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Epistemetrics – quantifying human knowledge

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Bio

Dr Hung Tseng received his BA from Peking University, PhD from Johns Hopkins Medical School, and postdoctoral training from Harvard Medical School. His research laboratory at PENN received funding from NIH, NSF, DAAD and INSERM. In 2008, he joined NIAMS/NIH as a scientific administrator.

Collaborators

Henry Small, SciTech Strategies Inc, Bala Cynwyd, PA 19004, USA

Further reading

Tseng, H, (2022) Patterns of basic knowledge. *iScience*, [online] 25(2), 103803, 1–19. [Accessed 05/12/2022].

Tseng, H, Small, H, (2019) Quantification of knowledge content of a high impact innovation: recombinant DNA. *Heliyon*, [online] 5(8), e02219, 1–16. [Accessed 05/12/2022].

Rescher, N, (2006) *Epistemetrics*. New York: Cambridge University Press.

The author's views in his research papers, 'Patterns of Basic Knowledge' (2022) and 'Quantification of Knowledge Content of a High Impact Innovation: Recombinant DNA' (2019), are personal and do not represent those of his employers, NIAMS/NIH.

Epistemetrics – quantifying human knowledge

- For centuries, philosophers have pondered whether knowledge can be quantified, an area of enquiry called epistemology.
- Independent researcher Dr Hung Tseng works in a sub-branch called scientometrics, which focuses on measuring scientific knowledge.
- Tseng has addressed the philosophers' question by developing a framework –EApc – to measure and analyse knowledge produced by scientific research.

Can knowledge be quantified? If yes, how? Philosophers have been asking this question for centuries, and more recently information scientists have joined the quest. The theory of knowledge, epistemology, has been contemplated since the time of Aristotle, but a formalised academic discipline for measurement of knowledge – 'epistemetrics' – originated much more recently. In 2006 Nicholas Rescher's seminal book *Epistemetrics* spawned a research field dedicated to uncovering the results of human inquiry and 'knowledge structure' – the conception of facts and interrelated elements of learning as a cohesive body of knowledge with distinct patterns in its organisation.

While Rescher mentions scientometrics (a sub-discipline of epistemetrics that specialises in science and scientific research), he does not offer ways to accurately categorise or quantify such knowledge. Now new work by independent researcher Dr Hung Tseng approaches closing this gap, by proposing a categorisation scheme of knowledge, and by identifying the basic structure and patterns of knowledge. A common method in scientometrics has been to count research papers and scholarly books; this methodology faces criticism, however, as publications are packages of different types and combinations of knowledge – not knowledge in its purest form. Tseng likens this process to estimating a supermarket's sales and stock levels by counting the number of bags of groceries it sells: highly inaccurate. Instead, he highlights four fundamental questions for scientometrics: What is the basic unit of knowledge? How many kinds of knowledge exist? How do they relate to each other? Are there hierarchies within knowledge? To summarise: what are the patterns of knowledge?

Epistemetrics: knowledge categorisation

In 2019, Tseng and his colleague Dr Henry Small proposed a new knowledge-categorisation framework – EApc. This classifies knowledge as either basic or compound, basic being discovered or derived from experience and compound being a combination of basic knowledge that builds on existing learning. The knowledge that we use day to day is predominately compound.

EApc divides basic knowledge into four subcategories: *entity*, *action*, *property*, and *condition* – hence the acronym. An *entity* is a physical or mental object, a *property* denotes the entity's attributes, an *action* is a physical or mental process that changes an entity or a property, and a *condition* indicates the action's attributes. The researchers' goal was to reveal 'knowledge patterns' – the underlying structure of knowledge at a fundamental level.

Unprecedented knowledge measurement

Tseng demonstrates how the EApc framework can be used to quantify knowledge by applying it to the invention of recombinant DNA technology – whereby genetic material from unrelated species is combined to create new DNA molecules. This resulted in knowledge measurement with unprecedented accuracy. The epistemetrics framework reveals underlying knowledge structure by identifying key (ie, minimum) basic knowledge components. Moreover, it gives insight into how humans explain the natural world. In contrast to the usual citation-based methodology, the EApc framework assesses scientific research purely on knowledge content – independent of subject matter, research goals, and citations.

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EApc: uncovering knowledge structure

To further understand how knowledge is structured and improve the EApc framework, the researchers examined how knowledge is organised in more diverse scientific disciplines. They analysed several scientific fields, including linguistics, scales (emergence theory), database (entity-relation theory), cause and effect in statistics and human cognition, as well as the work of leading historical and contemporary thinkers. These investigations suggested a parallel between linguistics' *noun, verb, adjective*, and *adverb* concepts and EApc's *entity, action, property,* and *condition* categories. This supports the idea of existence of individual units of knowledge and the application of EApc to human cognition and communication. Examining cause and effect for statistical inference, the embodied mind and metamorphic human cognition confirmed that the cause–effect concept is captured in EApc's *action* category.

Introducing mathematical rigour in the form of set theory strengthens and refines the EApc framework. As shown in the database theories, entities and their associated properties, and actions and their associated conditions, can be described as sets. The relationships between sets are then expressed using set notation. Thus, the structure of information in databases also corresponds to EApc's categories. To demonstrate the similarities, Tseng examined some typical databases, including PubMed, the 'Merck Index' of chemicals, organism taxonomy, drugs, biologicals, and planetary physical parameters. This suggests that monitoring database updates could measure knowledge accumulation and progression more precisely than counting research papers.

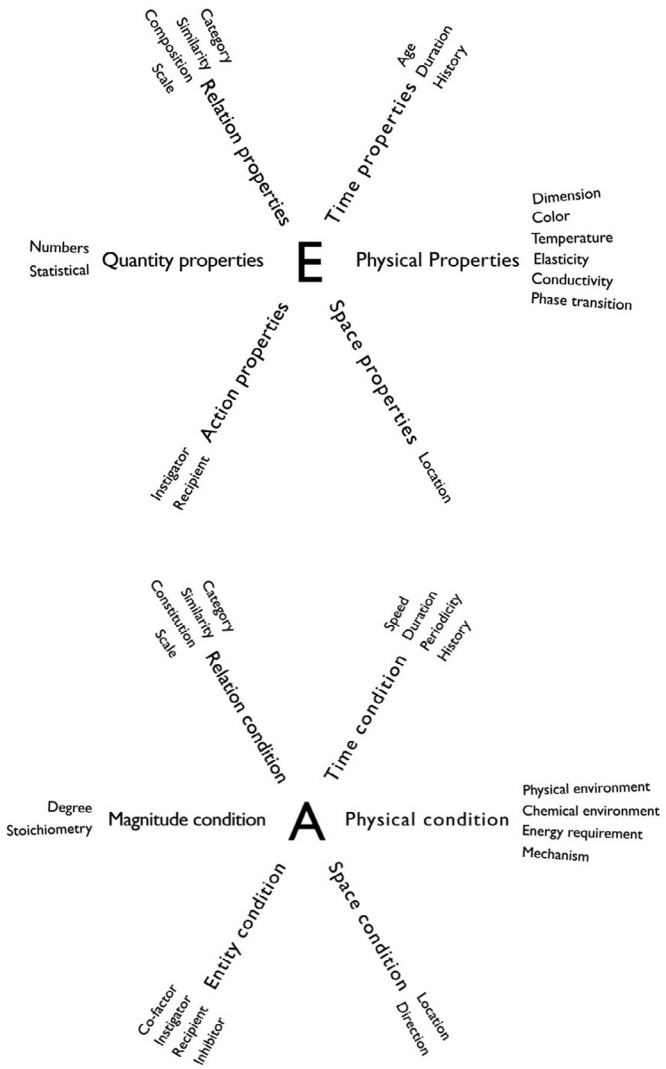

Figure 1. The proposed models of Entity (top) and Action (below), the two units of basic knowledge. Reproduced from Tseng, 2022, iScience under Creative Commons Licence 4.0.

Personal response

What real-world applications do you think will benefit most from the EApc framework?

One of the immediate goals to understand how knowledge is organised in our mind is to help manage scientific enterprise, to evaluate its products, to optimise its financial support, and to preserve and organise effectively the knowledge generated by scientific research, which is expensive both fiscally and in terms of human effort.

What has been the most rewarding aspect of your investigations?

Like most scientists, satisfying my own curiosity is a very rewarding experience. I think epistemetrics is an important but understudied area in human inquiry into the natural world. I would be very happy if I could make a contribution to it.

Can you tell us a little about what you plan to do next with EApc?

My immediate plan is to work on applying EApc framework to study compound knowledge, which has not been touched upon in depth in the two works mentioned here.

As a result, the researchers hypothesise that basic knowledge is made up of two descriptive systems. Basic knowledge either describes an object as an entity and its properties or describes a process as an action and its conditions (visualised in Figure 1). This implies that the basic knowledge units are entity and action, an important finding of knowledge structure.

Limitless dimension and complexity of knowledge structure

In the EApc framework, properties and conditions define the entities and actions respectively. The relationship of an entity with other entities is determined by its properties. Likewise, conditions control the relation of an action with other actions. Combining matching properties and conditions enables entities and actions to be linked to generate compound knowledge, eg, the compound knowledge 'fire melts ice' is combining the heat-generating property of fire (entity) to transform (action) water (entity) from solid to liquid because the phase transition of water is dependent on temperature (a property of water). There is no limit to the variety, complexity, and dimension of the structures of compound knowledge that can result from just two basic units of knowledge, assuming enough different entities and actions are available.

> **Epistemetrics spawned an academic discipline dedicated to uncovering the results of human inquiry and knowledge structure.**

'The development of the EApc framework is still in its infancy; thus, many aspects of the framework need to be investigated, improved, and most likely revised,' says Tseng. Nevertheless, the EApc framework reveals that knowledge at the fundamental level has a very simple and inherent structure, which suggests an independent value system, differing from many of the current evaluation criteria applied to measuring the quantity and merit of research products. Encompassing the two descriptive systems, EApc is not affected by size and complexity of an object or action. It can describe knowledge structure from subatomic particles to entire galaxies, providing new ways to understand scientific research and assess its impact. The researchers' achievement brings new understanding to epistemetrics, revealing the basic elements and patterns in knowledge structure.

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