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Title: Evidence Based Medicine as Science

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Abstract:

Evidence based medicine has claimed to be science on a number of occasions but it is not clear that this status is deserved. Within philosophy of science four main theories about the nature of science are historically recognised: inductivism, falsificationism, Kuhnian paradigms and research programmes. If evidence based medicine is science knowledge claims should be derived using a process that corresponds to one of these theories. This paper analyses whether this is the case. In the first section, different theories about the nature of science are introduced. In the second section, the claim that evidence based medicine is science is reinterpreted as the claim that knowledge claims derived from randomised controlled trails and meta-analyses are science. In the third section the knowledge claims valued within evidence based medicine are considered from the perspective of inductivism, falsificationism, Kuhnian paradigms and research programmes. In the final section possible counter arguments are considered. It is argued that the knowledge claims valued by evidence based medicine are not justified using inductivism, falsificationism, Kuhnian paradigms or research programmes. If these are the main criteria for evaluating if something is science or not, evidence based medicine does not meet these criteria.

1. Introduction:

Evidence based medicine has had a significant influence on modern medicine since the concept was first articulated in 1992. It has been used to produce vast numbers of clinical guidelines and these guidelines dictate which medical interventions are provided and funded (1). Evidence based medicine has been important in the governance of medicine providing standards that medical care can be judged against. These standards have facilitated the identification of variation in medical practice and may provide the legal standard of care (2). It has also influenced the medical research agenda becoming increasingly dominant as the mainstay of medical research funding (3). Evidence based medicine has therefore become extremely important to research and policy makers.

Evidence based medicine has been claimed to be science on a number of different occasions. Many of the earliest hierarchies of evidence professed to be scientific (4, 5, 6) and some commentators claimed that evidence based medicine constituted a new Kuhnian paradigm (7, 8, 9). Indeed, it has also been the case that 'scientific medicine' was proposed as an alternative name for evidence based medicine when the concept was first developed. This name, however, was abandoned because it implied that medicine had previously been unscientific (10).

Science is often considered epistemically superior to other forms of knowledge because it uses the scientific method to provide justification for knowledge claims

that are made (11). This use of the scientific method gives knowledge claims arrived at through this approach a privileged status making such claims more difficult to challenge (12). By claiming to be science evidence based medicine is seeking to ensure that its knowledge claims deserve this privileged status. It follows that if evidence based medicine is not science this privileged status is not deserved and we may question whether the concept should have such a significant influence on modern medicine.

The aim of this paper is to analyse the claim that evidence based medicine is science. In the first section, different theories about the nature of science will be presented: inductivism as practiced by the logical positivist movement (13), falsificationism (14), Kuhnian paradigms (15) and scientific research programmes (16). In the second section, the claim that evidence based medicine is science will be reinterpreted as the claim that knowledge claims derived from randomised controlled trails and meta-analyses are science. In the third section, these knowledge claims will be considered from the perspective of the different theories about the nature of science. In the final section possible counter arguments are anticipated. As we shall see the claim that evidence based medicine is science cannot be justified on this basis because the knowledge claims made by evidence based medicine are not justified by the four theories that are presented.

2. Theories about the Nature of Science:

There is a common misconception that there is a single scientific method. However, within philosophy of science, four main theories about the nature of science are recognised to be historically important: inductivism (13), falsificationism (14), Kuhnian paradigms (15) and research programmes (16). All of these theories are considered problematic from an epistemological perspective and no one theory is considered superior to the others. These theories about the nature of science have been comprehensively discussed elsewhere (11, 17, 18, 19). Here they are presented in sufficient detail to provide a foundation for the analysis presented in the rest of the paper.

The first theory that will be outlined is inductivism. Inductivism places a high value on explanatory theory and proposes that scientific method involves the confirmation of theory by observation. In inductivism, theories are used to generate predictions and these are tested in experiments. When a predicted outcome is observed the theory is confirmed and the observation is considered to provide justification for the knowledge claim made by the theory (13). Inductivism is considered problematic because inductive argumentation is fallible (11). This problem led Karl Popper to develop falsificationism (14).

Falsificationism also places a high value on explanatory theory but this theory proposes that scientific method involves the *falsification* of theory by observation.

Falsificationism employs deductive reasoning therefore any conclusions are necessarily true if the premises are true (14). Falsificationism has also been considered problematic because theories are not simply tested through falsification but in conjunction with auxiliary assumptions and background knowledge. As a consequence an observation that challenges an existing theory does not necessarily prove that the theory is false because it might also be that an auxiliary assumption or background knowledge was false (11, 17).

The third theory that will be considered is the theory of Kuhnian paradigms. Thomas Kuhn argued that normal science occurred within an established paradigm and was characterised by puzzle solving. Puzzle solving is guided by a disciplinary matrix and exemplars. The disciplinary matrix includes the general theoretical laws, instruments and assumptions that scientists use and governs permissible concepts, problems and explanations. Exemplars demonstrate the problem solving techniques that can be used to extend and elaborate the scope of a paradigm (15).

Puzzle solving by scientists within an established paradigm has three important elements: the matching of facts with theory, the articulation of the consequences of theory and determination of significant facts. The paradigm is assumed to guarantee the existence of a solution to every puzzle and failures within normal science are blamed upon individual scientists not the paradigm itself. However, as normal science progresses, experimental and theoretical anomalies accumulate and a crisis emerges. Crises are resolved by the emergence of a new paradigm and a paradigm shift occurs (15).

The theory of scientific research programmes was developed by Imre Lakatos. A scientific research programme consists of a hard core of fundamental principles surrounded by a protective belt of auxiliary assumptions. Work within any research programme is guided by the heuristic and may involve the falsification or confirmation of theory through observation. This theory differentiates between degenerating and progressive research programmes. A degenerating research programme only accommodates known facts whereas a progressive research programme continues to produce novel facts. Within this theory science is characterised by the continued production of novel facts (16).

The four theories introduced in this section are all theories about the nature of science. Nonetheless, it is important to make a distinction between inductivism and falsificationism on one hand and Kuhnian paradigms and scientific research programmes on the other hand. Inductivism and falsificationism are theories of scientific method whereas Kuhnian paradigms and research programmes are broader theories that emphasise the importance of the framework within which science is undertaken. This distinction is important when we consider the claim that evidence based medicine is science.

3. Evidence Based Medicine:

Superficial consideration of the claim that evidence based medicine is science suggests that the claim may be meaningless. Evidence based medicine is used to determine the most appropriate medical care whereas the aim of science is to provide explanation and understanding (19). However, the claim can be reformulated so that it is meaningful. When evidence based medicine is claimed to be science what is really meant is that the knowledge claims that inform decision making within evidence based medicine are science.

Within evidence based medicine hierarchies of evidence are used to rank the importance of knowledge claims derived from different study designs (20). These hierarchies of evidence generally rank meta-analyses and randomised controlled trials as the highest level of evidence, observational studies as an intermediate level of evidence and expert opinion as the lowest level of evidence (21, 22). Evidence based medicine does not only use evidence derived from meta-analyses and randomised controlled trials but it has a clear preference for knowledge claims derived using these study designs.

Randomised controlled trials, meta-analyses and indeed all comparative studies, are typically set up to test the null hypothesis that there is no difference in outcome between a treatment intervention and a control intervention. If a difference is found, the probability of the observed difference occurring by chance, if there really is no

difference between the two treatment interventions, is calculated. The null hypothesis is then accepted or rejected depending upon a preassigned probability value.

It is important to appreciate that the treatment interventions that are tested in randomised controlled trials and meta-analyses are supported by underlying theory. These treatment interventions undergo rigorous laboratory and animal testing before randomised controlled trials are undertaken on human subjects (23). During this development, experiments are repeated, new instruments are developed and underlying theory may be modified. However, this underlying theory is not directly tested when the null hypotheses is accepted or rejected. We therefore make an important distinction between knowledge claims made within basic medical science and knowledge claims made using randomised controlled trials and meta-analyses.

If knowledge claims derived from randomised controlled trials and meta-analyses are science the method that is used to produce these knowledge claims should correspond to an established theory about the nature of science. The hierarchies of evidence themselves should not be confused with science as they simply rank the importance of evidence derived from different study designs. However, this does not mean that the hierarchies are unimportant. The hierarchies of evidence are actually fundamental to our analysis because they dictate the study designs that are preferred within evidence based medicine.

There has already been a limited discussion in the literature about whether randomised controlled trials use inductivism or falsificationism (9, 24, 25, 26, 27). However, this discussion is generally predicated on the assumption that randomised controlled trials are science. Senn (1991) argued that the method used by clinical trials to produce knowledge claims corresponded to falsificationism (24). This argument was disputed by Shahar (1997) who argued that null hypotheses could not be falsified (25). Shahar (1997) instead claimed that randomised controlled trials used inductivism although this claim was disputed by Kerry et al (2012) because the results of these studies were presented in terms of probabilities (27). Thompson (2010) has claimed that randomised controlled trials did not use either inductivism or falsificationism because they did not provide explanation (26).

As the theories of Kuhnian paradigms and research programme are broader theories about the nature of science it is more meaningful to consider whether evidence based medicine itself is science in relation to these theories. The claim that evidence based medicine is a new paradigm has been discussed in detail in the medical literature (9, 28, 29, 30, 31, 32, 33, 34, 35, 36). This claim has proved contentious and considerable disagreement exists with a number of different arguments being used to both support and refute the claim. Interestingly the discussion in the literature assumes that evidence based medicine is science but this assumption is not explicitly considered. There has been no discussion in the literature about whether evidence based medicine corresponds to the theory of research programmes. There is therefore a need to analyse the claim that evidence based medicine is science in relation to the four theories presented.

4. Evidence Based Medicine as Science:

Having laid the groundwork we will now analyse the claim that evidence based medicine is science. We will first consider whether the method used by randomised controlled trials and meta-analyses, within the framework imposed by hierarchies of evidence, corresponds to the scientific methods of inductivism or falsificationism. We will then consider whether evidence based medicine itself can be considered science using the theories of Kuhnian paradigms or scientific research programmes.

4.1 Inductivism:

Inductivism places a high value on explanatory theory and involves the confirmation of theory by observation. Randomised controlled trials and meta-analyses do not use inductivism because they are set up to test null hypotheses. The theory underlying the treatment intervention that is investigated cannot be confirmed because it is not directly tested. Null hypotheses are actually accepted or rejected using inference to best explanation. This does not mean that underlying theory is not considered when knowledge claims are interpreted but this theory is not relevant to the production of the knowledge claim.

The hierarchies of evidence contain a variety of different study designs in addition to meta-analyses and randomised controlled trials. One of these study designs, the prospective case series, does employ inductivism. In a prospective case series all patients are given a treatment intervention and outcomes are recorded. The theory underlying the treatment intervention is then confirmed to a greater or lesser extent depending on the outcomes that are observed. Prospective case series can provide compelling evidence for the effectiveness of a treatment intervention when all study subjects benefit from treatment. This is the 'all-or-none' study design. However, prospective case series are usually excluded or devalued by hierarchies of evidence. We are aware of only one hierarchy of evidence that ranks 'all-or-none' study designs amongst the highest levels of evidence (37). It appears that evidence based medicine does not value the one study design that does use inductivism.

The hierarchies of evidence rarely include explanatory theory and this type of evidence would normally be subsumed within expert opinion. Hierarchies usually rank expert opinion as the lowest level of evidence. Evidence based medicine has a clear preference for knowledge claims derived from empirical study designs that accept or reject null hypotheses using inference to best explanation and does not appear to value explanatory theory. We would therefore argue that the knowledge claims that are important within evidence based medicine are not justified using inductivism.

4.2. Falsificationism:

Falsificationism involves the falsification of theory by observation. Randomised controlled trials and meta-analyses do not use falsificationism because they are set up to test null hypotheses. If the theory underlying the treatment intervention is not directly tested it cannot be falsified. When null hypothesis are rejected the alternative hypothesis is accepted using inference to best explanation. Falsificationism is characterised by its rejection of theory using deductive inferences and inference to best explanation is not a deductive inference.

Explanatory theory is fundamental to the scientific method of falsificationism but such theory is not valued by hierarchies of evidence. Few hierarchies of evidence explicitly include explanatory theory. Again the prospective case series study design can be used to falsify theory but this study design is devalued by most hierarchies of evidence. We would therefore argue that the knowledge claims that are important within evidence based medicine are not justified using falsificationism.

4.3. Kuhnian Paradigms:

Evidence based medicine can only be considered a Kuhnian paradigm if it engages in puzzle solving. Puzzle solving within an established paradigm has three important elements: the matching of facts with theory, the articulation of the consequences of

theory and determination of significant facts (15). In order to determine whether evidence based medicine is a new Kuhnian paradigm we therefore need to consider whether the empirical study designs prioritised by hierarchies of evidence can be used to match facts with theory, articulate the consequences of theory and determine significant facts.

Randomised controlled trials and meta-analyses do not use inductivism or falsificationism and they do not directly test the theory underlying the treatment intervention that is investigated. If underlying theory is not directly tested it is difficult to see how these study designs can match facts with theory or articulate the consequences of underlying theory. Evidence based medicine may still be considered normal science if the conclusions of randomised controlled trials and meta-analyses are significant facts. However, knowledge claims derived from these study designs are based upon a probabilistic interpretation of the results. We would suggest that knowledge claims derived in this way are not significant facts in the sense that Kuhn intended. This does not mean that knowledge claims derived from randomised controlled trials and meta-analyses cannot usefully inform clinical decision making. We should nonetheless avoid conflating evidence based medicine as a clinical decision-making tool with evidence based medicine as science.

The argument that evidence based medicine does not engage in puzzle solving can be developed further. Scientists engaged in normal science within an established paradigm assume that the paradigm guarantees a solution to every puzzle. Failures in puzzle solving are blamed upon individual scientists not the paradigm itself.

However, this is not how evidence based medicine is presented (38, 39). Randomised controlled trials and meta-analyses are not expected to solve puzzles, even when they are undertaken to a high standard, because of bias inherent within all study designs. If randomised controlled trials and meta-analyses are not expected to solve puzzles evidence based medicine cannot be normal science. We would therefore argue that evidence based medicine cannot claim to be science using the theory of Kuhnian paradigms.

4.4. Scientific Research Programmes:

Evidence based medicine can only be considered science according to this theory if it is a progressive research programme. All progressive research programmes have a hard core of underlying theory, heuristic and continue to produce novel facts. The hierarchies of evidence could represent the hard core of an evidence based medicine research programme if they are conceived as a tool for conducting science. The hierarchies do possess some of the characteristic features of a hard core as they are generally unquestioned within evidence based medicine and they have changed with time. However, hierarchies of evidence consistently rank randomised controlled trials and meta-analyses as the highest level of evidence when theoretical support for this claim is uncertain (22, 40, 41, 42). We would therefore argue it is problematic for the hierarchies of evidence to represent a hard core of underlying *theory* for medical research programmes.

If hierarchies of evidence are unable to provide the hard core, we could argue that they could provide an important heuristic device. Several hierarchies have been claimed to be heuristics to facilitate rapid decision making (43, 44, 45) although this claim has not been extended to heuristics within a scientific research programme. If the hierarchies of evidence provided the heuristic there would need to be a separate hard core of underlying theory. To our knowledge a hard core has not previously been articulated although this does not mean that this could not be done. The hard core could possibly include axioms such as treatment interventions must be biologically plausible and treatment interventions that are tested in humans should be supported by laboratory and animal studies.

Even if a hard core of underlying theory was articulated, independent of the hierarchies of evidence, which provided the heuristic, novel facts would still need to be produced for evidence based medicine to count as science. Any 'evidence based medicine research programme' would surely prioritise knowledge claims derived from randomised controlled trials and meta-analyses? However, as we have seen these study designs do not employ inductivism or falsificationism and they reject null hypotheses based on probabilistic inferences. We argue that these study designs do not produce novel facts in the sense intended by Lakatos (13). If novel facts are not produced evidence based medicine cannot be progressive research programme and there are serious questions about whether or not it can count as science in its current form.

5. Possible Counter Arguments:

The knowledge claims made by evidence based medicine are not justified by the theories of inductivism, falsificationism, Kuhnian paradigms or research programmes but this does not necessarily mean that evidence based medicine is not science. It is important to consider possible counter arguments in order to present a balanced view of evidence based medicine as science.

Inductivism, falsificationism, Kuhnian paradigms and research programmes have been considered in detail because, from a historical perspective, they are of fundamental importance to the philosophy of science and we have been able to build upon previously published work. We acknowledge that each of these theories is problematic from an epistemological perspective and there are other theories about science that have not been considered. It could be argued that inductivism, falsificationism, Kuhnian paradigms and research programmes should not be used to determine whether a discipline is science because they are epistemologically problematic. We would counter argue that, in the absence of necessary and sufficient conditions for the demarcation of science from non-science (19), these theories do provide a useful guide to the status of a discipline as science.

The theories presented in this paper all place a strong emphasis on underlying theory but this is not true of more modern theories about the nature of science. Experimentalism refers to a range of approaches that seek a secure basis in

experiment rather than underlying theory (18). Within experimentalism the results of experiments can provide support for a claim, in the absence of underlying theory, if the claim has been severely tested to eliminate possible sources of error (46). Experimentalism does allow a probabilistic interpretation of results and it could be argued that randomised controlled trials, and thus evidence based medicine, were science using this theory. This possible counter argument is acknowledged but it is important to appreciate that experimentalism is not without its own epistemological problems. Experimentalism has been criticised precisely because it does not value underlying theory (18) and it could be argued that it described a theory of empiricism not science.

6. Conclusion:

Evidence based medicine has been claimed to be science on a number of different occasions. This claim enhances the status of evidence based medicine and may make knowledge claims harder to challenge. However, although evidence based medicine claims to be science, the knowledge claims that are proposed through its methods are not derived using a process that corresponds to inductivism, falsificationism, Kuhnian paradigms or research programmes. This is because the study designs prioritised by evidence based medicine, randomised controlled trials and meta-analyses, accept or reject null hypotheses based on a probabilistic interpretation of the results. If randomised controlled trials and meta-analyses do not directly test underlying theory they cannot employ inductivism or falsificationism,

produce novel facts or engage in puzzle solving. We would therefore argue that evidence based medicine in its current form cannot be claimed to be scientific.

If it is accepted that evidence based medicine is not science any knowledge claims that are made through this approach do not deserve the status of science. This strips the concept of its power and may make it more susceptible to challenge. This does not mean that evidence based medicine is not important or that the knowledge claims derived from this approach should not inform medical decision-making. In many circumstances the results of randomised controlled trials and meta-analyses will provide the strongest evidence to support treatment recommendations but they do so in a non-scientific way.

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