The Making of an Indian STM

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‘Technological Jugaad’ as a Culture of Innovation[[1]](#footnote-1)

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Abstract: This article is an historical account of the making of one of the earliest Scanning Tunneling Microscopes (STM) in India at the University of Pune. The article discusses some of the innovative methods the scientists used in overcoming resource constraints and also at the same time working with collaborators and ‘other ways’ of knowing and doing things, even as the research and outcomes were at the cutting edge of modern science.

Using the case of the making of the STM, the article conceptualizes and characterizes a culture of locally embedded and influenced innovation that is called ‘Technological Jugaad’. It discusses some of the critiques and questions related to this form of innovation and instrument making.

Finally, the article compares Technological Jugaad to other cultures of innovation such at ‘bricolage’ and user-driven innovation to make the case for the de-centring of innovation cultures as also the de-centred nature of the cultures of innovation.

**The 1986 Nobel Prize for Physics**

One half of the Nobel Prize for Physics for 1986 ([TRSAS, 1986](#_ENREF_53)){, 1986 #14761} was awarded to Dr. Gerd Binnig and Dr. Heinrich Rohrer of the IBM Research Laboratory, Zurich in Switzerland for the successful development of the Scanning Tunneling Microscope (STM)[[2]](#footnote-2). The significance of the instrument, that is universally credited with having spawned the now hugely popular and ever expanding field of nanoscience and technology (NS&T) is now well known.

The first significant images from this first STM had been reported in late 1981 but it took a few years more before the STM gained recognition and popularity ([Binnig and Rohrer, 1986](#_ENREF_5)). One of the first significant scientific gatherings around the STM was held, in fact, only a couple of months before the Nobel prize itself was announced. This was the 1st STM conference organized in Santiago de Campostela, Spain by Dr. Nicolas Garcia of Universidad Autonoma de Madrid. It was attended by most of those individuals who find a prominent mention in any historical account of the development of STMs and the field of Scanning Probe Microscopy (SPM) that followed from it - Binning and Rohrer, of course, but also others like Dr. Richard Colton of the Naval Research Laboratory (NRL) Washington, United States of America (USA) and Dr. Paul Hansma from the University of California, Santa Barbara, USA([Mody, 2011b](#_ENREF_34)).

**An Indian STM**

There is one name in the list of participants of this conference that is of particular interest from an Indian point of view - surface scientist from the University of Pune (UoP), Dr. CV Dharmadhikari. He attended not only the 1986 conference, but also the 2nd STM conference that was held in Oxnard in California, USA in 1987 and about a year later, in 1988, Dharmadhikari successfully installed his first indigenously made STM under the stair case in the Department of Physics in the UoP.

Students had also already started working with him on the STM project. In 1987, the first Master of Science (MSc) project ([Bendre, 1987](#_ENREF_3)) related to the STM had been completed under his guidance. The first peer reviewed article on an aspect of STM construction ([Bendre and Dharmadhikari, 1988](#_ENREF_4)) was published in 1988; the first Master of Philosophy (MPhil) degree ([More, 1990](#_ENREF_35)) for the “development of a simple electronic control system” for an STM was awarded in 1990; and the first Doctorate (PhD) ([Yehia, 1999](#_ENREF_59)) was awarded for STM related work under his supervision in 1999. In 1988, in fact, when a joint Indo-US project titled ‘Scanning Tunneling Microscope (STM)’ was initiated with SS Wadhwa of the Central Scientific Instruments Organization (CSIO), Chandigarh, India and Richard Colton from Naval Research Laboratory, Washington, USA, as the Principal Investigators, Dharmadhikari was drafted in as one of three other Indian players who had experience and could make a significant contribution.

From 1988 to 2010, the year that Dharmadhikari retired from the university[[3]](#footnote-3), the Center for Advanced Studies in Materials Science and Solid State Physics that he headed, had made a series of STMs and Atomic Force Microscopes (AFMs). 12 students had completed their Master of Philosophy (MPhil) degrees ([Chaudhary, 2002](#_ENREF_8), [Dambe, 1995](#_ENREF_10), [Sawant, 1994](#_ENREF_50), [Patil, 1994](#_ENREF_37), [Iyyer, 1994](#_ENREF_19)) and eight, their doctorates ([Chaudhary, 2011](#_ENREF_9), [Dey, 2010](#_ENREF_14), [Iyyer, 2006](#_ENREF_20)), all of these while working on various aspects of making these instruments. Many of these students then worked on post-doc fellowships and eventually moved to permanent positions in leading scientific institutions in India and abroad. The research group also published more than 60 papers including in the world’s leading peer reviewed scientific journals such as *Applied Physics Letters* ([Sastry et al., 2001](#_ENREF_49), [Godbole et al., 1997](#_ENREF_16)), *Langmuir* ([Chaki et al., 2004](#_ENREF_7)), *Surface and Interface Analysis* ([Datar et al., 2004](#_ENREF_12), [Patil and Dharmadhikari, 2002](#_ENREF_38)) and *Advanced Materials* ([Kumar et al., 2001](#_ENREF_25)).

The brief account above is suggestive of the fact that the efforts of Dharmadhikari and his students were a success within the framework and demands of research in an emerging field of science and technology. This success was, importantly, achieved in a context and reality quite different from that in Europe and North America where the instrument was first made and the making of which has been studied and documented ([Mody, 2011a](#_ENREF_33)).

This article, therefore, is an exploration of the larger context of the scientific journey made by Dharmadhikari and his students; the instruments they fabricated; the materials, processes and people that were recruited in the process; the bridges that were built, new meanings that were generated and the scientific output that they jointly delivered.

Junk markets, scrap materials, roadside spring making workshops, traditional knowledge practices and the notion of jugaad are not generally associated with the modern laboratory and certainly not with cutting edge scientific instrumentation and research. Yet, this is exactly what happened here.

**Science and Technology Studies (STS)**

This article is an outcome of my on-going doctoral research in Science and Technology Studies (STS) as part of which I am trying to understand the ‘cultures of innovation’ in NS&T research in India. I approach the subject as a sociologist of science & technology (S&T) working in collaboration with the Indian NS&T scientists and researchers themselves.

The research is qualitative in nature and uses methods such as open-ended interviews, historical analysis, and laboratory ethnography that are drawn primarily from sociology and anthropology. It is about a ‘culture of innovation’ that links the macro with the micro and what is done within the lab with the world outside, a world that is a much bigger influence than is generally believed. This is the culture of ‘technological jugaad’ –innovation that is deeply embedded in the historical, political, social and economic context in which research and innovation happens.

It would be relevant here to note that almost no conversation on innovation in India, particularly north of the Vindhya Mountain Range, can happen without a reference to jugaad. It is a term that is both extremely maligned and used with extreme pride and in what follows there is, first, a brief journey through this world of jugaad. We then return to the laboratory, to the making of the STMs and further on to the conceptualization of technological jugaad. The paper ends with characterization of this new idea and providing a conceptual framework that should help provide a new understanding of and engagement with innovation as it is nested within the wider socio-cultural setting.

**Exploring jugaad**

Jugaad is a word in many Indian languages in the upper half of the country such as Hindi, Marathi, Gujarati, Punjabi, Oriya and Mythili that does not have an easy equivalent in English. The plasticity of the word and range of its usage is evident in the fact that jugaad can be concept, process and product all rolled into one at the same time; it means reconfiguring materialities to overcome obstacles and find solutions; it could mean working the system to one’s advantage; and it is also used as a synonym in certain contexts for gambling and corruption. Jugaad is not just an inextricable part of local vocabularies in India, it is an integral part of the way life is lived and the world negotiated. It is noun as much as it is a verb; an idea and an articulation that has a wide range of meanings and usages that revolve primarily around problem solving or solution finding.

It is not surprising, then, that jugaad comes up repeatedly in discussions related to innovation with as many translations and interpretations as there are authors – “creative improvisation” ([Krishnan, 2010](#_ENREF_24)); “developing alternatives, improvisations and make dos” ([Prahalad and Mashelkar, 2010a](#_ENREF_42)); and “an arrangement or a work-around, which has to be used because of lack of resources” ([Rangaswamy and Sambasivan, 2011](#_ENREF_47)). A comprehensive and evocative rendering of what jugaad means in its multiple facets is provided by Pavan Varma[[4]](#footnote-4):

There is an Indian expression and, like others, is quite impossible to adequately translate: jugaad. People are encouraged to use some jugaad when faced with a blank wall, or a difficult situation. Jugaad is creative improvisation, a tool to somehow find a solution, ingenuity, a refusal to accept defeat, initiative, quick thinking, cunning, resolve and all of the above([Varma, 2004](#_ENREF_54)).

The diversity and the richness are evident in the different ways jugaad is translated, interpreted and used.

**Two extremes of looking at jugaad**

One strain of discussion on jugaad ([Purie, 2010b](#_ENREF_45), [Datta, 2010](#_ENREF_13), [Giridharadas, 2010](#_ENREF_15)), particularly in the popular media has an evidently feel good and celebratory air about it. The popular news magazine *India Today*, for instance, notes in the editorial of a special issue on innovation that, “The best translation of that word is a combination of innovation and enterprise (…) *Jugaad* to Indians was both instinct and inspiration. The drive for a better way out, after all, is in India’s bloodstream” ([Purie, 2010b](#_ENREF_45)). This celebratory slant notwithstanding, it is evident that jugaad in such publications is dealt with only in a perfunctory manner. The *India Today* special issue, for instance, profiles 20 innovators and innovations that range across diverse fields such as traditional pottery, modern medicine in the time of the swine flu epidemic and the development of a pedal power driven machine for washing clothes. Jugaad, however, does not appear anywhere in any of the detailed accounts of these innovations.

On the other end of this spectrum jugaad encounters much skepticism and even serious denial ([Datta, 2010](#_ENREF_13), [Krishnan, 2010](#_ENREF_24), [Munshi, 2009](#_ENREF_36), [Prahalad and Mashelkar, 2010a](#_ENREF_42)). An extreme illustration of this is the recent, wide ranging and damning account by Birtchnell ([2011](#_ENREF_6)) where he notes that “jugaad impacts on society in negative and undesirable ways (…) It is wholly unsuitable both as a development tool and as a business asset” (ibid. p. 357).

Krishnan ([2010](#_ENREF_24)), notes on similar lines that “India remains stuck in a more unscientific paradigm of innovation, often labeled as jugaad” (ibid, p. 170) and that the journey that needs to be made is clearly one away from jugaad and towards ‘systematic innovation’.

Prahalad and Mashelkar ([2010a](#_ENREF_42)), too dismiss jugaad because “the term (…) has the connotation of compromising on quality”. They prefer to use the term ‘Gandhian Innovation’ for examples such as the development of the ‘Nano’, the world’s cheapest car available at a price of US$ 2000 or the development of a super computer by an Indian firm at a cost of US $ 20 million.

The position these authors have on jugaad is evident and yet there are two elements that, though unstated, stand out in almost all these narratives. Firstly, there is little if any empirical engagement with the concept– we have no details of the examples of jugaad that the authors have chosen to dismiss with emphasis. Second, and this is of particular relevance here, there is no discussion at all of jugaad in relation to research and development in the science & technology enterprise of the country.

If jugaad is indeed inferior, unsystematic and a compromise on quality as noted above, it is not a surprise that it has no place in discussion about formal S&T in the mainstream; S&T research is, after all, the holy grail of innovation, creativity and progress. It is a significant paradox then, that the genesis of this article lies in my empirical work that provides evidence to the contrary - jugaad, as I found out and the subsequent narrative will illustrate, appears to be alive and kicking in the modern scientific laboratory, the scientific method and where there is no compromise on the quality of the output either. Importantly, and in line with a fundamental tenet of STS research, I am not using jugaad here to describe and characterize what I, as a researcher, saw in the laboratory; it was a term and an idea that Dharmadhikari, the principal scientist I was interacting with, used himself.

**The best known examples of jugaad**

Perhaps, the best known product identified with jugaad is an automobile found across northern and western India that is created using a non-standardized manufacturing process, is not registered with the relevant authorities, does not exist within any formal legal framework and was banned recently by an order of the Supreme Court of India (???). Every such vehicle differs from the other and the only thing that binds them together is the fact that they are fabricated locally and by assembling different parts, commonly from other scrapped vehicles - engines, tyres, wooden planks, steering wheels, seats and even water pumps. They are even called differently in different parts of the country – Jugaad ([Jolly, 2009](#_ENREF_21)) and Maruta ([Purie, 2010a](#_ENREF_44)) in parts of northern India and Chakda in certain regions of western India ([Varma, 2004](#_ENREF_54)). The automobile so created is, generally, a locally crafted solution to an immediate problem such as a bottleneck in transporting agricultural produce to the nearest *mandi* (whole sale market for farm produce) or to transport people in a landscape of limited connectivity and mobility choices.

Another well documented though less prevalent form of jugaad is the use of an existing artifact for purposes completely different from what is was originally created for – “materials put to uses few could have imagined” ([Philip et al., 2012](#_ENREF_40)). The best known example of this is again found in parts of north India where washing machines are used to prepare *lassi*, the popular local drink made from churning curd, sugar and water at high speeds.

Evidently this jugaad is a locally crafted solution to an immediate problem and often a personalized survival tactic in situations of obvious resource constraints and/or denial ([Varma, 2004](#_ENREF_54), [Rangaswamy and Sambasivan, 2011](#_ENREF_47)). The jugaad that we are talking about here also involves a very prominent element of reconfigured materiality. This, in particular, is what I am calling ‘technological jugaad’ – a conceptual category that deals centrally with technical and technological artifacts and where reconfiguring materiality to bestow new meaning and create new uses is one of its most important characteristics.

**Technological jugaad and the STM**

It is this concept of technological jugaad that I saw operating prominently in Dharmadhikari’s laboratory and his STM enterprise of more than two decades as is illustrated in the set of three quotes that follow:

Like some of the piezos we used from (…) the older models of ink jet printers. Jugaad is something like the spectrometer we used for the tunneling and photon microscopy - we got it from junk, repaired it, improvised and used it. (…) I used to go to juna bazaar [junk market] and find out how much is the resolution of stepper motors (…) To develop techniques to measure how many steps it goes, (…) I think, is jugaad because you find one technique, you use another one, (…) plug them together and once you do it, you have all the technology that they already invented – for something else” (Dharmadhikari, Interview, March 2011).

“There was a huge magnet and I got a bobbin – a plastic bobbin from a tailor and we had a coil on that. That coil was put in a magnet and we hammered it with a wooden hammer. Then we looked at the resonance frequency – simple technique (…). Now with (…) the latest vibration system we are getting the same resonance frequency after 20 years (…) Then we developed one [STM] in a fridge. I had a student from the Middle East and when he was leaving (…) he gave it to me. So we removed the compressor and it was a good acoustic shell (…) It’s a totally new concept – it was used for nanotechnology” (Dharmadhikari, Presentation[[5]](#endnote-1), March 2011).

“To protect the STM from acoustic noise, the total system is encased in a fridge-case (from which compressor was removed), since the fridge case has [a] metal frame which shields the STM from high frequency noise. [The] body has glass wool insulation which protects the STM from acoustic noise. It was found that the acoustic signal inside the fridge is less than 2dB”([Iyyer, 2006](#_ENREF_20)).

Discarded refrigerators ([Iyyer, 2006](#_ENREF_20)), stepper motors from junked computers, tubes from car tyres ([Datar, 2004](#_ENREF_11), [Patil, 2002](#_ENREF_39)), bungee chords ([Patil, 2002](#_ENREF_39)), viton rubber tubing ([Dey, 2010](#_ENREF_14)), weights from the grocers’ shop, alluminium vessels generally used in the kitchen and bobbins from sewing machines were only some of the components that went into the making of the first prototype and the other probe microscopes that followed.

The parallel with the examples of jugaad from outside the laboratory is immediately evident – existing materials and artifacts used in completely new ways and/or combined with each other to construct and operationalise a new idea or concept.

The another important dimension to this instrument building was the collaboration that was struck up with a number of other ‘unexpected’ players. This included, among others, a small time entrepreneur with a spark erosion machine, a road side workshop for alluminium sand dye casting and the procurement of springs from a workshop owner who could not be explained the spring constant, but could deliver the needful based on the Dharmadhikari’s explanation of the requirements and tacit knowledge embedded in his fingers. In another marginal case, Dharmadhikari even enrolled the traditional plating technique of *kalai*, the practitioners of which travel from house to house in rural and urban areas offering tin plating services to housewives for their copper and brass utensils.

**Critiques, questions & answers**

Discussions with Dharmadhikari, with a set of scientists that either know him or his work and a perusal of wider literature on S&T in the context of Dharmadhikari’s instrument building threw up many interesting and challenging critiques and questions. Some of these were of a very general nature, others were very specific to Dharmadhikari, his style of working and the instruments he and his students made.

**The commercialization question**

One of the most consistent critiques of Dharmadhikari were related neither to the quality of his instruments nor the (jugaad) way he made them, but the fact that he never tried to commercialise them. ‘If these were such good instruments and they were producing good results why did he not take them to the market?’ was a constant refrain.

This is strong reflection on a prominent paradigm of thinking today that believes it not innovation if money is not made and if benefits are not accrued at the earliest: “A nation’s ability to convert knowledge into wealth and social good through the process of innovation will determine its future” ([Mashelkar, 2011](#_ENREF_29)); “If an idea of technology cannot be successfully commercialized, it’s not an innovation” (Bob McDonald, CEO of Procter and Gamble quoted in Radjou et. al. ([2012](#_ENREF_46))) and “The translation of an invention or discovery into a commercial application unlocks its value, and it is this combination of invention and application that is innovation” ([Krishnan, 2010](#_ENREF_24)) are the truisms of today. All discussions on innovation are pivoted around these axioms these days.

The frameworks of evaluation appear very Schumpeterian in how innovation is defined, operationalize and evaluated. According to John E. Elliot “The strategic stimulus to economic development in Schumpeter’s analysis is ***innovation,***defined as the commercial or industrial application of something new ([Schumpeter, 2012 (1983, 1934), Intro., p. xix (emphasis added)](#_ENREF_51))[[6]](#footnote-5). This is important. While there is nothing wrong with the framework itself, the question might be about it’s appropriateness in this context. The Schumpeterian engagements with entrepreneurship and a certain mode of economic and industrial production are sought to be imposed on a completely different human endeavor without in any way factoring those imperatives. Forcing the question of commerce and the market on a scientist or a researcher who has no claims to or interest in entrepreneurship is akin to asking a mass produced product like a shoe or a television set why it is not differentiated from the other and does not have an unique individual aesthetic? Or more crudely why a mango does not smell and taste like an apple? The limitation lies in the frame of the innovation discourse and the question, therefore, needs to be asked of this framework as well, and not just of the scientist or the scientific enterprise.

**Changing the terms of the conversation**

In their own way, Dharmadhikari and his students did exactly that when the commercialization question was posed to them. Is it not that they are not aware of or were not engaged with the commercialization question themselves. Anything but that. Their experiences and responses were, in fact, very alive and sensitive to many other dimensions, including the one of commercial viability.

The practicality and viability of possible commercialization initiatives was put into sharp perspective by Shivprasad Patil who made an Atomic Force Microscope as part of his doctoral work under Dharmadhikari’s supervision and currently heads the Nano Mechanics Lab at the Indian Institute of Science Education and Research, Pune:

In India it is rather difficult to (…) spin off companies like what they do in western countries (…) The reasons are many and just not because of the funding or because of our structure (…) For instance, if you look at mobile phones - there is a huge market (…). But suppose I want to make an AFM and sell it there is no huge market for such things (…) You [also] have to have the support system in universities itself - incubation and other things and these things don’t happen in India as much as they happen in the western world” (Patil, Interview, 2011).

The reality on the ground is surely far more complex than it is made out to be.

While Dharmadhikari too acknowledged that the commercialization idea was considered, his primary response was simpler and more direct as the three short quotes below effectively illustrate:

…“We never thought of it [commercialization]. We were so busy in publishing papers (…) doing science and I think the best way to test your instrument is to use it for (…) doing good science”…

…“At the same time I realized that doing your (…) on experimentation is always interesting – more interesting more challenging. [There is] less throughput, of course (..) but in universities this is a better approach because you are training the students.”…

…“I realized that if I can make simple ones [instruments] through the students, not only [will] we learn a lot about these techniques, (…) but we were also creating future generations which [was] proven later because most of the students got jobs in [the field of] nanoscience.” (Dharmadhikari, Interview, ???)

This commercialization question, interestingly, was being dealt with by changing the terms of the conversation – “doing science” and “training the student” were at least as important as thinking about the possibilities of commercialization.

**A pedagogic tool**

The training of students perspective, in fact, fits in very well with the considerable discussion that exists in literature on instrument making and doing things oneself as a pedagogic tool ([Kaiser, 2005](#_ENREF_22), [Mody, 2004](#_ENREF_30), [Rasmussen, 1997](#_ENREF_48)), including for the specific case of probe microscopy in the USA ([Mody, 2005](#_ENREF_31), [Mody, 2004](#_ENREF_30)).

The value of this training and opportunity for hands-on-work was, in fact, most strongly articulated by many of Dharmadhikari’s students themselves. This is what Patil had to say:

“One thing that people blame you for is reinventing the wheel (…) I don’t buy this argument at all because a lot of the people think that if I have a commercial AFM then I can work with it. Why develop one? There are various reasons why you should build your own thing (…). If you have [an] AFM [from] the market, your ability of asking the question is itself limited because (…) [of] what a given instrument is able to do (…). No vendor, no one in the world, no company in the world is going to customize for your needs and if they do they will charge you so heavily, you can’t imagine (…) If (…) right from your PhD you are building your equipment there is (…) this freedom, this kind of sublimeness (…). It liberates you (…). The moment you buy one or two crores worth of equipment you are stuck (…) Your mind is tied to it – to the instrument. You do only what that instrument allows you to. [You] are scared to use it to its fullest capacity. (…) [What are] artifacts, what is true information, what is the false signal – those things– you know much better if you build your own stuff. People say you are reinventing wheel [but] is not so, because it is really helpful at that time.”

The training in and experience of doing things one self and the confidence that this helped him gain, held Patil in good stead between 2003 and 2007 when he was a post-doctoral fellow, first at Wayne State University in the USA and then at the Madrid Microelectronic Institute, Spanish National Research Council (IMM, CSIC) in Madrid, Spain. The benefits continue even today as he himself gets into more senior leadership positions and takes his training into his teaching as well.

This is also directly related to one of the main challenges that scientists and science administrators all around the world are beginning to face and articulate – two prominent examples being David W. Piston, Director of the Biophotonics Institute of the Vanderbilt University School of Medicine, USA, and P. Balaram, Director Indian Institute of Science (IISc), Bangalore and also editor *Current Science.* In a short comment in *Nature,* [Piston (2012, p. 440-441](#_ENREF_41)) notes how “over-reliance on automated tools is hurting science”, that there is a “need to do a better job of teaching students how techniques work before they start using them,” and also that “the research community must take more responsibility for teaching the coming generations (…) how to build, implement and troubleshoot their own experiments at the most basic level.” Agreeing with Piston’s observations, Balaram ([2012a, p. 1241-1242](#_ENREF_1)) rues the absence in India of “trained technicians with a high level of competence in operating and maintaining facilities”. He points out that as a consequence “major facilities are sub-optimally used and sophisticated instruments are rarely exploited to their full potential.” In a subsequent editorial ([Balaram, 2012b, p. 1383-1384](#_ENREF_2)), he notes further that, “many new institutions that are being created find it easier to acquire equipment than to recruit faculty (…). As Indian laboratories in academic institutions accumulate the increasingly expensive tools and technologies of science, it may be important to re- member that tools are only as good as the workmen who handle them.” This, one may argue, is precisely the kind of challenge that Dharmadhikari’s way of doing science and training students is capable of taking up.

**Characterising technological jugaad; then comparing**

The argument made so far is that jugaad in general and technological jugaad in particular is innovation that is socially, culturally and economically embedded, even as it engages with the more general concerns and considerations such as those related to commercialization and of it’s pedagogic value. The milieu in which innovation and technological development is located influences practices and ways of knowing which, as the STM example explicates, allows and even encourages reconfiguring of material objects in varied, though co-existing worlds. The junk market, then, becomes as important a resource for economic survival in rural India as it is for cutting edge science in the modern physics laboratory.

Keeping this is mind and based on the detailed discussion and extended inferences drawn from the same, I first present in this chapter an initial characterization of the technological jugaad that I have tried to illustrate and also conceptualise thus far. This is then followed by a discussion that compares and contrasts technological jugaad to ‘cultures of innovation’ from other parts of the world - regularly used concepts such as user-driven innovation and bricolage and relatively lesser known ones such as the re-assembled cars in Taiwan.

**Characterising technological jugaad**

Technological jugaad can be accounted for by seven characteristics that I present here mainly as signposts; pointers that can initiate further empirical research, help in gaining information and insights and also promote further discussion:

**Reconfiguring materiality**: One of the cornerstones of technological jugaad we have seen, be it the automobile in rural North India or the STM in a modern physics lab - is the reconfiguration of materiality – giving new meaning to old objects (old refrigerators, discarded computers, sewing machine bobbins) and finding uses that they were not initially created for.

**Problem solving**: Technological jugaad mainly involves finding a solution to an immediate problem. The immediacy of the problem is often linked to economic survival. It may not be exactly the same in a physics laboratory, but can still be understood as an explicit manifestation of the imperative of continued existence. In that sense, then, it is different from invention or an activity of leisure such as pursuing a hobby.

**Driven by resource constraints**: One of the key conditions driving technological jugaad is resource constraint or denial. There is, therefore, no option but to find new meanings and uses for existing objects – a direct linkage to the first characteristic of reconfiguring materiality just as it is linked to the last one of – ‘a culture of recycling’.

**Bridging knowledge systems and ways of knowing:** This paradigm of innovation, as we have seen particularly in the case of the physics lab, embodies an inter-disciplinarity. There is an awareness of what is happening elsewhere and both the capacity and the willingness to bring in ways of doing things that are located outside and, therefore, not considered part of the system.

**Legally grey**: The production process as well as the final object created, like in the case of the jugaad automobile, might lie outside the existing legal framework – an area that is grey as far as the law is concerned.

**Not (intended) for commercialization**: Available evidence, albeit limited, suggests technological jugaad does not have much success in upscaling and commercialisation. Commercialization, in fact, is not the primary intention of jugaad, though there is no reason why it should not become successful commercially. In the first instance, however, it lies outside the broad framework of the market place.

**A culture of recycling**: There is a way of looking at waste; a culture of recycling that is central to the jugaad enterprise. This is linked to conditions of a society where resources are scarce and access is limited. One has to be make the best of what is available and this is also linked to formal and informal systems where waste, scrap and junk are indeed available for reuse.

Evidently, many of these characteristics are integrally and inextricably linked to each other. Established categories get disrupted in the process because there is no more a universal entity or quality called waste. It is contextual, even cultural as it helps re-engage with the idea of looking at waste as a misplaced resource ([Venkateswaran, 1994](#_ENREF_55), [GTZ, 2000](#_ENREF_18), [Gregson and Crang, 2010](#_ENREF_17)). The inter-associations are constantly dynamic and interdependent as they flow simultaneously in multiple dimensions – sometimes in parallel and sometimes in outright opposition even as they continue to intersect and weave their way through. Does a culture of recycling, for instance, allow for reconfiguring materials and giving them new meaning? Is it a situation of serious resource constraint that forces a culture of recycling or then, or is it because people are embedded in and constitute multiple systems of doing and knowing that they are able to find relevance and new uses for objects and systems discarded as waste or obsolete? The cause – effect relationship is not a clear one at all and studying different situations might reveal the existence and operation of many different, though subtly tuned permutations and options.

It would also be relevant to reiterate here, particularly in the context of jugaad happening outside the laboratory, that a large section of India’s population lives in poverty and with seriously limited access to financial and material resources. Even more, a major chunk of the economic activity and employment is to be found in the informal sector ([Varma, 2004](#_ENREF_54), [Kapila, 2010](#_ENREF_23)), where there is no social security neither any security related to employment or work ([Kapila, 2010](#_ENREF_23)). It is this context of resource deprivation or denial that jugaad forms a bulwark of the livelihood and survival support system of millions, a value that seems lost of a number of critics who, as we have seen already, summarily dismiss jugaad on various counts. Technological jugaad might not perform precisely the same function inside a modern laboratory, but it is, undeniably, a part of the same continuum.

Significantly, the technological jugaad that I have just presented is not a stand alone, unique way of doing things that is confined only to a certain geography of India. The possibility, presence, and the spread of this can be inferred from the fact that different geographies around the world have, simultaneously, similar physical, cultural, social, economic and political conditions on the one hand and unique cultures, languages and ways of doing on the other.

**The reassembled cars of Taiwan**

The first one I pick up bears a striking resemblance to the jugaad automobile of North India. These are the ‘reassembled cars’ of Taiwan ([Lin, 2009](#_ENREF_28)) with names such as ‘iron cattle’, ‘siqizai’ or ‘laqizai’ given to them by local communities:

“Iron cattle” refer to reassembled cars that use single-cylinder motive power such as a water pump, a cultivator prow, or a motorcycle engine. “Siqizai” refers to reassembled cars that use four-cylinder engines; “laqizai” refers to six-cylinder engines ([ibid, footnote, p. 93](#_ENREF_28)).

Like in the case of jugaad in India, ‘reassembled’ in Taiwan also has a negative social connotation – often meaning “unprofessional, unsafe or insecure” ([ibid, p. 92](#_ENREF_28)) and Lin notes that the government along with the media worked together to put in place policies and to create an environment that would allow for “tightening controls of old cars and implementing strict inspection to weed out unqualified ones” ([ibid, p. 105](#_ENREF_28)).

It was part of an explicit strategy of stigmatizing and regulating ‘reassembled cars’ to allow the auto-industry a foothold in the market at a time when it was floundering in the 1950s and 60s. The negative image and repeated government clampdowns notwithstanding, the reassembled cars in Taiwan survived. In some cases they were even procured by government agencies like the police and local land offices and proved to be particularly useful in providing relief in disaster situations and also for transportation of farm produce.

Lin notes that the ‘reassembled cars’ were, if fact, automobiles with many advantages which included among others, “their safety, low prices, and flexibility in production and use, thanks to the collaborated network consisting of salvage yards and reassembled car makers” ([ibid, p. 91](#_ENREF_28)). In an insightful comment on safety and quality, Lin quotes figures to show that the accident rate for reassembled cars that were considered unsafe in the general perception was, in fact, much lower than that for mass-manufactured automobiles. The latter being built for a particular system of transport with high speed being one of the priorities were made of thinner and lighter steel and where casualties were high when a crash did occur. These vehicles were, similarly, very unstable and unsafe when used in mountainous regions.

The inference therefore is that quality parameters cannot be universalized and have to be looked at in the specific context they operate. Where are they being used, for what purpose and by whom? Exactly the same would apply in the case of jugaad and the same question needs to be asked of those who make a generalized statement that jugaad means poor quality. For [Prahalad and Mashelkar (2010b](#_ENREF_43)) jugaad is “compromised quality”; for Dharmadhikari the use of jugaad helped deliver outputs that were at par with some of the best in the world an acceptable in prominent peer reviewed scientific journals. This would certainly not have been if it was poor or compromised quality. This is also not to say that all jugaad is always of great quality (whatever that might be), but to note that something cannot be dismissed as bad quality or unsafe just because it is jugaad.

**Bricolage and user-driven innovations**

Jugaad also finds resonance in the French idea of ‘bricolage’ ([Levi-Strauss, 1962 (Translated 1966)](#_ENREF_26)), where the bricoleur “is (…) someone who works with his hands and uses devious means compared to that of the craftsman (…) is adept at performing a large number of diverse tasks” and where the “bricoleur has no precise equivalent in English (…). [He] is a man who undertakes odd jobs and is a Jack of all trades”. Bricolage is made up of “elements [that] are collected or retained on the principle that ‘they may always come handy’” and where none of the elements has just “one definite and determinate use” ([ibid, p. 16-18](#_ENREF_27)).

There is an uncanny likeness between bricolage and jugaad and in some cases authors have even used the words interchangeably. Birtchnell ([2011, p. 358](#_ENREF_6)) calls the jugaad vehicle, “a bricolage vehicle”, while in the Hindi translation of the abstract of a paper on science education in a small village in rural India ([Sharma, 2008](#_ENREF_52)), the translator who is a noted Hindi educationist himself, uses the word jugaad as a literal translation for bricolage in the original text.

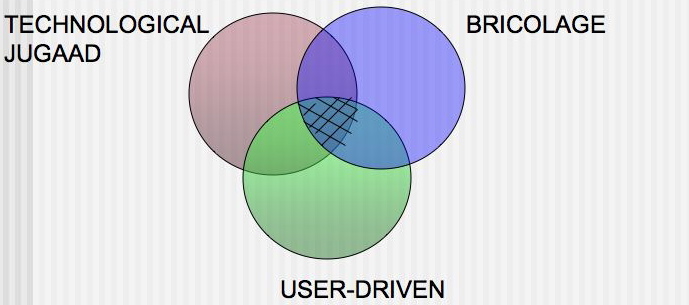
The examples of technological jugaad that have been discussed also appear to have a prominent overlap with the now well established idea of ‘user – driven’ innovation ([von-Hippel, 2006](#_ENREF_57), [von-Hippel, 1988](#_ENREF_56)). In a study of the development in the west of scientific instruments across four instrument families – the gas chromatograph, nuclear magnetic resonance spectrometer, ultraviolet spectrophotometer and the transmission electron microscope - von Hippel found that nearly 80% of this development had been done by the users, the scientists themselves ([von-Hippel, 1988](#_ENREF_56)). The story of jugaad and of the development of the ‘home made’ STM in India then becomes even more interesting. The outcome (development of the instrument) may have been the same, but was the route followed similar to the one followed in the Indian case? What were the kinds of materials used in the creation of the instruments? Where were they sourced from? At what cost, if any?

Valuable insights can be gleaned in this context from Cyrus Mody’s engaging account of the commercialization of scanning probe microscopy (that includes both STMs and AFMs) ([Mody, 2006](#_ENREF_32)). He notes the prominent role of commercial sources that early STM builders accessed to get components such as “vacuum chambers, piezoelectric crystals, [and] video output device” ([ibid, pp. 62-63](#_ENREF_32)). He also notes that in other instances there was a “whimsicality (…) accompanied by bricolage in instrument building, [where STM] probes [were made] from pencil – leads [and] (…) AFM tips from hand-crushed, pawn-shop diamonds glued to tinfoil cantilevers with brushes made from their [researcher’s] own eyebrow hairs” ([ibid, p. 66](#_ENREF_32)). It could well have been an account of what happened in Dharmadhikari’s lab, only the specific artifacts were different.

**Finding a middle space for innovation cultures**

Jugaad, siqizai, bricolage, user-driven innovation,– four terms from for different languages, cultures and histories that span the entire globe – yet there is something that ties them together. Problems are solved, new ideas are generated and innovation happens in all these frameworks – in that sense one is like the other. At the same time however, they happen differently - de-centered both, in space and in action – in what [Wyatt and Balmer (2007, p. 622](#_ENREF_58)) refer to as “the place between theories, between audiences, between levels”, as also “a way of making connections across time, discipline, community and place.” While the respective forms of innovation are de-centred, the overarching **culture** (innovating, problem solving, finding solutions) of these ‘cultures of innovation’ can be located in the middle.

It is in the process of studying, analyzing and articulating these different ‘cultures of innovation’; through this mangle of an ethnographer’s practice, that a middle ground of new patterns and possibilities seems to emerge. This is what I try to make visible through the ‘Venn Diagram of the ‘De-centred Cultures of innovation’’ that appears below.



The diagram does many things at the same time. It provides a simultaneous view of the (possibilities of) commonalities just as it illustrates the existence of obvious differences. We realize that there are characteristics that are common to two that are either absent in the third or present only marginally. On one parameter, two of these cultures will show a complete overlap, while on another the two will have nothing in common. In other situations there might be varying levels of engagement and expression and in another, one would have such a distinctly different characteristic that there may be nothing at all in mutual with the others.

Jugaad and bricolage, for instance, are different in that they come from different languages, are based in different geographies and in the set of people of who use them. If use of devious means was, however, the parameter for evaluation, bricolage and jugaad (of which technological jugaad is a derivative) are highly sympatric. User-driven, similarly, is what a lot of technological jugaad is about, but those involved in technological jugaad are not von Hippel’s “lead users”, those “ahead of the rest with respect to a related and important market trend” ([von-Hippel, 2006, p. 4](#_ENREF_57)). Whether it is the maker of the reconfigured automobile in rural north India or the STM inside the laboratory, those doing jugaad are more often than not, trying only to ‘catch up’.

While a shortage of resources might drive all three forms of innovation, technological jugaad would stand out for its use as a survival strategy in situations of extreme poverty and deprivation. And then there is the difference of the acceptance and use in the academic and other worlds of these terms itself. Bricolage and user-driven innovation are well established and accepted; jugaad on the other hand evokes mixed feelings and technological jugaad is not even part of the discussion yet. There are indeed a number of permutations and combination possible on the nature of similarities, differences and overlaps. The idea is also not to create a detailed inventory of all the combinations but just illustrate the nature of all that could be possible.

There is the one space in the diagram then that we are finally left with. This is the central triangle where the three intersect and where characteristics of all three match up. The most obvious example of this is ‘problem solving’, which all three are centrally about and which is what all innovation is about in any case. A claim can also be made that, often, re-configured materiality features in all three. We have seen that it is a central characteristic of technological jugaad and the overlap is visible when Mody ([2004](#_ENREF_30)) refers to the making of probe microscopes by the users in American labs as a process of bricolage (discussed above). This then is the middle ground – that which the ethnographer’s work has brought into being. Here a new pattern emerges that illustrates, and in a paradoxical move, locates innovation in it’s specific context and at the same time unifies that what is de-centered.

This middle space works both ways – it draws attention to what is common to the three circles by highlighting their fundamental de-centeredness; at the same time in showing that there is a common ground, it emphasizes that there is much that is different. This clears up the messiness which then which works iteratively to highlight multiplicity, diversity and locality – the very characteristics that were responsible for the creation of the messiness in the first place. What this suggests, more importantly, is that can be no central cannon of innovation, that one form of innovation is not necessarily better than another, that context decides relevance and the nature of the innovation practice.

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1. This article is a substantially extended and worked upon version of Sekhsaria (2013) ??? [↑](#footnote-ref-1)
2. The other half of the prize was awarded to Professor Ernst Ruska for his fundamental work in electron optics, and for the design of the first electron microscope [↑](#footnote-ref-2)
3. He is presently visiting faculty at the Indian Institute Scientific Education and Research (IISER), Pune [↑](#footnote-ref-3)
4. I would like to thank Rishikesha Krishnan to draw my attention to this work by Pavan Verma. It is striking to note that Varma’s exposition of jugaad appears not in the ‘Technology’ chapter in his book, but the chapter titled ‘Wealth’. The ‘Technology’ chapter deals only with India’s much discussed Information Technology (IT) sector. [↑](#footnote-ref-4)
5. [↑](#endnote-ref-1)
6. For Schumpeter innovation was “the carrying out of new combinations” broadly understood: “(1) The introduction of a new good-that is one with consumers are not yet familiar – or of a new quality of a god. (2) The introduction of a new method of production, that one not yet tested by experience in the branch of manufacture concerned, which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially, (3) The opening of a new market, that is a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before. (4) The conquest of a new source of supply of raw materials or half-manufactured goods, again irrespective of whether this source already exists or whether it has first to be created. (5) The carrying out of the new organization of any industry, like the creation of a monopoly position (for example through trustification) or the breaking up of a monopoly position. (Schumpeter, 2012 (1983, 1934), p. 6). [↑](#footnote-ref-5)