies many implicit assumptions and encourages unnecessary constraints of thought. A nonlinear intercontextual view also provides a way to reconsider what constitutes a fundamental unit in a body of knowledge. This leads us to new conclusions about the underpinnings of our scientific fields, our theoretical assumptions, and a set of meta-fundamentals that can redefine the manner in which scientific knowledge is set forward into the world.

KWs: Cognition of Science, Philosophy of Science, Meta-theory

Introduction

The smallest common denominator is often thought of as something shared most widely. While in mathematics this is characterized in the form of numbers, in scientific discovery this is often the short-hand for a fundamental unit. As such, getting to the fundamental is often conceived of as a one-way path to reduction. Yet to truly discover why something is considered fundamental, we need to treat this path as a circular path that treats reductionism as a first step towards reconstituting the body of knowledge reliant on those fundamentals in a context-appropriate manner.

Using examples of the fundamental from a wide range of knowledge domains helps to develop the ideas of fundamental units, the practice of utilizing epistemic systems, and how linguistic descriptions reveal both short- and longer-term trends. While a meta-examination of the fundamental seems to take us away from discussing the roots of objective reality, it actually helps us escape the invisible bounds of intersubjectivity [1, 2]. While intersubjectivity allows for concepts and information to be shared and verified between individuals, it also presumes entrenched cultural constraints and intellectual assumptions. By doing so yields an intercontextual perspective that provides an alternate view of the natural world between fields of study and human cultures as an inverse social construction.

What is fundamental?

Fundamental units of analysis can be classified as two forms of scientific practice: reduction and abstraction. The fundamental units of reduction involve working to find mechanism, but not always at the same scale. As a matter of scientific practice, reductionism is usually justified in the pursuit of mechanism [3, 4], but may also be implicit assumptions of prevalent approaches in the field [5]. In physics, the fundamental units of reduction are particles. In Neuroscience, the fundamental units of reduction are molecular and cellular features. In Sociology, the fundamental units of reduction are individuals. For each discipline, however, the fundamental unit is a heuristic that is useful within a certain domain of study.

By comparison, the fundamental units of abstraction works to find the most generalizable system. The fundamental units of abstraction lend themselves to theory-building. In some cases, these are compatible approaches, while in other case they are not. When integrated across multiple fields and levels of analysis [6], the fundamental units of abstraction reveal mechanistic processes such as learning and memory. These mechanistic processes may in turn also be generalizable enough to form the basis of general theories [7]. In the case of learning and memory, multiple types of neural architectures (birds, mammals, insects) with a common mechanism can produce similar results. Yet all of these architectures have synaptic networks. This is also consistent with connectionist architectures such as neural networks which operate at the same scale.

1. Fundamental is Cultural Practice. The term fundamental is used in multiple sociocultural contexts, and refers to the core set of beliefs that drive the procedures and behavior of cultural practice [8]. In some cases, fundamental features are those that require a period of acquisition (learning). Fundamental features may also be used to establish a tightly self-referential set of practices that resembles circular reasoning. The consistency of this set is reliant upon claims that are only understood in the context of itself. Examples include flat-earth theories and certain libertarian arguments. Such tightly self-referential set might resemble a strange loop [9], and can contain seeming contradictions that make sense in context.

In education, it is often said that mathematics or reading is fundamental. In this case, mastery of each subject opens up an array of other subjects. For example, mathematics opens one up to understanding physics, just as reading does. Learning physics first is not as effective, and some students might find it impossible. While there are folk or naive theories of physics that are attainable without knowledge of reading and mathematics [10], it is then impossible to construct formalisms that other people can understand. While it is important to understand that reading and mathematics are themselves culturally-specific tools for transmitting physics knowledge, within a cultural context they can be understood as fundamental building blocks.

2. Fundamental leads to Building Blocks. The idea of building blocks is also essential to perception and action. In sports, skills and training that generalize as many modes of performance. These performance differences produce fundamental sequences which require specific memory consolidation, conditions for recall, and muscle synergies. As such, basic motor training exercises might be a prerequisite for engaging in more complex "moves" or "plays". This is similar to how players in the game of chess must learn how to assemble moves in terms of pieces and rules before they can strategically respond to their opponent. In the study of science itself, the building blocks of perception and action define what phenomena have meaningful structure. This structure must have identifiable properties, whether they be discriminable by our senses or distinguishable by our statistical methods.

In the case of social or religious fundamentalism, the idea of building blocks can work the other way. Instead of building up from a few core attributes, fundamentalism isolates a few stereotyped beliefs or cultural practices and builds a self-reinforcing set of interactions. In social fundamentalism, core beliefs are selected and reinforced *post hoc*, resulting in a set of reconstituted building blocks. Yet rather than serving as the foundation for additional structure, fundamentalism simply collapses cultural practices and their background belief structure to the building blocks themselves.

In all of these cases, a process of occurs in which the observer must categorize fundamental information. This information allows an individual to generalize from those fundamental components in the course of building a coherent worldview. In a scientific context, this process is deeply dependent on the practice of description and analysis. Different scientific fields have their own standard building blocks of knowledge that allow for discovery of the fundamental. In the case of science, however, building blocks often occur as a series of vertically-oriented scales. This leaves us with somewhat of a loose end: how do fundamental building blocks interact with the process of reductionist inquiry?

3. Fundamental further leads to Structure. In the practice of data analysis, particularly in machine learning and other forms of data science, the fundamental features of objects are treated as the building blocks of the material world. These fundamental properties are also expressed in the construction of ontologies, which provide a link between the linguistic and material worlds. As properties of a probabilistic system, fundamental features can often be used to bootstrap correct predictions. These features are used in a heuristic manner in everyday life as assumptions that enable quick (sometimes life-and-death) decisions. In this sense, the fundamental and cognitive decision-making become interdependent. This interdependency can be seen in domains such as political and weather forecasting, where fundamental preconditions are used as statistical priors, and often constrain the range of possible solutions.

Viewed in this way, the fundamental is reliant upon a "vertical" component: rather simply defining the relevant scale of organization for the study of Physics or Neuroscience, the fundamental can also define the aformentioned building blocks that provides an easier route to order than would otherwise be the case. While this definition of fundamental can often change with what is currently fashionable, empirical depth, and measurement techniques, it does provide insight into the relationship between scientific practice and the reductionist lower bound. This presents us with a challenge: is the reductionist lower bound always fundamental, or is there a fundamental scale that best explains the phenomenology of a given subject area?

4. Fundamental is Descriptive. The quest for the fundamental is a matter of both classification and reductionism. This is consistent with [11] in that reductionism does not directly allow for constructivism, which is what is needed to build scientific theories and attain understanding. This type of selective inclusion will hold true for so-called fundamental units as well. For example, while all matter consists of particles and the resulting structure, generalizations made from observations of matter are not mere extensions of the subatomic domain. This is true even in light of a highly-developed and validated particle theory. In many fields, there is a consensus at to the degree of acceptable reductionism. For example, in neuroscience, the lower bound includes the analysis of features best characterized through the application of molecular biology, but the primary objects of study themselves tend to be cells and ultrastructural features. It is notable that theories of the brain do not easily follow from large amounts of data collected from observations at these scales. Even though it would be conceptually useful, neuroscience has been slow to embrace the whole-brain and behavioral perspectives [12]. Therefore, at least from a sociocultural standpoint, what is fundamental relies heavily on what is relevant and what is culturally familiar to a particular group of researchers.

Yet what determines this fundamental limit and the resulting consensus scales of study? Part of it involves the cultural contingency of domain-specific knowledge [13], and we can use Neuroscience as an example. Drawing from knowledge in the natural and medical sciences, early neuroscientists focused on the study of cells, axons, and synapses. A later focus on molecular and genetic mechanisms has been contingent on what was most accessible, relevant, and obvious during formative years of the discipline. Discovering fundamentals is not only about reduction and representation. Sometimes it is about description, particularly the relative attainability of those descriptions [14]. Computational linguistics has provided a framework for fundamental ontologies, which are hierarchical descriptions of data that stem from the most essential descriptors for a given body of knowledge.

Science as Relevance

We cannot discover the fundamentals of a practices or scientific discipline *a priori*, therefore we must expand our systems of knowledge to incorporate new facts about the world relative to fundamental aspects of their organization. This expansion of synthesis requires the most basic of models to be amended in accordance with new information but without the oft-invoked revolution [15]. This brings us to the idea of scientific relevance and the application of relevance theory [16]. In relevance theory, the substance of a belief system is based on what is relevant to the practitioners.

This is easily demonstrates in science by the topics that are investigated and revisited over time. An empirical evaluation of linguistic relevance [17] with data from Computer Science conference proceedings (NIPS and GECCO) and journal articles from the Evolutionary Biology literature (*Evolution* and *Evo-Devo*) demonstrate the conditions under which intellectual relevance either shifts and does not shift over time. In the case of the conference datasets, we can witness changes in topical emphasis over time. In the Evolutionary Biology dataset, we can observe changes in the boundaries of academic disciplines relative to time. According to this analysis, the problem space of a given discipline is explored differentially with respect to length of time observed and prior topics.

Conclusions

In this essay, the fundamental contributes to science and intellectual discovery in three main ways. First, reductionism is often used to discover the fundamental components of a system or activity, but does not always lead to the same objects of analysis. Reductionism can occur in a wide variety of forms, from training regimens to experimental designs. Secondly, the discovery and acquisition of fundamental units result in the formation of building blocks, which are essential to perpetuating knowledge and operating on it in the world. Building blocks are usually classificatory in nature, although they can also be tied together as a series of theoretical statements. In any case, building blocks contribute to structure, which creates an activity or area of inquiry distinct from its fundamental antecedents. Finally, further description of the world as arising from fundamental components can be done in the form of abstraction and representationalism. These types of approaches are filtered further through determining the most relevant features of the existing structure, which then allows us to revisit the fundamental components.

An intercontextual view of the fundamental contains components of relevance, classification, and reductionism. In contrast to the intersubjective view of most cultural artifacts, the intercontextual view recognizes the path to and from the fundamental rather than simply assuming so from current theory and measurement. As a meta-theory of scientific inquiry [18], the intercontextual view goes beyond the notion of science as something to learn, demonstrate, and practice. Whereas intersubjectivity requires a common set of assumptions, intercontextuality requires meta-knowledge of the phenomenon under investigation and even developing theories with this meta-knowledge in mind. The analysis in [17] moves us towards this meta-knowledge in a number of ways, but also suggests that a process of structure discovery similar to the one proposed in this essay can provide us with meta-fundamentals. Most importantly, we much recognize that knowledge serving as our guide to the fundamental components of understanding is often influenced by culturally dependent structure. For this and many other reasons, defining the meta-fundamental is perhaps just as important as defining the fundamental for the advancement of scientific inquiry.

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