Is the production of knowledge always a collaborative task and never a product of the individual?

1586 words

February 2019
[gzn364]

Whether or not the production of knowledge is *always* a collaborative task depends strongly on the definition of collaboration. In this essay I will consider two definitions: cooperative (necessitating personal interaction) and non-cooperative collaboration, in order to investigate how I can know *when* the production of knowledge is a collaborative task, and how I can know if the production of knowledge is *ever* a product of the individual. I will focus on two areas of knowledge: Mathematics and the Natural Sciences.

In the Natural Sciences, knowledge is produced collaboratively due to the nature of the Hypothetico-Deductive Model. This model involves producing and testing[1] a hypothesis, and ultimately superseding it with new hypotheses. Scientists produce hypotheses by considering prevailing theories and new evidence - the work of other scientists.[2] This use of others' previous work is clearly collaborative in the non-cooperative sense of the word. Also, modern scientific hypotheses are increasingly hard to test, requiring international collaboration on an enormous scale. For example, gravitational waves were first directly observed in 2016 by the LIGO and Virgo Scientific Collaboration[3], some 100 years after they were predicted by Albert Einstein.

Furthermore, the Natural Sciences produce knowledge collaboratively in that scientific consensus must be reached before a new idea can be accepted.

---

[1] Through experimentation - in an attempt to falsify the hypothesis

[2] This is because scientific research takes time to conduct, so scientific knowledge must be built up over many decades; its evolution comprises such a great number of disproved hypotheses that it would be impossible for an individual to produce and test all of them within their lifetime.

[3] BBC News. (2016). *'Ripples' from black holes detected.* [online] Available at: https://www.bbc.co.uk/news/science-environment-35524440 [Accessed 7 Mar. 2019].

This is achieved partly through the process of *peer review*, which all research must undergo before it can be published in a scientific journal. Experts from within the relevant field analyse the quality and credibility of each research paper, and determine whether or not it should be accepted into the journal. This procedure inhibits invalid research from being accepted, as only peer-reviewed research, published in reputable scientific journals, is considered credible by the scientific community. Also, researchers are typically biased towards validating their own ideas (confirmation bias), and are therefore incentivized to disprove the ideas of other researchers, especially those which contradict their own. The upshot of this is that scientific research is finely scrutinized by many scientists, and experiments are often repeated or modified many times in an attempt to falsify their findings.

On the other hand, if the definition of collaboration is limited to actual cooperation between scientists, many cases arise where the production of scientific knowledge is not collaborative. Thomas Kuhn argued that scientific understanding is advanced most through *paradigm shifts*: radical theories which challenge the scientific status quo, and which are often the result of the genius of an individual scientist; one example would be Einstein's Theory of General Relativity, which superseded Newtonian Physics. In that these revolutionary scientists do not cooperate with other scientists on their research, they produce knowledge which is solely a product of the individual - in a non-collaborative way. However, such knowledge can never be entirely uninspired by, or independent from, the countless obsolete scientific theories which came before it. In this way, provided collaboration is *not* limited to cooperation, the production of scientific knowledge is always collaborative.

The recent use of AI (artificial intelligence) in the production of knowledge in the Natural Sciences might present an instance of knowledge being produced solely by an individual. AI algorithms are mathematical functions, which identify relationships between vast amounts of input data and output cases. For example, AI has been trained to diagnose cancerous tumours from scans[4]. When it successfully diagnoses a cancerous tumour, the AI produces something analogous to intuitive knowledge. Further, an AI's only perception of the world is through the data that it is fed; it cannot interact with reality in any other way, nor can it cooperate with humans[5]. Therefore, perhaps AI is an example of individual production of knowledge.

But does AI actually produce *knowledge*? At its current stage of development, AI does not exhibit general intelligence or consciousness (although AI systems could conceivably develop these abilities in the future), and so lacks any *belief* component of knowledge. An oncologist - the human equivalent of the cancer-diagnosing AI - might produce intuitive knowledge, from prior experience of similar situations (analogous to an AI's 'training'). However, unlike AI, they also require initial instructions on diagnosis, through formal education. Clearly then, oncologists do not produce their diagnostic knowledge solely individually.

AI might be more useful in Mathematics, due to its abstract nature; Mathematics involves the production of absolute truth within a system of

---

[4] Tucker, I. (2019). *AI cancer detectors*. [online] The Guardian. Available at: https://www.theguardian.com/technology/2018/jun/10/artificial-intelligence-cancer-detectors-the-five [Accessed 5 Mar. 2019].

[5] However, it must rely on humans to design data collection systems - in this way AI cannot produce scientific knowledge without collaboration.

axioms, primarily through reason[6]. Axioms are the premises from which mathematical knowledge is constructed. For example, the axioms which describe a Rubik's cube would include a set of all its possible permutations (including a definition of the solved state) and how these relate to each other through various transformations (turns of each face). An example of mathematical truth produced within this system would be *God's Number, G* - the maximum distance in optimal moves of any permutation from the solved state (which has been to be proven equal to 20)[7]. As in the Natural Sciences, Mathematical research is presented in papers which are peer reviewed before being published in academic journals. It is therefore a similarly collaborative discipline. But how else can I know that the production of knowledge is collaborative in Mathematics?

Firstly, the fact that Mathematics produces absolute truth enables Mathematicians to collaborate logically, without actual cooperation. Once a conjecture has been proved mathematically, it can be used as an assumption in another proof. Mathematical conjectures are often extremely complex, requiring solutions to smaller sub-conjectures, which together imply a proof of the original. These sub-problems sometimes span many disciplines within maths, necessitating collaboration. For example, Fermat's Last Theorem - that there are no integer solutions to $a^n + b^n = c^n$, for $n > 2$ - remained unsolved

[6] Future AI could perhaps be taught reason - and be used not just to produce mathematical proofs, but also to check the logic of those written by humans.
[7] Cube20.org. (2019). *God's Number is 20*. [online] Available at: https://cube20.org/ [Accessed 5 Mar. 2019].

for 365 years[8]. Andrew Wiles proved it indirectly in 1995, by proving a different conjecture (the modularity theorem of elliptical curves) which, within a logical cascade of previous proofs, implied a proof of Fermat's Last Theorem.

This kind of logical collaboration is necessary, partly because research takes a long time to write; it took Andrew Wiles 7 years to develop his proof of Fermat's Last Theorem. Also, the alternative to building on others' work would be to start from scratch, from mathematical axioms derived from intuition and sense perception. This would not only be very hard, but would also not advance collective mathematical knowledge, as the mathematics would probably have already been discovered. Presumably, no human could ever be smart enough to re-discover thousands of years-worth of mathematical research from scratch, within their lifetime. Thus *not* collaborating in mathematics is extremely ineffective. Notably, the speed of mathematical progress could be greatly increased in the future with the advent of General Artificial Intelligence. This type of AI could potentially be much faster and smarter than human mathematicians, churning out mathematical proofs faster than humans could understand them. However, the AI would presumably still need to be programmed with a set of axioms; in providing the AI with these axioms, humans would essentially be collaborating with the machine.

Additionally, mathematics is collaborative in that historically, mathematical paradigms have differed across cultures. For example, while

[8] Guinness World Records. (2019). *Longest-standing maths problem (ever)*. [online] Available at: http://www.guinnessworldrecords.com/world-records/longest-standing-maths-problem-(ever) [Accessed 5 Mar. 2019].

Arabic decimal numerals (0123456789) are now used by the vast majority of the English-speaking world, the Babylonians used an entirely different number system: sexigesimal, or base 60[9]. This difference illuminates the fact that even the number system we use today is the result of collaborations and decisions made by early mathematicians, and that its modern constitutes collaboration with those mathematicians.

But again, if the definition of collaboration is limited to cooperation, then the production of knowledge is *sometimes* (not never) an individual endeavour in Mathematics. For example, Andrew Wiles kept his work on Fermat's Last Theorem a secret for much of the time for which he worked on it. Although he incorporated the previous work of many other mathematicians, by the cooperative definition of collaboration, he produced mathematical knowledge individually. However, I think that ignoring non-cooperative collaboration is unacceptable - both cooperative and non-cooperative collaboration involve the exchange of ideas through language and reason. It's not useful to separate the two, and thus even knowledge produced without cooperation with other mathematicians should be regarded as collaboration.

In conclusion, collaboration is a fundamental part of the Natural Sciences and of Mathematics. By the cooperative definition of collaboration, knowledge is *sometimes* produced (in both areas of knowledge) non-collaboratively; however, I have found this definition to be obsolete. Further, humans live for a relatively insignificant amount of time, and so significant discoveries require collaboration across time periods. Recognising this fact is

[9] Notably, as with many other primitive number systems, the Babylonian system did not include the concept of zero

important in our approach in both disciplines: mathematicians and scientists should be prepared to contribute to theories that they don't see concluded during their lifetimes, due to those theories' increasing complexity. Also, given that the majority of scientific and mathematical collaboration is non-cooperative, removing paywalls and subscription fees from academic journals would accelerate the production of knowledge. Due to the current business model of these journals, access to leading scientific and mathematical research is restricted, especially to people in developing countries.

One argument against the production of knowledge always being collaborative is that this would imply that mathematical and scientific knowledge could be traced back through time indefinitely, raising the question of where it originated. However, I think this argument is flawed in that language is necessary to the mathematical and scientific processes. Before the development of language, primitive knowledge might have been produced through intuition and sense perception - perhaps as a sole product of the individual - but could not have been formalised in the sense in which Mathematics and the Natural Sciences operate today. That said, the production of knowledge in these disciplines through ways of knowing other than language and reason would be an area for potential further investigation.

Bibliography

- BBC News. (2016). *'Ripples' from black holes detected.* [online] Available at: https://www.bbc.co.uk/news/science-environment-35524440 [Accessed 7 Mar. 2019].
- Tucker, I. (2019). *AI cancer detectors*. [online] The Guardian. Available at: https://www.theguardian.com/technology/2018/jun/10/artificial-intelligence-cancer-detectors-the-five [Accessed 5 Mar. 2019].
- Cube20.org. (2019). *God's Number is 20*. [online] Available at: https://cube20.org/ [Accessed 5 Mar. 2019].
- Guinness World Records. (2019). *Longest-standing maths problem (ever)*. [online] Available at: http://www.guinnessworldrecords.com/world-records/longest-standing-maths-problem-(ever) [Accessed 5 Mar. 2019].