Theory of Knowledge Essay

2. How can we reconcile the opposing demands for specialization and generalization in the production of knowledge? Discuss with reference to mathematics and one other area of knowledge.

Word Count: 1596

May 2024

The production of knowledge is the process of gathering information, developing new tools, and broadening our understanding of the world. It is driven by two main, seemingly conflicting forces – specialization and generalization. Specialization has limited scope, focuses on a solitary case, and delves into details to produce accurate knowledge, which, however, may be too specific to be applied in many scenarios. Conversely, generalization embraces a holistic approach, looks at multiple examples, and aggregates information to generate knowledge that is broadly applicable, but may lack some precision. Therefore, reconciling these approaches is tempting in order to maximize benefits and minimize drawbacks in the pursuit of knowledge. In this context, reconciling means settings boundaries and defining tasks for each approach to allow their cooperation. However, one may argue that the two demands are not necessarily opposing and that their coexistence is essential in many situations. Accordingly, this essay shall analyze how the two demands can be harmonized and how they are already harmonized in the production of knowledge, taking into consideration two areas of knowledge: mathematics and natural sciences.

Mathematics can be divided into two categories: applied mathematics and pure mathematics. Applied mathematics involves describing the real world using precise mathematical notation and is characterized by the tension between generalization and specialization. While a comprehensive and detailed mathematical model of reality might work in all scenarios, it is likely to be too complex to comprehend. In applied mathematics, we address this challenge by creating general yet simplified models to present a broad, easy-to-understand overview devoid of some details. Additionally, we develop specific models to showcase individual cases with all the necessary details. Therefore, reconciling generalization and specialization in applied mathematics requires recognizing our current knowledge production needs and choosing the appropriate solution from these two approaches. An illustrative application of this mechanism is the entityrelationship (ER) diagram, which is derived from graph theory. ER diagrams play a key role in database management by creating knowledge about existing data (entities) and their connections (relationships) (Bordoloi & Kalita, 2013). The construction of ER diagrams is governed by the principles of generalization and specialization (Bordoloi & Kalita, 2013). Generalization follows a bottom-up approach, where individual ER diagrams are grouped to form a bigger picture. For instance, one might consolidate diagrams for programmers, management, and human resources into a larger diagram named “employees.” In contrast, specialization adopts a top-down approach, where an ER diagram is divided into several diagrams. For example, the ER diagram of programmers could be split into 'back-end' and 'front-end' programmers. While generalization offers a broader perspective on the available data, it lacks detailed information (e.g., the specific types of programmers). Specialization, however, provides specific details but focuses on a subset of the data (e.g., one employee type), as overly intricate diagrams can be difficult to understand. Hence, to successfully reconcile these two techniques, for the purpose of knowledge production, it is crucial to be mindful of the specific information needed at a given moment. This involves making judicious choices and, when necessary, altering between these two options based on the specific requirements of the situation.

However, pure mathematics is concerned with the development of models of thinking and abstract reasoning, the use of which may not be immediately apparent. In pure mathematics, specialization involves crafting knowledge in a specific branch of mathematics or working on a particular theory, while generalization refers to the wholeness and oneness of mathematics as a set of rigorously defined rules for thinking. In this sense, the two demands produce different kinds of knowledge and are not necessarily opposing. Accordingly, they are, in a way, reconciled by definition; they coexist without interfering. This perspective is exemplified by a series of books on modern mathematics titled “Éléments de mathématique.” Covering topics such as integration, set theory, and general topology, the series was authored by a French group of mathematicians under the pseudonym “Nicolas Bourbaki” (Leo, 2023). The authors aimed to showcase the unity of mathematics and provide knowledge about the general ways of reasoning in mathematics (Robert R. & Herbert, 2023). However, the mathematicians forming the group were also drawn to specialization as each member found success in their respective fields. For example, Henri Cartan gained renown for his substantial contributions to algebraic topology (Britannica, 2023b), while André Weil significantly advanced areas like number theory and algebraic geometry (Britannica, 2023a). In this way, while emphasizing generalization, they also pushed specific branches of mathematics forward. Thus, in pure mathematics, the production of knowledge is indeed driven by both specialization and generalization. However, these demands are not conflicting and are reconciled by principle. This means that they provide different kinds of knowledge that are nonetheless equally valuable and can be pursued simultaneously.

The corollary of the above discussion is that specialization and generalization are managed differently in pure and applied mathematics. In pure mathematics, specialization and generalization are not opposing forces in the creation of knowledge. They provide different information, but essentially coexist without any problems – they are inherently reconciled. However, in applied mathematics, specialization and generalization are indeed conflicting forces in yielding knowledge. Therefore, one must alternate between them, depending on what information one needs to obtain at the moment.

Contrary to mathematics and its rigorous proofs, in physics, a theory cannot be disproven or proven with absolute certainty. Instead, confidence in a theory as a credible model of reality (generalization) grows gradually with many experimental confirmations of the predictions of the theory accumulated over time. In other words, a theory must work in each and every case (specialization) to be classified as "reliable" through inductive reasoning. The reconciliation of generalization and specialization in the production of knowledge in physics occurs because generalization is defined through specialization. This means that, to achieve generalization and devise a general model of reality, one must ensure that the model works in all specific cases. This system of reconciliation in physics is demonstrated by the Standard Model – the most successful theory that explains the quantum fabric of the universe. More specifically, the Standard Model describes all fundamental forces, except gravity, and elementary particles known to man (Weinberg, 2004). However, the confidence that we now have in the Standard Model is the result of many years of theoretical work and experiments. For instance Sheldon Glashow, Steven Weinberg and Abdus Salam developed the electroweak theory (part of the Standard Model) in the 1960s, which did not earn much recognition until the experiment conducted at CERN in 1973 confirmed its prediction (Weinberg, 2004). Similarly, the existence of Higgs boson was predicted by the Standard Model in the 20^{th} century, but its experimental confirmation was found in 2012 (Lerner, 2022). Therefore, generalization is depended on specialization in the production of knowledge in physics because these two forces are not opposing and one can reconcile them by understanding that a model must work in every situation to be considered a trustworthy creator of universal knowledge.

In contrast, biology does not rely merely on theories. Indeed, one of the most prominent methods through which biology produces knowledge about the world is by grouping organisms into general categories. This approach enables the easy sorting and comparison of organisms, which would be challenging otherwise given the rich Earth ecosystem. The grouping or classification is accomplished by applying specialized knowledge about the differences between organisms. Biologists obtain different generalizations, or categories of organisms, by employing various biological evidence. In this regard, the key to the reconciliation of generalization and specialization in the production of knowledge in biology lies in the realization that specialization aids generalization and makes it more accurate. In practice, this is shown by the reclassification of the figwort family. Initially, the figwort family was established based on the presence of irregular flowers and comprised the 8^{th} largest family of flowering plants (Clegg, 2014). However, the members of the figwort family exhibited too much dissimilarity in structure, leading biologists to seek a way to reclassify the family (Clegg, 2014). This reclassification became feasible only recently with the emergence of new knowledge about the differences between organisms found in DNA. Through the study of chloroplast DNA, the family was split into 5 distinct families, enabling much more accurate and plausible generalizations (Clegg, 2014). Accordingly, generalization is facilitated by specialization, and this is how the two demands are reconciled in the biological creation of knowledge: the accuracy of generalization improves as new specialized biological evidence emerges.

Thus, in natural sciences, specialization and generalization are not opposing demands in the context of the production of knowledge. Quite the contrary – their coexistence is essential. However, the difference lies in how they are reconciled. In physics, generalization is defined through specialization. The model is required to work in each and every case in order to gain reliability as a mirror reflection of the universe. In biology, however, specialized knowledge plays a crucial role in the creation of generalization. If differences between animals are studied only superficially, the generalization is devoid of precision and meaningless.

The above discussion has shown that specialization and generalization are not necessarily opposing forces in the creation of knowledge. Of course, there are fields in which specialization and generalization cannot be applied at the same time (applied mathematics) and the only way to reconcile them is to determine our current need and choose between the two. However, in the majority of knowledge-producing cases, specialization and generalization either must cooperate or does not affect each other and can be pursued at the same time. Therefore, the pressure for specialization that exist in today's world may not be entirely justified. It has been demonstrated that recognizing the significance of the co-existence of specialization and generalization may bring huge benefits to our knowledge and understanding of the world.

Bibliography

Bordoloi, S., & Kalita, B. (2013). *E-R Model to an Abstract Mathematical Model for Database Schema using Reference Graph*. https://api.semanticscholar.org/CorpusID:17644760

Britannica, T. E. of E. (2023a). André Weil. In *Encyclopedia Britannica*. https://www.britannica.com/biography/Andre-Weil

Britannica, T. E. of E. (2023b). Henri Cartan. In *Encyclopedia Britannica*. https://www.britannica.com/biography/Henri-Cartan

Clegg, C. J. (2014). *Biology* (2nd ed., Vol. 560). Hodder Education.

Leo, C. (2023). *algebra. Encyclopedia Britannica*. https://www.britannica.com/science/algebra

Lerner, L. (2022, June 6). *Scientists announced the discovery of the Higgs boson 10 years ago. What's next?* Chicago News.

Robert R., S., & Herbert, E. (2023). *set theory. Encyclopedia Britannica*. https://www.britannica.com/science/set-theory

Weinberg, S. (2004). The Making of the standard model. *Eur. Phys. J. C*, *34*, 5–13. https://doi.org/10.1140/epjc/s2004-01761-1