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Dewey, Science and Society: A Pragmatic Critique of the New 'Impact Agenda'

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Overview

The impact agenda can be seen as the attempt to actively promote the positive, external effects that science can have beyond academia. The writing of the Pragmatist philosopher John Dewey allows us to frame this motivation in terms of two types of inquiry – common sense and scientific. By studying Dewey's thoughts on the topic, supplemented by the views of Fleck and Chang, it is possible to challenge the contention that scientific research needs actively steering towards externally-impactful outputs. Furthermore, through a case study on the development of quantum cryptography, it can be argued that the impact agenda is likely to fail in the long-run.

Accountability and the Origins of Impact

A prevailing trend in UK public science funding in recent decades has been a move towards greater accountability for allocated funds. This increased accountability has taken various formulations over the years. As noted by Martin (2011), the process began in the 1980s under the government of Margaret Thatcher as part of a wider push for "value for money" (Martin 2011: 247) in government spending. Beginning in 1986 and running up to 2008, the 'Research Assessment Exercises' (RAEs) were introduced in order to provide a framework for evaluating academic research.

Within this general trend of increased accountability, however, a specific emphasis on the importance of the applicability of scientific research '*outside* of the academy' has emerged. The idea was first introduced in the 1993 white paper 'Realising Our Potential: A Strategy for Science, Engineering and Technology' (official-documents.gov.uk):

> "The understanding and application of science are fundamental to the fortunes of modern nations. Science, technology and engineering are intimately linked with progress across the whole range of human endeavour: educational, intellectual, medical, environmental, social, economic and cultural." (pp. 1: 1.1).

It is concluded that the government must (as part of a range of measures) engage in a "long-term" effort to

> "…ensure that the needs of firms are fully taken into account in decisions on the direction, nature, and content of publicly funded science and technology." (pp. 12: 2.6).

Taking a brief philosophical departure at this point, it is interesting to note that the recognition of the *importance* of science in wider society (as in the first quotation from the white paper above) does not commit us to the proposition that the immediate needs of wider society must be incorporated into the direction of publicly funded science. This will be returned to later.

Specifying Impact

The idea that the impact of scientific research outside of academia should form part of the criteria for the channelling of funds is finally crystallised in the Research Excellence Framework (REF), due to replace the RAE in 2014, through the incorporation of 'Impact' into the 'Overall Quality Profile' of the research activity of a department. Impact is defined as:

> "an effect on, change, or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, *beyond academia*" (ref.ac.uk, 'Assessment Framework and Guidance on Submissions', Annex C: Definitions of research and impact for the REF, pp. 48, paragraph 4; emphasis added.).

This definition is the broadest given in the numerous REF documents that have been produced since the exercise began. Various other formulations of the concept of impact are outlined in relation to specific academic disciplines ('units of assessment'), but the common element is the exclusion of internal academic impact. Indeed, the above definition would seem to be almost uselessly broad were it not for the inclusion of the phrase 'beyond academia'.

The phrase 'impact agenda', then, refers to the incorporation of the *external* impact of research into the criteria for evaluation. It is a feature novel to the REF and will account for 20% of the assessment of a department's research, a percentage which is expected to rise in the future (ref.ac.uk, 'Decisions on Assessing Research Impact', pp. 4, 10c). The time frame for the attribution of impact to a piece of research is specified as "15 years between the publication of at least some research output(s) that made a distinctive contribution to the impact and the start of the assessment period" (*Ibid*, pp. 4, 11e), although an extra five years may be added for an "exceptional case" (*Ibid*, pp. 4, 11e).

The proposed method of assessment for impact is through a department's submission of case studies which may include examples of research that have produced "social, economic or cultural impact or benefit beyond academia" (*Ibid*, pp. 1, 2b). A more specific idea of what constitutes a successful impact case study is instructive here.

An example given in the REF pilot exercise for Physics is research into methods for the emission and detection of safe, non-invasive and non-destructive terahertz radiation using semiconductor devices at the University of Cambridge (ref.ac.uk, 'Research Excellence Framework: Impact Pilot Exercise Example Case Studies from Physics', pp. 2-6). This research facilitated the development of technology to build three-dimensional imaging systems that are cheaper, faster and can capture details missed by other imaging systems such as infrared spectroscopy and X-ray (*Ibid*, pp. 2). Furthermore, researchers were able to establish a spin-off company, TeraView Ltd., which has attracted more than £16m of investment and employs 25 staff (*Ibid*, pp. 5). TeraView manufactures the TPI Imaga, the first commercial terahertz imaging system, one use of which has been to provide 3D maps of the manufactured drugs in order to ensure that the correct amount of active ingredients are used (*Ibid*, pp. 4).

The impact in this case is thus primarily economic: the research was almost immediately commercially useful. In this vein, it is interesting to note that the founding of spin-off companies has been emphasised by government in the past with mixed results (Martin 2011: 250). What is presumably admirable about this particular case is the speed with which 'internal' academic research was 'externalised' and monetised, leading to productive improvements in the pharmaceutical sector.

Science and Society: The Ivory Tower Stereotype

A key motivation behind the impact agenda, then, seems to be the encouragement of the swift 'externalisation' of knowledge beyond academia. In terms of science funding, higher quality profiles would be rewarded to departments producing research that results in tangible external benefits over relatively short time periods. The impact agenda can thus be seen as the attempt to steer the direction of publicly-funded science towards research that will result in socially and economically useful ends and away from projects that live up to the stereotype of 'ivory tower' academics, contributing little in the way of societal benefits.

We may agree that it is admirable when academic research contributes to the wider material and cultural health of society. It seems reasonable to ask, however, how the impact agenda squares with the views of those who have written on the subject of science and wider society.

It is argued in the next section that Dewey's ideas on the ways I which science 1) grows out of and 2) feeds back in to common sense inquiry helps to reframe the way we think about this relationship.

Dewey: Science and Common Sense

Dewey's thoughts on the relationship between science and society are outlined in his discussion of two types of inquiry - common sense and scientific (Dewey 1938: 444). Common sense inquiry, for Dewey, "occurs for the sake of the settlement of some issue of use and enjoyment" (*Ibid*, pp. 444). Examples of issues of 'use and enjoyment' typically include the ways in which human beings are directly involved with the world around them – practical questions concerning "food, shelter, protection, (and) defense" (*Ibid*, pp. 447), for instance. Common sense inquiry is thus characterised by the aim of "adjustments in behaviour" (*Ibid*, pp. 444) and an involvement with the "*immediate* environment" (*Ibid*, pp. 444, emphasis original). Through them, we seek knowledge for the sake of a particular end, typically helping us to make better use of the materials and environment around us.

Scientific inquiry, on the other hand, pursues knowledge "for its own sake" (*Ibid*, pp. 444) rather than for some immediate practical purpose. Scientists therefore tend to become concerned with "systematic relations of coherence and consistency" (*Ibid*, pp. 449), the relations between different ideas about the world as objects of study *in themselves*. Furthermore, whereas common sense inquiries largely treat knowledge in a "*qualitative*" (*Ibid*, pp. 449, emphasis original) way, the history of scientific inquiry seems to be characterised by the "*elimination* of the qualitative as such and upon reduction to non-qualitative formulation" (*Ibid*, pp. 449, emphasis original).

Consider Dewey's example concerning scientific theories of light and colour. The development of a quantitative science of light "takes its departure of necessity from the qualitative objects, processes, and instruments of the common sense world" (*Ibid*, pp. 453) and becomes increasingly abstract and technical. It is still "*about* the colours and light involved in everyday affairs" (*Ibid*, pp. 454) but involves the structure and properties of light and colour as objects of study "*independently of any particular immediate application*" (*Ibid*, pp. 454, emphasis added).[1] These general differences between

[1] This example is illustrative of both the genetic and functional relationships that will be outlined later. For now, however, it stands as a neat demonstration of the formulations of the differences between typically

common sense and scientific inquiries, Dewey notes, distinguish the "theoretical from the practical" (*Ibid*, pp. 444) in the course of human inquiry.

It is worth raising a potential difficulty with Dewey's account at this stage in order to remedy a possible misunderstanding. It may be objected that the differentiation fails to account for a huge amount of research that falls somewhere between Dewey's characterisation of common sense and scientific knowledge.

Take the example given earlier in the REF pilot case study involving research into the behaviour of terahertz radiation. The scientific study of the properties of this radiation was combined with a practical consideration – the building of safer, more accurate three-dimensional imaging systems. This type of scientific research seems to fall somewhere between Dewey's characterisations of scientific and common sense inquiries. Cases such as this seem to exist on the boundary between practical and theoretical inquiries and may thus be seen as problematic for Dewey's distinction.

This worry, however, rests on a misreading of Dewey. The distinction between science and common sense is not intended as a concrete, binary dichotomy. Indeed, as Brown (2012) observes, a central feature of Dewey's philosophy of science is the contention that the natural sciences are in a sense "continuous" (Brown 2012: 262) with common sense inquiries. While there are clear differences in many cases, there is no "sharp or final distinction" (*Ibid*, pp. 263-4). Modern science is to an extent an "outgrowth and refinement of, practical or "commonsense" [sic] inquiry" (Brown 2012: 262). The particular form of this close relationship will be outlined below in the discussion of the genetic and functional relations between the two. For now, though, it is important to note that Dewey's account of science and common sense gives us a description of the two ends of a spectrum, rather than a cleavage of all inquiries into one camp or another.

In this way, Dewey's account gives us a clearer way of thinking about the issues raised by the REF. The impact agenda, by promoting science that yields direct economic, social and cultural benefits, can be seen as the attempt to shift scientific research towards the 'common sense' end of the spectrum. It encourages research such as the terahertz radiation example at the expense of 'pure' or primarily theoretical investigations. Is this shift likely to promote scientific research that contributes to the 'fortunes of the nation' in the long-run? Dewey's thoughts on the specific nature of the link between scientific and common sense inquiries, supplemented by other thinkers on the topic, help us to answer this question.

The Genetic and Function Relationship: Dewey on Situation

Despite the evident differences between common sense and scientific inquiry in particular cases, Dewey argues that the relationship is far more reciprocal and interwoven than we might first consider. The first stage to be considered is Dewey's analysis of what will be called the 'genetic relation' between the two.

The genetic relation is outlined clearly in the following statements:

> "In the first place, science takes its departure of necessity from the qualitative objects, processes, and instruments of the commons sense world of use and concrete enjoyments and sufferings." (*Ibid*, pp. 453).
> "Scientific subject-matter and procedures grow out of the direct problems and

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scientific and common sense inquiries.

> methods of common sense, of practical uses and enjoyments" (Dewey 1938: 450).

Common sense issues of use and enjoyment, then, are posited as the birthplace of scientific inquiry.

An example given by Dewey is the growth of astronomy from the practical needs of primitive groups "in care of animals with respect to mating and reproduction, and of agricultural groups with reference to sowing, tilling and reaping" (*Ibid*, pp. 454). Observations of changes in constellations and of the positions of particular stars proved useful in confronting these practical issues (a paradigm case of common sense inquiry) and led to the development of "instrumental devices" (*Ibid*, pp. 455) and quantitative measurements. Gradually, and by processes and events "originally unplanned" (*Ibid*, pp. 454), facts and theories became amassed independently of the original situation, forming what Dewey calls "a background of materials and operations available for the development of what we term science" (*Ibid*, pp. 454). Dewey's picture posits practical and common sense needs as the basis for scientific inquiry. Such practical issues lead to the amassing of knowledge and theories which then become generalizable beyond the particular problem ('situation') which they initially addressed.

It is interesting to consider how we should conceptualise this picture. One interpretation is that Dewey is making a straightforward empirical claim about the historical development of science. The highly speculative nature of Dewey's history here, however, should dissuade us from taking this path. It would be misleading to interpret Dewey's thoughts as arising from a careful historical study. Rather, they are better understood as stemming from a philosophical notion of the importance of "situation" (*Ibid*, pp. 450) in the course of human inquiry. Dewey's notion of common sense inquiry as the root of science flows naturally from his emphasis on the importance of the 'situatedness' of knowledge. But what does Dewey mean by "situation"?

The core of the concept is somewhat related to what we might understand by the phrase 'historical context'. Dewey asserts that we "never experience nor form judgements about objects and events in isolation, but only in connection with a contextual whole" (Dewey 1938: 450). Indeed, there is always a "*field* in which observation of *this* or *that* object or event occurs" (*Ibid*, pp. 451, emphases original). This "contextual whole" or "field" is the situation in which we cognise the world around us and formulate investigations, whether common sense or scientific. Dewey notes that a situation is "a whole in virtue of its immediately pervasive quality" (*Ibid*, pp. 452). This statement is made in order to stress the essential unity of the constituent parts of a situation, despite their separation in time and space. An example is helpful.

Brown (2012) asks us to imagine a biologist performing an experiment into the effects of a certain chemical substance on rats (2012, pp. 271-2). The biologist is about to dissect a recently euthanized rat in order to ascertain information about the effect this substance may or may not have had. While the focus of the situation is the rat in front of the biologist, numerous other pieces of information and states of affairs are relevant – "the fact that some rats were given an experimental treatment and others were not", "the rest of the rats currently living in their cages in another part of the lab", "the microscope that our biologist will soon use to observe" (*Ibid*, pp. 272). We can add to this list such factors as the prior training of the biologist, the work of other biologists in the team and the numerous published articles and papers that led to this particular experiment. Furthermore, even such factors as common ethical standards have conditioned the fact that the experiment is taking place on rats (somehow seen as morally less important than other organisms) as opposed to chimpanzees or humans. These features all form part of the *situation* in the sense that they condition the way the agent observes the insides of the rat; they are part of the “field” in which the particular parts of experience will be understood.

Relating this idea more specifically to common sense knowledge, it is important to note that the idea of situation has been expanded beyond the basic ‘scientific’ knowledge base behind the inquiry. Numerous aspects of a situation (both scientific and common sense knowledge, for example) can determine the way in which a scientist may observe and attach meaning to a particular focus of observation within the situation.

In addition to the posited genetic relation between scientific and common sense inquiries, Dewey’s concept of situation also points to a close *functional* interrelation between the two. In addition to science emerging from common sense inquiries, science then goes on to “react into the later in a way that enormously refines, expands and liberates the contents and agencies at the disposal of common sense” (Dewey 1938: 450). This is the second side of the reciprocal relationship between the two forms of inquiry. The point is fairly easy to grasp and so will be given considerably less explication.

As an example, consider the ways in which scientific advances influenced the situation in which the biologist above finds themself. They will use a microscope to observe the parts of the rat that are of interest, and the administering of the original active substance under study may well have involved the chemical isolation of a particular active chemical from a more common compound. These technological and scientific advancements shape the situation in which the scientist carries out the inquiry.

The functional relation thus primarily concerns the ways in which the results of scientific inquiry subsequently go on to impact the ways in which we live our lives in the world of common sense inquiry. As a further example, we can consider the influence of scientific and technological advancements on the ways in which we approach the problem of communication over long distances. Hundreds of years ago, prior to the harnessing of electricity, manually-delivered letters constituted the experience of communicating between towns and cities. Scientific advancements in the field of electrical engineering subsequently revolutionised this method through the invention of the telephone. In this way, scientific inquiry “liberates the contents and agencies” (*Ibid*, pp. 450) of the common sense world in which we act.

It has been shown that Dewey’s picture of the relation between science and common sense is a highly interwoven and reciprocal one. Not only do common sense inquiries often serve as the root of scientific ones, but scientific inquiries can then go on to shape future situations. The notion of situation, as outlined through the various examples given above, ties these two themes together by stressing the essential importance of the current state of affairs (both scientific and non-scientific) on the agent at the heart of a situation. But how does this relate to our critique of the impact agenda?

The first point to make is that the genetic and functional relation between science and common sense seems to posit a much closer connection between the areas of academic scientific research and practical (economic, social etc.) problems than we might first expect. Consider that the impact agenda aims to promote research that results in “an effect on, change, or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, *beyond academia*” (ref.ac.uk, ‘Assessment Framework and Guidance on Submissions’, Annex C: Definitions of research and impact for the REF, pp. 48, paragraph 4; emphasis added). We can say that this rests on a worry that research may become overly esoteric (the ‘ivory tower’ stereotype) and far removed from practical applications unless the gap between academia and the immediate problems facing our economy or society is bridged.

Dewey's discussions of the relationship between scientific and non-scientific problems thus posit a much closer connection between the two than is implicit in the impact agenda. The boundaries between science and wider society are not concrete or in need of breaking down through the encouragement of direct impact in science. They are 'naturally' tied to one another through Dewey's notion of a situation. Moreover, Dewey's general emphasis on the continuity between science and common sense as forms of inquiry, if accepted, seems to undercut the need to 'bridge the gap' between scientific inquiry and the world of common sense inquiry. The need to actively promote impact seems less pressing when we see the two as essentially tied.

Dewey is not alone in his insistence on the close connection between scientific and common sense inquiry. Other writers such as Ludwik Fleck and, more recently, Hasok Chang have also emphasised this relation. Fleck's study of the history of the Wasserman reaction as a test for syphilis outlines the important role of the prescientific notion of syphilis as a "carnal scourge" (Fleck 1935: 77). Fleck identifies the presence of age-old "religious teachings, claiming that the disease is a punishment for sinful lust" (*Ibid*, pp. 2-3) in the conception of syphilis right up to the start of the twentieth century. In this way, common sense notions of the disease are combined with scientific inquiry to form the contemporary concept of syphilis that formed the basis of Wasserman's scientific inquiry.

In a similar vein, Chang emphasises the close connection between scientific and non-scientific concepts through his study of acidity (Chang 2012). He finds that the common sense notion of acidity outlasted numerous incompatible conceptions from science, leading us to reject the idea that the everyday notion is "a pale and imperfect reflection of a coherent and cogent scientific concept" (Chang 2012: 698). By contrast, "the everyday concept is the unifying force that holds together a plurality of scientific concepts" (*Ibid*, pp. 698).

The thought of Fleck and Chang is not raised in order to argue that they would agree with everything we have said in relation to scientific and non-scientific knowledge. Merely, their inclusion is intended to show that Dewey is not alone in arguing for a close connection between scientific knowledge and the common sense world. As we can see from Dewey's thoughts on "situation" - and also through Fleck and Chang's examples on the concepts of syphilis and acidity respectively - scientific and common sense knowledge can be much closer together than might otherwise be supposed.

To conclude this section, we can remark that the close connection posited between science and common sense seems to challenge a basic contention behind the impact agenda. As was seen towards the beginning of the essay, the impact agenda attempts push research in the direction of practical (common sense, in Dewey's terms) usefulness. According to Dewey, Fleck and Chang, however, the two have a natural way of relating to each other, both genetically and functionally which does not necessarily need active policy encouragement.

Quantum Cryptography: An Illustration

Thus far, it has been argued that Dewey's insistence on the centrality of 'situation' to scientific inquiry challenges a quite basic thought behind the impact agenda. We can expand on this theoretical critique by examining a case which illustrates a potential practical difficulty for REF. The case of quantum cryptography is suitable because it illustrates some of the ways in which the impact agenda fails to account for the serendipity that emerges from the relatively chaotic trajectory of scientific inquiries over longer periods of time. It also ties together the various strands of inquiry that we have talked about thus far. The field of quantum cryptography is large, too large to be covered adequately in an essay of this length. For our purposes, then, the science will be simplified down the minimum necessary to make the point required.

Cryptography, the science of secure communications, is rooted in the practical issue of encrypting information in such a way that only the intended recipient can understand. An interesting feature of cryptography, as noted by Steane (1998), is that “it is not possible to prove by experiment that a cryptographic procedure is secure” (Steane 1998: 143). Indeed, by the time the sender of information realises that security has been breached (the message has been ‘eavesdropped on’, as the cryptographic theorists term it) it will often be too late to do anything about it. Instead of empirical procedures, then, the field is heavily reliant on *a priori* mathematical arguments for the security of a given procedure. Prior to quantum cryptography, a widely used method of encryption relied on the “difficulty of factoring large numbers” (Bennett et al. 1992: 3) as a way of securing information from eavesdroppers.

The field of quantum cryptography is possible because of an interesting feature of the way particles behave at a quantum level. The field dates back as far as the late 1960s, when physicist Stephen Wiesner wrote an unpublished paper on the possibility of theoretically secure codes transmitted on a quantum level (*Ibid*, pp. 4). The relevant feature of quantum theory for the purposes of cryptography is the unavoidable disturbance involved in the process of measurement, related to Heisenberg’s well-known Uncertainty Principle (UP). Rather than relying on assumptions about the difficulty of factoring large numbers or other methods used to make codes harder to crack, quantum cryptographers can harness a property the UP in order to securely know that “the information has not gone anywhere else, such as to a spy” (Steane 1998: 125). In order to see why this is the case, we must first go back to the 1920s and Heisenberg’s development of the UP.

First, it is worth noting that Heisenberg never used the word ‘principle’ in his original work; instead, he spoke of “uncertainty relations” (Hilgevoord et al. 2006: Sec. 1) between the position and momentum of a piece of quantum matter. This basic uncertainty relation posits a trade-off between the accuracy of measurement of the position and the momentum of the particle. In Heisenberg’s original writings, he considers the example of an electron being examined under a microscope (*Ibid*, Sec. 2.2). The accuracy of our measurement of the position of the electron depends on the wavelength of the light illuminating it; by decreasing the wavelength we can get a better reading for position. However, by decreasing the wavelength of the light, we subject it to collision from the light rays such that “the electron undergoes a discontinuous change in momentum” (Heisenberg’s original 1927 paper, as translated in Hilgevoord et al. 2006: Sec. 2.2). The effect is increased as the wavelength is shortened, leading to an uncertainty relation (a trade-off) between our knowledge of the position and momentum of the electron and vice-versa.

This is the basic formulation of the UP that is necessary to understand the basics of quantum cryptography. We have a pair of values that are essentially incompatible in terms of levels of accuracy. Quantum cryptography makes use of such uncertainty relations by transmitting information via a series of photons that may or may not be the subject of an attempted eavesdropping on the journey between sender and intended recipient (Bennett et al. 1992: 4). Through what is known as ‘conjugate coding’, a pair of photons are said to be conjugate if measuring one of them “randomises the other” (*Ibid*, pp. 4) in a way parallel to the decreased accuracy of momentum compared to position in the UP. The photons are sent in pairs in this way from the sender to the recipient. At the end of the process, the sender and the recipient's information can be compared to see if enough of the pairs of values match (*Ibid*, pp. 4-5). If they do not match, then an observation has been made somewhere between sender and recipient and an eavesdropper has been detected. If they do match, then the data is secure.

Quantum cryptography thus presents a process for detected eavesdroppers on messages. Steane (1998) outlines the ways in which the quantum properties of particles can be used to advance cryptographic techniques in a way that is "feasible with current technology" (1998, pp. 144). He notes that successful trial runs of data transmission using "23km of standard telecom fibre" (*Ibid*, pp. 144) have taken place under lakes in Geneva.

The impact of this research is potentially enormous. Consider the difference between non-quantum information, based on the difficult procedure of factoring large numbers alone, and a quantum code. In the former case, no matter how difficult the information is to decipher, the receiver will never know for sure whether or not it has been eavesdropped on and potentially decoded. The complexity of the encryption itself is the sole source of security in this case. As we have seen through the UP, however, quantum matter is inevitably disturbed when observed and the eavesdropper would thus be detected by the receiver.

This case is interesting because of the long and winding road from 'pure' theoretical formulation by Heisenberg in the early decades of the twentieth century to application in the field of cryptography around the turn of the millennium. From his position in the 1920s, Heisenberg could not have possibly foreseen this potential impact. Indeed, compare this time period to the typical fifteen year window in the impact agenda. The point to draw is that even science that is apparently relatively remote from Dewey's "common sense world" in its first instance can often come back and interrelate into practical issues and have enormous impact *beyond academia*. This process, however, can be a long one involving a large amount of serendipity.

In terms of Dewey's functional and genetic relations, we see that the strand of scientific inquiry represented by quantum theory eventually came back into practical, functional interrelation with the common sense issue of how to securely transmit information. This is clearly not common sense *knowledge* in the sense that most people are privy to it (as was the case with the concepts of syphilis and acidity earlier), but it relates to an issue in the *direct world* around us as a piece of technology that is could soon be used widely and on an everyday basis by all bank customers, intelligence agencies and other companies holding secure information.

This case is not presented as 'evidence' against the impact agenda in the usual sense of the word. Rather, it is intended as an illustration of the way in which the impact agenda may fail to promote impactful science in the long run. Supporters may argue that, despite the theoretical objections raised earlier in the essay, the REF is worth supporting on a cost-benefit basis. Such an argument may insist that 'tough decisions' need to be made regarding funding and that potentially impactful science is the most worthy of prioritisation.

On the face of it, this seems to be a fairly persuasive argument. But when we consider the above case study, it surely loses its appeal. If the stated aim is to encourage impactful science, then supporters of the REF and its impact agenda should be worried by the fact that one of the most important scientific developments of the past century, quantum theory, would have been impossible to justify in terms of impact in its initial stages. To suppose that Heisenberg, Schrödinger and others would have been able to write a persuasive impact case study at the beginning of the century seems misguided in light of the complex and serendipitous path that has been sketched of the development of quantum cryptography. Quantum theory is developing beyond the stages of purely theoretical interest and is starting to give hope of exciting practical applications.

Conclusion

To conclude, we have seen that the thought of Dewey, supplemented by examples from Ludwik Fleck and Hasok Chang, posits a much closer connection between scientific and non-scientific knowledge than is implicit in the impact agenda. When we consider the close genetic and functional relations between common sense and scientific inquiry, as well as the related importance of "situation", there is no reason to worry about the 'ivory tower' stereotype that seems to be part of the motivation for the introduction of impact. In addition to these more theoretical considerations, the example of the development of quantum cryptography vividly illustrates the potential of the impact agenda to miss the development of important, impactful science. Research that takes over fifteen years to find an impact would be disadvantaged under the REF regime, this would be a travesty.

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