Judging Scientific Creativity: The Case of the Early Jagadis Bose

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Abstract

In my book (Dasgupta, 1999), Jagadis Chandra Bose's creativity was assessed as it was given. The article (Dasgupta, 2009) investigated Bose's cognitive style as used in his scientific work. In this paper, on the basis of a framework taken from recent creativity studies, I explore the question: How creative was Bose as a scientist?

Key words: Coherer, Historicity, Indian scientific consciousness, Jagadis Chandra Bose, Microwave optics, Photoconductivity, Radio waves, Scientific creativity, Semiconductivity.

1. CREATIVITY AS HISTORY-MAKING

As many creativity scholars (see, e.g., Taylor, 1988) have noted there are at least a half-a-dozen broad definitions of creativity, all of which are reasonable, pointing to the plurality of the idea of creativity itself. The view here – as being the most relevant to science in particular – is the *historicist* theory: To be creative is to *make history*. Before expanding on this let me introduce two terms I will use throughout this paper. By *artifact* I mean anything produced by human effort; that is, a non-natural thing. This may be a material thing (that necessarily obeys physical laws, e.g., a scientific instrument) or an abstract entity (which is independent of physical laws, e.g., an idea, a mathematical theorem or a design). By *artificer* I will mean the producer of an artifact.

The historicist perspective proposes that an artificer is creative if she makes history. Boden (1991) actually identified two kinds of history-making. One is when an artificer produces an artifact that is original with reference to the *artificer's personal history*. Boden called this *P-*

creativity. Others may have created the same artifact before her but this does not dilute the artificer's cognitive achievement. Boden's second sort, which she called *H-creativity*, is when the artifacts is original with respect to *all* of its past history, that is, with respect to all of time *preceding* the time when the artifact was created.

In this discussion I will ignore *P-creativity* because the focus of interest here is Bose's historical place in world physics.

But the artifact's originality with respect to historical time alone is never sufficient. There is also the question of *how* original the artifact is. The artifact must be *valuable* in some significant sense. This may be because the artifact is surprising in its behavior; or in the way it is a derivative of prior artifacts; or because the artifact resolves a long-held dilemma; or because it falsifies a current theory or belief; or it is perceived or found to have *consequences* that shape the future history of the relevant domain.

This lattermost situation, referring to future time, I have elsewhere (Dasgupta, 2011)

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called *consequential creativity* (*C-creativity*). This is manifested if one can discern an *epistemic connection* between an artifact produced at some point of historical time and one or more artifacts produced at some future time. That is, the knowledge embedded in the earlier artifact serves, in part at least, as an input in the production of the later artifact (Dasgupta, 2013).

But there is another possibility. An artifact is produced at some point of historical time and it is discovered at some (possibly *much* later) time that another artifact was created bearing a marked similarity to the earlier artifact, though there is no evidence of an epistemic connection between the two. I will call this situation *anticipatory creativity* (or *A-creativity*).

So from a historicist standpoint we can identify three varieties of creativity: *H-*, *C-* and *A-creativity*, the first referring to past history relative to the making of the artifact, the second and third referring to future history.

We also note that creativity is not a binary affair. An artifact may be more or less original than another; thus an artificer – in a particular context – may be judged as more or less creative than another. Indeed, the same artificer may be judged as having been more or less creative in the making of one artifact than in the making of another. In other words, in this view, creativity is a matter of historical, epistemic and cognitive *judgement*.

So who does the judging? For every act of creation there will be, not just an artificer but also a *consumer* of the produced artifact. In the case of the sciences, this will be a fellow scientist or a science studies scholar. The consumer may be contemporaneous with the artificer or at a temporal distance – perhaps decades or even centuries later. In the context of the sciences the only kind of consumer who can serve as a reliable judge is one who possesses the knowledge, training and

expertise to make responsible and informed judgement. I will call such a person a *peer consumer*.

2. THE JUDGES OF THE EARLY BOSE'S CREATIVITY

Thus, in the present context, Jagadis Bose is the artificer, his scientific discoveries and instruments are the artifacts, and scientists (both his contemporaries and those who came later) are the peer consumers who can serve as judges. Now, as is well known, there were really three scientific Boses whom I called the 'early Bose' (the physicist), the 'later Bose' (the plant physiologist and biophysicist) and the linking 'middle Bose', the author of what I called the Boseian thesis which claims that there is no discontinuity between the living and the nonliving (Dasgupta, 1999). In this paper I will focus on the early Bose — the physicist.

The first significant peer consumer of Bose's physical researches was Lord Rayleigh, who communicated (and recommended) all the papers Bose submitted to the Royal Society between 1895 and 1898 for publication in its *Proceedings*. However, none of these papers was actually refereed. The only other contemporaries of Bose who served as peer consumers/judges of his work on radio waves were J J Thomson and the editors of the trade periodical *The Electrician* and the journal *Philosophical Magazine*. Indeed, it was not till the mid-20th century that we see the emergence of a roster of peer consumers of the early Bose's artifacts. In what follows I will have occasion to refer to their judgements.

3. JUDGING THE EARLY BOSE'S CREATIVITY

So let us examine the early Bose's creativity by considering its judgement by various peer consumers. For this purpose I will consider, individually, his principal artifacts, some material, some abstract.

3.1 Generation of Millimeter-Length Radio Waves

Bose (1897) announced the production of waves ‘about 6 mm’ in length in the pages of *Philosophical Magazine*. J J Thomson (1905) in his *Encyclopedia Britannica* article acknowledged the originality of this production. But Meghnad Saha (1940) in his obituary on Bose noted that contemporaneously the Russian Pyotr Nikoleevich Lebedov and the Italian Augusto Righi had produced sub-centimeter waves. Thomson also mentioned Righi as did the engineers John Ramsay (1958) and Charles Susskind (1969), while Darrell Emerson (1997) has mentioned Lebedov as ‘independently performing experiments’ with 5-6 mm radio waves. Thus the evidence of these peer consumer-judges suggest that Bose was *one* of the first (but not *the* first) to produce such short length waves. On the other hand, in the *general* domain of radio wave production Heinrich Hertz (in 1887) and Frederick Trouton (who repeated Hertz’s experiments in 1889) were their clear antecedents. Bose was thus an *epistemic descendant* of Hertz and Trouton. And he manifested, alongside Righi and Lebedov, the highest level of *H-creativity* in the domain of mm-length radio waves. On the other hand there is no evidence, according to the judges cited, that his production of mm-length waves had any consequences in the sense that other investigators drew on *his* work to further the study of mm-length radio waves. There seemed to have been no epistemic descendants of Bose: he was not *C-creative* in this respect.

3.2 Microwave Optics

Between 1895 and 1898 Bose published some eleven papers on the quasi-optical properties of microwaves. But he was not the first to conduct such investigations: Hertz (1887-1888) was the pioneer; and in his lecture on Hertz, Oliver Lodge (1894) also described his own work on the optical properties of radio waves. J J Thomson (1905)

cited Hertz’s work extensively and mentioned Bose’s ‘verification’ of the ‘laws of reflection, refraction and polarization’. As for the double refraction of radio waves Thomson believed that its observation was first made by Righi, while Ramsay (1958) refers to Lebedov’s experiments published in *The Electrician* in 1895, contemporaneous to Bose’s paper on double refraction in the same journal.

Thus, in the study of the optical properties of radio waves, Bose was an epistemic descendant of Lodge who in turn was an epistemic descendant of Hertz.

The responses of later judges follow that of Thomson. Thus Susskind (1969) mentions Bose as *one* of several investigators of microwave optics as did Ramsay (1958) before him, but neither discussed the significance of his work. Likewise Emerson (1997) mentions some of the results of Bose’s experimental techniques but says nothing of the significance of the results. It seems reasonable to say that Bose’s studies in microwave optics yielded *facts* about the optical attributes of radio waves that corroborated what Hertz and then Lodge had found but *had no larger significance*. Nor had they further consequences. Rather, according to the judgements of such consumers as Thomson (1905), Ramsay (1958) and Susskind (1962, 1969), far more consequential was Righi’s treatise *L’ottica delle oscillazioni elettriche* (1897).

3.3 Radio Wave Transmitter

Bose’s transmitter was an oscillator that was an *improvement* on Lodge’s transmitter which in turn was an improvement on Hertz’s transmitter (Lodge, 1894). Bose *eliminated* a problem with Lodge’s transmitter and obtained a more reliable artifact — one that could produce much shorter waves than Hertz or Lodge had produced. And though it was an epistemic descendant of Lodge’s transmitter it was an original artifact. In this

respect Bose's *H-creativity* was significant; it had no predecessors.

But was Bose's oscillator an epistemic antecedent of other artifacts? None of the consumer-judges referred to earlier seem to suggest anything in this regard. Emerson (1997) describes Bose's transmitter at some length with interesting photographs but his conclusion is simply that Bose was involved in millimeter wave research some one hundred years earlier. But he does comment that radio wave investigators also shifted their attention to larger wave-length phenomena. Amongst more recent Indian consumers of Bose's work Visvapriya Mukherji (1978) was perhaps the most judicious in his judgement, but he too had nothing to say about the consequentiality of Bose's transmitter. We can only conclude that Bose was not *C-creative* in this regard.

3.4 Coherers

In all the discussions of the history of radio wave research, perhaps the greatest interest amongst commentators, consumers and judges was on the receivers or detectors of radio waves. And in this realm Bose's contributions have generated some controversy.

The detectors most relevant to this discussion were termed *coherers* by Lodge (1894) which he described as 'the most astonishingly sensitive detectors of Hertz waves' (p. 136), an opinion with which Thomson (1905) later concurred. Coherers manifested the property that the resistance between metallic contacts, such as a pile of iron turnings, diminishes markedly in the proximity of an electric discharge.

Now if we accept the opinions of our peer judges, both Bose's contemporaries and ours, the epistemic pathway on which Bose's coherers appear properly originated with the Frenchman Edouard Branly in 1890 (Lodge, 1894; Thomson, 1905; Susskind, 1969). Branly's device

consisted of metallic filings enclosed in a glass tube, and in this invention he was *C-creative* in that several other investigators, including Lodge (1894) were influenced by him. Thus there was an epistemic link between Branly's and Lodge's coherers. Bose's (1895) spiral spring coherer was created in response to the limitations of Lodge's coherer; it was thus an epistemic descendant of the Branly device *via* the Lodge coherer. Bose (1899) then went on to invent a self-recovering coherer, announced in the Royal Society's *Proceedings* (once more communicated by Lord Rayleigh). Interestingly, Thomson (1905) makes no mention of this receiver in his article. According to Susskind (1969), Bose was one of the first (but again, not *the* first) to devise a self-recovering coherer. In particular, that same year (1899) the Italian Thomas Tomassina published a paper in the French journal *Comptes Rendu* describing a carbon-based self-recovering coherer. So Bose's *H-creativity* in respect to self-recovering coherers was at about the same epistemic level as that of Tomassina. If we view Bose as improving on his own non-self-recovering spiral spring coherer of 1895, this also means that his *H-creativity* rested on the fact that his invention was, on the one hand, an epistemic descendant (and improvement) of his own spiral spring detector.

Bose's self-recovering coherer has another claim to originality. It was mercury-based. However, almost contemporaneous to Bose's 1899 paper being read before the Royal Society, Tomassina presented a paper to the Academie des Sciences in Paris describing a mercury-based coherer (Anon 1899, Phillips 1993, personal communication 1998). So once more, in regard to the invention of mercury-based coherers, Bose must share his *H-creativity* with Tomassina.

4. WAS BOSE'S MERCURY-BASED COHERER CONSEQUENTIAL?

The controversy over Bose's mercury-based coherer lies in the claim made by one peer

consumer-judge, Probir Bondyopadhyay (1998) that Marconi's later coherer, used in the first transatlantic radio transmission of 1901 was based on Bose's design. As I have argued elsewhere (Dasgupta, 1999, pp. 252-253), drawing extensively on the work of yet another peer consumer-judge Vivian Phillips (1993), there is *no evidence epistemically connecting* Bose's invention with Marconi's. As Phillips tells us, Marconi's coherer does connect epistemically with *other* predecessors, notably the Italians Luigi Solari and Paolo Castelli; but none with Bose's device. A later scholar Sunghook Hong (1996), also referring to Phillips, discussed Marconi's coherer but makes no mention of Bose.

In other words, in regard to the invention of his mercury-based coherer Bose was not *C-creative*.

5. THE SIGNIFICANCE OF BOSE'S 'ARTIFICIAL EYE'

In a sense the culmination of the early Bose's researches on radio waves was his invention of what he fancifully called 'artificial eye', *circa* 1901, which was granted a US patent in 1904 (Bose, 1904).

According to Pearson and Brattain (1955), in 1874 the German physicist Ferdinand Braun discovered the rectification property of contacts between certain materials – specifically galena (PbS) and pyrites (CuFeS₂). About the same time the British physicist Arthur Schuster reported a similar property for contacts between copper oxide wires (Orton, 2004). Very recently Grundmann (2016) has recorded that photo conductivity in selenium was discovered in 1876 by W G Adams and R E Day, and by William Siemens. Thus these two fundamental properties of semiconductors – rectification and photoconductivity – had been observed well before Bose began his research into radio waves.

However, Pearson and Brattain have also stipulated that Bose was the discoverer of the

rectifier as a detector of radio waves. Bose applied for a patent in 1901 for his 'artificial eye' in which point contact with galena served as both a self-recovering coherer and as a photoconductor, the patent being awarded in 1904 (Bose, 1904). There were others about the same time who discovered radio wave detection properties of various other semiconducting materials, but Bose's patent grant preceded their publications (Pearson & Brattain, 1955; Grundmann, 2016). Furthermore, Bose had presented his 'artificial eye' in his May 1901 lecture at the Royal Institution (Bose, 1901). Yet, oddly enough, in his history of semiconductors Orton (2004) refers to point contact rectifiers ('cat's whiskers') as radio wave detectors but makes no mention of Bose. Nor do we find mention of Bose in Herold's (1955) article on semiconductors.

But Bose's goal in creating his artificial eye went beyond the invention of a patentable material artifact. He had also published a paper (Bose, 1901) in which he presented the results of experiments with light and radio waves on a variety of matter (but not galena).

Thus there seems no doubt of the originality of Bose's discovery of galena as both a radio wave detector and a photoconductor. Yet his *H-creativity* in the realm of semiconductivity must rank below that of Braun's. With respect to the detection of radio waves Bose's *H-creativity* appears to have had no predecessor. In the realm of photoconductivity one consumer-judge seems to suggest that Bose's discovery of the photovoltaic effect in galena under the influence of electromagnetic radiation was considerably earlier than other comparable discoveries of the effect of radiation on galena (Moss, 1955).

Thus, overall, Bose's *H-creativity* in the realm of galena-based radio wave detection and photoconductivity must be judged as of a very high level, though in the realm of semiconductivity it was less so.

Do we have any evidence of Bose's *C-creativity* in this regard? Several judges have noted that very soon after Bose's patent was granted (in 1904) a number of other discoveries of the radio wave detection property of semiconducting materials were reported by various investigators (Pearson & Brattain, 1955; Herold, 1955; Grundmann, 2016). This invites us to ask: did Bose's work serve as a precursor to these efforts? As far as the evidence suggests, this remains an open question. In the longer term, however, as Pearson and Brattain note, interest in point contact detectors faded very soon thereafter because of the invention of the vacuum tube.

6. WAS BOSE EVER *A-CREATIVE*?

Some of the literature on Bose mentions him as having anticipated many features of later electronic and microwave technology (Ramsay, 1958; Sengupta, Sarkar & Sen, 1988; Emerson 1997). Earlier, I 'defined' *A-creativity* as being manifested by an artificer if he or she created an artifact (abstract or material) at some point of historical time that is found to bear marked similarities (in structure or function) to a (possibly much) later artifact, even though there is no *epistemic* transfer from the former to the latter. Thus *A-creativity* may prevail even if *C-creativity* does not. In this regard we must conclude, based on Ramsay's and Emerson's judgements, that components of the apparatus Bose demonstrated in England at the British Association meeting in 1897 and then published the same year (Bose, 1897) anticipated later developments. Thus Bose was *A-creative* in this respect.

As regards the implied claim by Sengupta *et al* that Bose's galena receiver anticipated 'semiconductor diodes' this is more problematic. As noted above, Bose did not *discover* semiconductivity nor that galena manifests rectification properties. If by 'semiconductor diode' is meant an artifact with the property of rectification, then Bose was by no means the first

to 'anticipate' this artifact. His *A-creativity* in the realm of semiconductor diodes thus lies well below those of Braun and Shuster.

7. CONCLUSIONS

Our conclusions, based on the judgements of a variety of peer consumers of Bose's physics can be summarized as follows.

a) He was *H-creative* in almost all his discoveries and inventions but never at the highest level of creativity. b) It remains an open question whether in inventing his galena-base receiver he was *C-creative*. c) In regard to some of Bose's material artifacts comprising his 'complete apparatus' for generating and detecting radio waves Bose can be deemed to have been *A-creative*. d) In the realm of semiconductors Bose was at best moderately *A-creative*.

In the language of Thomas Kuhn (2012) Bose's physics enriched the (classical) physics paradigm of his time, but as normal science, not extraordinary science. In the realm of world physics he was not by any means a revolutionary.

But, of course, Bose helped implement a revolution of *another* kind. By way of his physics he helped implement, in the minds of Indians, the seeds of a new *scientific consciousness*. It was this new consciousness which entered in broad outline the minds of some of Bose's eminent non-physicist consumers of his science – *lay* consumers, including Rabindranath Tagore, Swami Vivekananda, Sister Nivedita, Sara Bull, Patrick Geddes and, some time later, Ramananda Chatterjee.

As a consumer Geddes poses an interesting problem. Trained in biology, he may be regarded as a 'quasi-peer' consumer in casting a scientific eye in his biography on Bose (Geddes, 1920). Unfortunately, it was ultimately an *uncritical* eye. The reason is not hard to find: Bose and Geddes, introduced to one another in 1900 by Sister Nivedita (Meller, 1990, p. 227), were close friends.

According to Geddes's biographer Bose cared warmly for Geddes and 'Geddes tried to repay him by writing his (Bose's) biography' (*Ibid.*). Close friendship between biographer and biographee is not conducive to objective, let alone critical, biography. For this reason we must regard him as another lay consumer of Bose's science amongst the latter's 'circle'. His scientific judgement, as those of Tagore, Nivedita or Vivekananda is of little value.

Much more significantly, the most effective consumers of this new consciousness were the first generation proper of Indian scientists who would enrich and build upon it in the course of the 20th century. In his role as an implementer and shaper of this modernist Indian scientific consciousness lay Bose's most unequivocal claim to the highest level of *C-creativity*.

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