Introduction

This essay began as a textual comparison of two books, 'TS Kuhn and Social Science', by Barry Barnes[1], and 'Scientific Knowledge and its Social Problems.', by Jerome Ravetz[2]. However, as I worked on it, the symmetries between the texts created some new ideas in my mind, allowing this paper to fit into the larger picture of work on my honours thesis.

What I am saying, and what this paper is (hopefully) going to show, is that some aspects of the finitism of Barnes and Ravetz's theme of implicit craft knowledge are very similar, and support each other. Thus, a synthesis of these two sets of ideas may be very interesting, and important for philosophy of science, and sociology of science. Maybe it might even give the two fields something to come closer to agreement on.

I feel that the most important idea to come out of sociology of scientific knowledge in general, and Barnes and Ravetz in particular, is the acknowledgement that human beings are social creatures, and that social forces have to be considered when studying any area of human experience that involves more than one person. Especially in the case of modern, industrialised science[3], where there is not only a very large specialist culture of scientists, but also a very large amount of interaction between the scientific community and the rest of the community.

Of course, the recognition of the fact of social interaction in science and the operation of sciences began (as with many other things) with Kuhn. Barnes points this out, and then take the idea even further, incorporating philosophical ideas about finite conceptual sets (finitism), and using them to attempt to create some sort of coherent account of how scientific knowledge can be valuable in the absence of a neo-Platonic universe where the rules are waiting to be discovered by anyone who looks in the right way.

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[1] Barnes, B. *T S Kuhn and Social Science*, Macmillan, London, 1982

[2] Ravetz, J.R. *Scientific Knowledge and its Social Problems*, Second Edition, Transaction, New Brunswick, 1996 (originally published 1970)

[3] I owe a lot to Ravetz for developing this idea of modern, highly industrialised science, especially with reference to

Ravetz is also concerned with studying what makes science special, why it seems to work so well. In this both books are following a classic question in studying science. What makes these books interesting, however, is the realisation that social factors are important, and must be explained in some fashion.

To return to my own ideas, while reading and comparing the two, and having noticed this point about allowing for social factors, I noticed something about each text. Barnes' project seemed to be focused on providing some sort of philosophical basis for post-Kuhnian ideas of social construction of scientific knowledge, while Ravetz seemed to be focussed on how the social construction of scientific knowledge actually works, with particular reference to ideas such as implicit knowledge, the 'craft-like' nature of much scientific knowledge, and also what makes scientific knowledge special. Ravetz's ideas on intellectually constructed classes of things and events were also interesting for my ideas.

As I studied the two, I found that many aspects of one book would complement what the other book was *not* looking at, and thus a picture began to emerge. This picture is rich and variegated, with a recognition of the awesome complexity of knowledge in general. It's a picture that takes some of Barnes' ideas about finite clusters of instances and concepts, and also takes some of Ravetz's ideas about the importance of implicit knowledge, and attempts to put them together to create a coherent picture of how social factors can be important in scientific knowledge, while still retaining the special character of scientific knowledge (i.e. that is, it seems to work.)

The question that is begged by all of this is 'Why?' Why is a new take on concepts important, given the vast literature available on it already? I feel that Barnes' and Ravetz's sociological tendencies can be illuminating when applied to the normally strictly philosophical area of concept theory. To put it another way, I think that some of the ideas espoused by Barnes and Ravetz could prove very useful in understanding the mystery that is human conceptualisation.

To further this purpose, I will first briefly describe what Barnes and Ravetz have to say, and then point out the similarities between them, and the places where they

post-war science.

support each other. The purpose of this is to allow the reader to get an idea of the mental journey by which I have come upon my ideas, after which I will give an account of those ideas.

Barry Barnes, finitism, and learning by ostension

By the title of Barry Barnes book, 'T S Kuhn and Social Science', it seems obvious that his project is to 'sociologise' Kuhn to at least some extent. Whether or not he is successful in this is not what I am interested in here.

What I am interested in is some of the points that come up in Barnes' discussion of training, namely those that describe Barnes attempts at fitting the framework of finitism with extra sociological appendices. Barnes follows Kuhn in proclaiming the importance of paradigmatic examples:

> Abstract verbal presentation of concepts, definitions, rules and laws are pedagogically unsatisfactory, and take second place in science to teaching through paradigmatic examples.[4]

That is, merely presenting the laws will not work as a teaching method, but they instead require paradigmatic examples to illustrate those laws.[5] In the case of science, these paradigmatic examples are taught through the solution of textbook problems, or other problems given as practice (e.g. tutorial problems etc.):

> The exercises of the science textbook are akin to the finger exercises of the pianist, pedagogically preferable to the music of actual research.[6]

The obvious question to ask is: How is this done?

Teaching by paradigmatic examples: How?

Barnes uses Kuhn's example of a boy learning what a swan is while walking through a park with his father. The child points to birds as they walk through the park, and names them according to previously learned types of birds. So, when the child sees a duck, it will probably simply call it a 'bird', and the father, 'who can be taken as a

[4] op. cit. 1, p 18

[5] The idea of examples *instantiating* laws is important in my ideas, so please take note (this will be explained further later in this paper). Also, on a personal level, from my own experiences in learning maths, physics, and other 'hard' sciences, that I learnt far better when I was shown a set of examples first, and then shown an explanatory law afterward. This sort of phenomenon will also be important.

[6] ibid. p 18

source of the accepted usage of his community'[7], will correct him, informing the child that particular bird is a duck. Then, when the child sees another type of bird, it will either call it a duck or a bird, and will be corrected by the father. Thus, if the child sees a duck, a goose, and a swan, it will learn how to identify these birds.[8] This is learning by ostension, or by example.[9]

Barnes contrasts this with learning by rules and definitions, that is, learning by the application of a linguistically specifiable rule, such as a scientific law, or in Barnes example, an assertion such as 'A swan is a large, white-plumaged, orange-billed bird.' As Barnes points out, from this the implication is that the rest of language can be learnt in similar fashion. Barnes notes that Kuhn responded to this by pointing out that this kind of learning does not always apply. Processes of ostension, says Barnes, are 'a form of knowledge acquisition with practical advantages over learning by rule and definition and thus they cannot, without loss, be replaced by processes solely involving rules and definitions.'[10] What those practical advantages are may become clearer as we look further at Ravetz's ideas on crafts and craft practices.

However, says Barnes, 'learning by ostension and learning by rules and definitions are not competing strategies between which a choice is always possible.'[11] Later, he says, 'we can see now how false is the contrast between learning by ostension and learning by use of definition and rule. The real contrast here is between learning that relies *directly* upon ostension, and that which relies upon it *indirectly*. Nothing can be learned *ab initio* purely by verbal means.'[12] Barnes also puts forward the idea that 'what any given term in such a [ostensive] system refers to can never be characterised without reference to learned similarity relations.'[13] Thus, the importance of learning by ostension and the forming of implicit links between instances of a

[7] ibid. p 23

[8] example from ibid. p 23

[9] ibid. p 23

[10] ibid. p 26

[11] ibid. p 26

[12] ibid. p 27. To link this with the idea mentioned in footnote 5, I feel that learning by ostension must rely upon the spontaneous formation of links between properties of events classified as being 'in' a concept, as well as those classified as being 'outside' the concept. Thus, the ostensive learning events involve adding the experience to a web of experiences, both similar and dissimilar. Another relevant quote from Barnes: 'Any putative new instance will at once differ from, yet be similar to, the instances in both clusters.' (ibid. p 28.)

[13] ibid. p 28

concept is emphasised. After this, the project of understanding how teaching by paradigmatic examples can work becomes understanding how people can learn similarity relations between finite clusters of events. This is Barnes' term for encapsulating his system of finitism with sociological appendices. I shall now explain this further.

Learned similarity relations between finite clusters of events

Barnes uses this idea of learned similarity relations between finite clusters of events to explicate what is meant by learning by ostension. However, when written all as one phrase, it looks intimidating, so I shall unpack it slightly, and hopefully clarify exactly what Barnes means by it.

The 'finite clusters of events' part is there because, as Barnes says, 'for all the complexity and richness of language, experience is immeasurably more complex, and richer in information.'[14] That is, it is of course only ever possible to observe a finite number of instances of anything, let alone of one particular concept.[15]

The 'learned similarity relations' part seems to be there because Barnes is interested in how we create associations between events that are identified as being instances of a concept. As Barnes makes clear, we learn the similarity and difference between events identified as being 'within' the cluster, and we also learn similarity and difference between clusters.[16]

Barnes also notes that 'past experience and the past usage of a concept can never suffice to determine future usage.'[17] Thus, all of the differences and similarities between the new and old instances, and among the past instances are important in the judgement of what the new event is, that is, the judgement as to whether the event is an instance of a concept. Barnes: 'Formally... [the] ...assertion that an

[14] ibid. p 28

[15] Also note the implicit equivalence in Barnes' language in the previous quote between a concept and the language used to communicate it. This appears to be anomalous compared to the rest of the text, but it is something to keep in mind.

[16] from Figure 2.1, ibid. p 28

[17] ibid. p 28

instance falls under a term is only his contingent judgement to the effect that similarity outweighs difference.'[18] That is, the judgement is *contingent*, dependent on already existing factors. Implied is that the judgement is contingent on previous judgements, and other determinants of the mental state of the judger. Here Barnes also notes his belief that 'there is no natural or universal scale for the weighing of similarity against difference.'[19] This will become more important later[20], but is also important now, because this is the point where the relativism that some philosophers find objectionable first enters explicitly.

Learned similarity relations and Communities.

It would seem that the natural question to ask, if the previous is the case, concerns the father in the example. Who performs the analogous role if there is no universal authority figure for larger groups to refer to in order to set concepts? Given the title of the book, it is hardly surprising that Barnes ascribes this role to the relevant community.

> Proper usage is simply that usage communally judged to be proper, and is no more predetermined than idiosyncratic individual usage. Concepts cannot themselves convey to us how they are properly to be used. We ourselves must always agree or seek to agree that the application of a term to an instance is justified, that similarity should outweigh difference in that case.[21]

Barnes goes on to explain how a combination of our biological make-up and social upbringing makes the application of many concepts so routine as to appear innate. He also addresses the issue of problematic instances, such as: Is deuterium oxide water? In cases like this, says Barnes, the community must negotiate its way to a decision as to whether the instance is to be included or not. Barnes: 'And although the new routine may assist a community in its dealings with nature, nature itself sets no constraints on the form of the routine which is produced.'[22] And later: 'Meaning changes, or stays the same, as the community wishes to have it.'[23]

[18] ibid. p 28

[19] ibid. p 29

[20] That is, in my ideas about the importance of implicit knowledge in the maintenance of traditions of practice. Also, it should be noticed that the previous quote is the incommensurability of Kuhn in a new guise.

[21] ibid. p 29

[22] ibid. p 29

[23] ibid. p 30. This is a nice encapsulation of the idea Barnes is trying to convey.

This implies that the assignment of events to concepts is open-ended and revisable. This idea of concepts Barnes seems to owe in large part to finitism, from the work of Mary Hesse[24]. In Barnes' words:

> Finitism denies that inherent properties or meanings attach to concepts and determine their future correct applications; and consequently it denies that truth and falsity are inherent properties of statements. 'True' and 'false' are terms which are interesting only as they are used by a community itself, as it develops and maintains its own accepted patterns of concept application.[25]

Barnes maintains that this 'opens all instances of concept application... ...to sociological study as contingent judgements.'[26]

Barnes on Research

Following from all of the work on training is a picture of research itself. Given when Barnes was writing this, and the fact that he was explicitly 'sociologising' Kuhn, it makes sense that Barnes then begins to explain about paradigms and how these are maintained within a finitist framework.

To begin with, Barnes is talking about normal science. 'In agreeing on a paradigm scientists do not accept a finished product: rather, they agree to accept a basis for future work, and to treat as illusory or eliminable all its apparent inadequacies and defects.'[27] That is, scientists are well aware that there are problems with any theory, and these can be thought of as either opportunities for new work, or not worth considering.

Specifically, when a theory is first proposed, 'there is felt a need to improve techniques of measurement, and to extend them to more cases.' This is one type of problem that can be looked at in the normal procession of science.[28] Another type of

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[24] see reference, ibid. p 30

[25] ibid. p 31

[26] ibid. p 32

[27] ibid. p 46

[28] I find this idea of 'normal' science a bit too much like Kuhn's, but Barnes point seems to be that 'normal' science, far from being the stagnant puzzle-solving that people sometimes think of it as, is a growing, changing thing, somewhat similar to revolutionary science. The difference lies in the degree of the change. This is a thoroughly post-

problem is the extension of the paradigm to new areas, via 'the reconstruction of existing problem-solutions so that they fit new situations.'[29] In addition to these two extremes, there are many kinds of problems that combine elements of the two in varying degrees.

So, so far we have: a paradigm is accepted, with all of its flaws, and these flaws are either ignored or used as a basis for further work. This business of extending the theory by analogy, however, is very, very important in Barnes work. A later quote:

> Scientific inference, like empirical inference generally, is not deductive. It proceeds from particular to particular on the basis of resemblance and analogy. Knowledge is built up and extended a bit at a time by the revisable clustering of instances and applications.[30]

And again: '*Any 'deduction' about empirical phenomena involves a hidden analogical step.*'[31] That is, anyone who claims to be proceeding 'deductively' is, in reality, making an analogy to an already existing problem-solution in order to give themselves a frame of reference. Barnes makes the point a bit more clearly:

> Training displays similarity relations by linking instances to instances; research extends similarity relations by linking instances to instances. The links are made in both cases by analogy.[32]

And again, focussing on research:

> By seeing the unknown in terms of a known problem, inductive inference is possible: variables in the unknown situation are calculated by assuming that it behaves analogously to a known one. Thus science proceeds by analogy and induction, with the former licensing the latter.[33]

Thus Barnes feels that analogy is vital to scientific learning, and indeed learning in general. Analogy would seem from all of this to be the way in which individuals can extend similarity relations without the application of some authority. That is, without some authority to inform as to the way the community says things are, the only basis for a person to learn new things is by analogy to judgements they have already been

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Kuhnian SSK idea.

[29] ibid. p 47

[30] ibid. p 122

[31] ibid. p 122, author's italics.

[32] ibid. p 52

[33] ibid. p 53

informed about. Thus the boy in the swan example could classify other things as swans only on the basis of analogy with the instances previously observed and categorised by authority. Thus analogy becomes the most important component of any learning, and training becomes the learning of accepted instances to form a basis for the analogy that is used in research.

There is one remaining point that is important to note in considering Barnes, in relation to the purpose of this essay, and that is that communicated by the following quotes:

> But a piece of normal science does not generate a candidate problem solution which is then independently validated.[34]

This quote is specifically regarding the lack of an independent validation criterion for claims arising from the research process, and thus is related to what Barnes has to say about analogy.

Another quote:

> There is no logic to help determine the relative technical advantages of the alternative strategies of concept application: people simply have to agree which generalisations they will take account of, and agree in their practice how they will be taken account of.[35]

The most important parts of this quote are 'There is no logic' and the notion that people have to agree on generalisations. I have included the two quotes to illustrate the following point: There is no way to know before you begin working whether or not your question is answerable. This also applies to communities, in that there is no way to know without argument and discussion what the 'right' way is. The notion that 'There is no logic' is not as remarkable now as it was when Barnes book was written. Really, this is just a statement that there is no formal theory of how theories are arrived at.[36] The notion of agreement on generalisations is a reflection of the conventional character of knowledge in Barnes conception of science.

To summarise with a quote from Barnes:

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[34] ibid. p 50

[35] ibid. p 109

[36] Indeed, this would create a paradox, because then you would be able to know what you would know... see Popper, K. R. *The Open Universe: An argument for Indeterminism*, Hutchinson, London, 1982, p 62 for this idea in relation to determinism.

> In training, the scientist learns the accepted similarity relations by exposure to successive particular instances, or applications, of terms. He is judged competent when his subsequent development of similarity relations runs along the lines accepted by his community; this is indicated by the way he solves routine problems not completely familiar to him but familiar to his teachers. In research, the scientist solves problems by modelling them on existing solved problems or paradigms; and he thus again develops similarity relations to cover further cases. The difference is that this time the cases are as unfamiliar to the community as to him, and he must hope that the community comes to accept his work as sound.[37]

This does summarise the spirit of Barnes' work well, and also (not so coincidentally) happens to link in rather nicely with the work of Ravetz, which I will discuss next.

Jerome R Ravetz and implicit craft knowledge

If ever there was a book whose title clearly states the unorthodoxy of the ideas contained therein, it must be 'Scientific knowledge and its social problems.', by J. R. Ravetz.[38] What's that you say? Science causes *social problems*? But how can that be, when science is the right way to do things? Of course, this is not as contentious now as it was when first published.

A large part of Ravetz's work, and the part which I will be focusing on in this essay, concerns the craft-like properties of science. Ravetz points out many things about how science is actually done that seem very similar to ideas of 'craft-type' knowledge. I will proceed to explicate this somewhat.

To begin my explanation, Ravetz summarises his position like so:

1. Scientific Knowledge is a craft.

2. The objects of this work are not natural things, but are intellectual constructs, studied through the investigation of problems.

3. The work is guided and controlled by methods which are mainly informal and tacit, rather than public and explicit.

[37] ibid. p 52

[38] op. cit. 2

4. The special character of scientific knowledge is explained by the complex social processes of selection and transformation of the results of research.[39]

Although all four items are of interest, the fourth is mainly of interest with reference to Ravetz's motives in writing the book, that is, explaining the special character of scientific knowledge. The first three are very relevant to this examination and to my ideas, and so I will endeavour to explain them forthwith.

Science as Craftsman's work.

This is the title of one of Ravetz's chapters, and it describes the subject matter so well, I just had to use it too.

Let's begin the study of this idea with a quote:

> The craftsman works with particular objects; he must know their properties in all their particularity, and his knowledge of them cannot be specified in a formal account. Indeed, no explicit description of a craftsman's techniques, and of the objects on which he works, can be more than the simplest elements of the subject. They can be useful for the beginner, but he must develop a personal, tacit knowledge of his objects and what he can do with them, if he is to produce good work.[40]

This outlines Ravetz's conception of a craft. The most important things to note here are the importance of implicit, unspecifiable knowledge, and the relative unimportance of explicit, systematised, 'scientific' knowledge.[41]

Ravetz feels that the experience gained in solving 'textbook' problems is essential to learn the implicit rules of use for all the apparatus used, whether the apparatus is physical, as in laboratory instruments, or abstract, as in mathematics.[42] This includes information about how and when not to use the apparatus as much as information about actually using it. This idea is communicated in Ravetz's idea of pitfalls.

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[39] ibid. p 71-72

[40] ibid. p 75

[41] I use this term in quotes to be deliberately provocative. However, I think it would be difficult to argue that the idea of 'scientific' knowledge does not imply systematisation and an explicit nature. Also important here is the emphasis on ‘particular’ objects. This is important for Ravetz’s ideas of intellectually constructed things and events: see later section on this.

[42] see the discussion on the transformation of data into results (ibid. p 76-92) for examples of this. A primary example of the abstract kind of apparatus is statistics, which Ravetz uses repeatedly throughout the book.

Pitfalls are 'concealed traps for the unwary'.[43] These are errors that are easily identified as such in retrospect, but are difficult to impossible to detect when first using an apparatus. Thus, the education of a practitioner in the pitfalls of the apparatus is vital if the practitioner is not going to fall into 'simple' errors and end up looking amateurish.[44] However, as Ravetz points out, it is not possible to completely eliminate pitfalls from scientific inquiry, but it is possible to avoid them. This can be done in two ways: 'by the charting of standard paths which skirt them, and by each investigator becoming sensitive to the clues which indicate the presence of the special sorts of pitfalls he is likely to encounter in his own work.'[45] The first is communicated to students via explicit description, textbook problems and the like, but the second is wholly dependent on the investigator being proficient enough with their tools to recognise 'odd' data. As Ravetz says, 'when an individual scientist explores beyond the range of the well-established techniques, his craft knowledge must necessarily be more subtle and personal, for the pitfalls he is likely to encounter are peculiar to his particular materials and tools.'[46]

With respect to actual research, as opposed to training, Ravetz feels that the main differences are that 'a major part of the work is the formulation of the question itself; there is no simple rule for distinguishing a 'correct answer from incorrect' ones; and there is no guarantee that the question, as originally set, can be answered at all.'[47] As anyone who has ever prepared a paper can tell you, this is very much the case, even for undergraduate reports!

Classes of intellectually constructed things and events...

The idea of classes of intellectually constructed things and events[48] is used by Ravetz to provide a part of his rationale for the 'special' character of science, while maintaining the importance of social processes. Basically, Ravetz's argument is that

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[43] ibid. p 95

[44] 'At every stage of our exploration of the unknown, we are at risk of being mistaken, and of remaining in ignorance of our mistakes until irretrievable damage has been done.' ibid. p 95

[45] ibid. p 97

[46] ibid. p 97

[47] ibid. p 99

[48] This idea was rather important in the formation of my own ideas; see later.

science is the only field of human endeavour that operates wholly on objects that are not real in the same way as they are in handicrafts. They are negotiated and constructed via social processes in the scientific community. Also, and more tellingly, the objects themselves are special in some way distinct from those in, for example, theology, where the objects of inquiry are also intellectually constructed. It is unclear exactly how they are special, but perhaps the answer lies in Ravetz's ideas about tools and their use. Perhaps the answer is that it is the interaction of the scientist with the tools of their trade that creates special objects of inquiry, and therefore it is the tools that make science special. This would seem to follow from Ravetz's points about tools.

Ravetz uses the definition of 'substance' as an example. The concept represented by the word 'substance', as Ravetz puts it, 'is not a formalised description of a unique collection of material; rather, it is a class of things, the members of the class being defined by their possession of certain properties.'[49] Thus, to determine whether a new thing or event is an instance of a class, i.e. of this substance, we must decide whether the object is a 'sample'. To do this, we simply test for the defining properties of the class.

'Intellectually constructed' thus refers to objects that have been defined more strictly than their common-sense counterparts, via a process of negotiation conducted through social channels as much as the channels of published papers. Ravetz has the idea of a social process underlying his whole argument, but this is made most explicit in his section on method.

Methods: more implicit than explicit

In discussing method, Ravetz of course adheres to the view that, just as there is no 'Science', there is no one 'Method' that scientists follow. Rather, there are many methods, with a very large portion of these methods being transmitted in an implicit, craft-like fashion. A major part of this is accounted for by the criteria of Adequacy and Value.

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[49] ibid. p 111. Of course, in the text this example is more concerned with the classification of a particular substance, but I think that the argument generalises quite well.

These criteria are set only through social processes, through negotiation, the application of authority, and so on. The criteria of adequacy are used for the judgement of both arguments and evidence, and are an indicator of the maturity of a field. As Ravetz writes, regarding certainty in fields:

> For we have the historical knowledge that some fields of science do achieve objectivity and near-certainty in their results, while others do not... ...The difference between them does not lie in this logical aspect of their arguments and conclusions, but in the particular circumstances of their development.[50]

That is, the particular circumstances of their development that resulted in the creation of a certain set of criteria of adequacy are part of the reason that some sciences seem to succeed in obtaining objectivity and near-certainty. It can be seen that this idea of criteria of adequacy only really makes any sense when it is established and maintained by the community of scientists.

The criteria of value are similar in some ways, and if anything are more socially determined than the criteria of value. They have even more dependence on the conditions of the field, on such things as the amount of resources available for use, the perceived cost of the research, and the perceived reward.

Ravetz's implicit knowledge: Other points

Ravetz's book is filled with mentions of the idea that implicit craft knowledge is vital to science, and by extension with the assertion that we should thus study this implicit knowledge: its origins, maintenance, etc.

Before finishing this summary of Ravetz and moving to the textual comparison of Barnes and Ravetz, I feel that I should illustrate some remaining points that Ravetz makes. These will hopefully allow me to better explain the synergies and ‘meshing’ of the two texts in the textual comparison, as a prelude to my explanation of my ideas about concepts and science.

Firstly a quote on the originators of fields:

> Hence ... there will be a natural tendency for the author to

[50] ibid. p 155

> believe that the 'method' characterizing the new approach is as easily communicated to a wider audience as are the scientific results of the work. The subtle, particular, tacit component of the work will accordingly be neglected in the reflection of its principles, since this would obscure the message and decrease its prophetic effect.[51]

This quote concerns the founder(s) of a field, and how it is easy for them not to realise the implicit knowledge that goes into any method, and thus to produce an explicit account of their 'method' that fails to capture the nuances so important to performing actual work in the field. Of course, according to the Ravetzian account, it is the nuances that are not linguistically communicable that are the real basis for any method. Ravetz has more to say on this:

> But they [methods] have one feature in common: except for straightforward techniques, they are all largely informal or even tacit knowledge; and they are transmitted through the interpersonal channel of communication, rather than through the public channel of printed reports.[52]

In this quote, Ravetz again makes the point about the importance of implicit information. However, he is also using the 'channels of communication' terminology that he coins earlier. The interpersonal channel of communication is the primary means of transfer for implicit knowledge, (as in the master-student or peer-peer relationships), while the public channel of communication is the record of published works. Thus these two quotes serve to illustrate (however inadequately) a point about the importance of implicit knowledge, and indeed a point that I am unsure if Ravetz meant to imply. This is the underlying consequence of this talk about implicit knowledge: *It is possible to know something without knowing that you know it*. Again, it is possible for your brain to store information without that information being directly accessible to your introspection. This belief underlies all of Ravetz's work about implicit knowledge, and also some of Barnes' ideas about finitism and conceptual sets, and thus we come to a point where a consideration of the two is possible. Keep this idea of implicit knowledge in the back of your mind, because it is fundamental to both the comparison of the two works, and also to my own ideas. So what do these two have in common?

[51] ibid. p 170

[52] ibid. p 173

Tacit knowledge

Probably the thing that drew the two books together the most for me was the synergy between the authors of this idea of knowledge that is not explicitly transmittable, but instead only transmittable by experience and example. That is, knowledge that you do not know that you know.

Thus, Barnes' finitist ideas seem to mesh well with Ravetz's conception of science as craft work, in the following ways:

Barnes speaks of learned similarity relations[53] both between concepts and between instances of a concept. Ravetz speaks of implicit knowledge, and so on[54]. The way in which these two ideas merge may not be obvious, so I will consider an example, that of the solution of a number of similar textbook problems on the motion of a pendulum. These problems usually involve the measurement of the period of a pendulum's swing for a number of lengths of string.[55]

Barnes' point is that all of these solutions are part of the set of instances representing the concept of pendulum motion[56]. Ravetz argues that, when solving these sorts of problems, what is also learned are the proper modes of use for the apparatus, in this case, a pendulum, ruler, and clock of some kind[57]. Barnes argues that what is learned is not simply the overarching similarity relation, that of the observed motions to the ideal of pendulum motions, but also a multitude of other similarity relations between all these instances, keeping track of what is both the same and different to all the others for each[58]. This provides a mechanism for Ravetz's learning of implicit knowledge of apparatus operation. Those instances in which the apparatus is used 'correctly' are labeled as such by an authority (teacher or lab instructor), as are those in which the apparatus is used 'incorrectly'. These labelings enable the leaner not only to gain an idea of the concept of pendulum motion, but also each instance

[53] op. cit. 1, figure 2.1, p 28

[54] op. cit. 2, p 71-72

[55] It should be noted here that I use the word ‘problem’ in the Kuhnian normal-science sense, i.e. an exercise given that is in principle solvable. Here the purpose is ostensibly to train the pupils in the law under consideration, namely the law of constant acceleration in a gravitational field.

[56] op. cit. 1, figure 2.1, p 28

[57] see previous footnote, number 34

[58] op. cit. 1, figure 2.1, p 28

serves to educate regarding the correct modes of use of the equipment. In the pendulum example, a student may get unexpected results, only to be told that the were using the stopwatch they were given incorrectly. The student now not only has increased their understanding of pendulum motion, by understanding how the results they obtained differed from the established norm, but also has increased their understanding of the norms of stopwatch-use.

I will be the first to admit that this example is somewhat inane, given its simple subject matter, but the point is to communicate the idea that what I call intra-event learning, what psychologists call 'contextual effects'[59], is important in learning science.

What is the most important to note with respect to this material is the way in which Ravetz tends to say *that* an effect exists, and provide some descriptive evidence for *how* the effect works, Barnes concentrates on *how* and *why* such effects exist. In this way, I feel that Barnes provides a kind of philosophical 'basis' for Ravetz's ideas of craft knowledge. It was this feeling that originally put me on the path towards writing this essay and attempting to meld the ideas of the two books into a cohesive whole.

Analogical inference

Given the background of social studies of science shared by both works, it is hardly surprising that both share the idea that science relies heavily on analogy[60]. In Ravetz, the idea is less explicit[61], but I take it to be very similar to Barnes' idea that ' a scientist must actively construct an analogy between the known and the unknown'[62], and his assertions that *all* scientific inference is based on analogy.[63]

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59 Effects of the context in learning have been 'shown' (to the satisfaction of psychologists) with respect to many effects on animals. Most modern psychology of learning assumes this type of effect. (evidence for this is from my own experience with studying the psychology of learning at UNSW. See Westbrook, R.F. ‘Lectures on the psychobiology of animal learning’, Course Material, PSYC2081, Learning and Developmental Psychology)

60 Analogy seems to feature heavily in much of SSK. It would seem that an acknowledgement of the importance of social processes predisposes one towards analogical explanation. This makes sense, in that acknowledging the importance of social processes increases the importance of communication in science, and the analogy is used very often in communicating scientific thought.

61 see op. cit. 2, p 111, in that to test for membership in a set, one must establish similarity in important properties with the other members of the set. That is by establishing similarity in important properties with other members of the set, you are comparing your current situation to other, known situations, and thus using analogical reasoning.

62 op. cit. 1, p 49

63 see previous footnotes, numbers 25 and 26

Again, this is another area where Barnes provides a deeper explanation for Ravetz's detailed descriptions of science as a craft.

Mutation of questions

Both Barnes and Ravetz discuss the idea of the mutation of the problem under investigation as it is further studied. In contrast to other areas, Ravetz goes deeper into this idea than Barnes does, with Barnes only giving a brief explanation of the idea that problems do not generate candidate solutions automatically[64], whereas Ravetz looks into the idea that a major part of the work of research is in the formation of the question. The idea that your question can mutate as you work relates to the changing of concepts over time, through the obvious mechanism that your question is representative of your conceptual make-up as you consider a new area. As you learn more about this area, your concepts about it will inevitably change, changing the question you are asking.

Finitism and craft knowledge

What underlies all of these particular items, however is the idea of science being about concepts that are open-ended, revisable, and set via social processes. Barnes uses the finitist idea of open-ended concepts in order to ground his ideas about the social factors in the addition and subtraction of instances to and from concepts, and, most importantly, about the learning among instances of the same concept. The idea that relationships between events that are considered to be instances of a set are important is the idea that provides a basis for Ravetz's ideas about the importance of implicit knowledge. That is, knowledge that is neither explicit nor specifiable, in which respects it is similar to the knowledge possessed by practitioners of a craft. This is *very* important for my work, because it implies that the greater part of human knowledge is not directly communicable. A large part of my thinking is an effort to understand how this could be the case.

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[64] op. cit. 1 p 50

Final word

Ravetz and Barnes seem to link so well in my mind that it becomes difficult to see how anyone could read them both and not think about the similarities that I have pointed out in this paper. In thinking about the two books in conjunction, I have arrived at some preliminary conclusions of my own about the nature of conceptual sets, and the relation of this to the study of science. This of course primarily consists at the moment of broad generalisations without any argument or evidence at all, as these have been thoughts I have arrived at after reading the two books and mentally joining them.

Fuzzy, Finitist Concepts, and the philosophy and sociology of science.

Before I begin, I will take a moment to explain some of my motives in this project. I was originally writing a textual comparison of the two texts as a beginning exercise, to bring me up to speed. However, once I began reading the texts, the synergies I have enumerated began to make themselves apparent. My other motive was more complex. Because of a number of features of my life, duplication of effort is anathema to me. Thus, when I read literature from various fields and see the denigration of other fields of endeavour, *when those other fields are doing work clearly related to the first field*, I do not like it at all. So I determined that the best course would be to attempt to integrate things that made sense together into a coherent picture, without regard to where the ideas came from. Thus the ideas following probably have their roots in many things: sociology of science, philosophy of science, philosophy of language, the 'MIT AI hacker' ethic, and Zen philosophy. Thus, my goals in this are to remove what seems to me to be muddy thinking, and to eliminate wasted effort.

Central to this argument is the idea that concepts are created by the creation of associations between various events. These associated events become instances of the concept. The creation of the association may take place by personal reflection, by ostension (by example), or by the reclassification of previously observed events under a new concept. Personal reflection actually falls under learning by ostension, as it is using the example of previously classified events to guide the classification of a new one. That is, personal reflection is generally learning by analogy. As Barnes says, '*Any 'deduction' about empirical phenomena involves a hidden analogical* *step.*'[65] Or in another way, 'The real contrast here is between learning which relies *directly* upon ostension, and that which relies upon it *indirectly*.'[66] That is, learning by analogy can only proceed when there are instances with which to create an analogy, where those instances have been arrived at via ostensive learning. This is because ostensive learning is the only way we can establish a respectable level of certainty about an event's membership in a concept, because a source that is ‘authoritative’ has given a ruling as the event’s status. Following this, it can be seen that personal reflection also requires the use of analogy and ostension. Ostension, to establish the initial instances, and analogy to extend these instances. The difference is that in personal reflection, the analogy does not need to be as highly specified, as the implicit knowledge the person has will inform it.

Also important in this argument is the standard philosophical idea that membership in a concept is a binary function, that is, that an instance can only either be in the set, or not. This creates problems when dealing with cases that are 'borderline', and borderline cases are especially important when considering concepts. To this end, I suggest that conceptual sets should be thought of as 'fuzzy', in that membership in the set can be, and always is to some extent, governed by a non-binary, continuous, function.[67] That is, instances can be partial members of a set. ‘Partial’ here indicates that the membership in the set is uncertain. Thus, instances classified into a set by ostension tend to be more certain than those classified into a set by the application of a partially-learned generalisation[68], because the ostensive classification has been performed on the basis of the social power and authority of the instructor, whether that is a person, or a text, or whatever. However, with a generalisation that the person fully understands (or to use a hackerism, 'groks'), that generalisation is better at 'grabbing' instances than others.

However, the full meaning of a concept can only be understood by the person who 'owns' that version of the concept. This is because each person has a finite, and different set of instances from which to build their concept from. That is, because

[65] ibid. p 122

[66] ibid. p 27

[67] That is, in the 'fuzzy logic' sense.

[68] Where ‘partially-learned’ means ‘uncertain’, that is, where the person does not have enough instances classified under the concept to be able to draw a sensible analogy with a known member of a set.

each person can only ever observe a finite number of instances, and these instances must necessarily be vastly different from other peoples, each person will form a unique set for any concept. Thus, in order to fully understand an abstract generalisation that they have been taught, a person must acquire a set of instances known to be of the concept represented by that generalisation.

A major area in which I feel my ideas are different from Barnes in particular is that I feel that the creation of associations between events that are classified as being in the same conceptual set are as important if not more so than those between sets. I call this *intra-concept learning*, and it is fundamental to my conception of human learning.[69]

Any generalisation used to communicate a concept is, by design, a simplification. However, as I have already explained, membership in a conceptual set depends in no small part on the interrelationships of *all* of the members of the set, and, to a lesser extent, the interrelationships between all other instances, that is, the instances outside that concept. Thus any simplification of a conceptual set into a generalisation about the concept can *never* create the same impression in another person, as they will not have the same set of instances, and thus will end up with a (perhaps only slightly) different concept. Through the sharing of a set of well-defined, similar experiences, such as in scientific or craft training, the concept can be shaped to be similar to other peoples, in very large part, anyway.

It follows from this idea of uncertainty in learning that any conceptual set being comprised of a finite number of instances will always have some level of uncertainty. This is because each instance that is reasonably established as being a member of the set contributes to the knowledge about the set, but also introduces additional difficulties in defining membership in the set, as more properties are added that could be a basis for inclusion of other events in the set. Thus, each instance classified ostensively under the concept will further reduce the uncertainty associated with judgements as to membership in the conceptual set, by making the amount of overlap between instances less and less. That is, as more and more instances are

[69] In the following discussion, also keep in the back of your mind that all I have said about instances as members of a set that is a concept can also be applied to concepts as members of a set that is a world view. There is a nice referentiality about the two levels of representation.

classified ostensively under the concept, it becomes easier to decide whether to classify an instance under the concept, and the difficulties introduced by the members of the set added by other means are smeared out as more and more members are added, and the number of properties available for use as similarity relations diminishes.

This is because of intra-concept learning. The more instances you have, the more relationships between instances you have, and thus the more information you have, albeit implicitly, about what constitutes a member of the set. However, if your set of instances is different to another person's, you will have a different concept.

However, perfect certainty about set membership is not required to be able to use the concept, and that is something that many people fail to recognise. That is, some level of fuzziness in concepts is acceptable, and indeed unavoidable. However, the purpose of scientific and craft education is to create a reasonably regular conceptual web in the recipients of the training, by giving them similar instances. This eventually serves both to give a similar resultant concept, and also to reduce uncertainty, by adding a large number of 'standard' instances, which the person can then use as the basis for analogy, in order to extend and manipulate their own concepts.

These are only very preliminary thoughts, but they currently suffice to give an outline of the shape of my current thought on these matters. It does seem obvious, however, that if these ideas have any credence to them at all, I'm going to have my work cut out for me.

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