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The materiality of knowledge production

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Abstract
The following paper is based upon fifteen months of participatory ethnographic fieldwork within an NGO in Rajasthan, India. Based within a solar photovoltaic workshop for the production of lanterns and the training of 'solar engineers', the author reflects upon the different kinds of knowledges generated in the workshop and how they are constituted through particular kinds of material artefacts and approaches to learning. Drawing upon an 'after actor-network' approach to knowledge production the author explores the emergent and contingent character of knowledge performed. When knowledge is imagined as fluid like, as something that flows and transmutes with more or less viscosity (Mol and Law 1994), we are perhaps in a better position to conceive of its transformative and generative potential.

Keywords
Knowledge production, materiality, skills, learning, actor-networks

Introduction

The following paper has two principal aims. Firstly, I discuss a particular approach to social theory known as actor-network theory (ANT) which stresses the agency of nonhumans in the heterogeneous assemblages of human-material interaction. I contrast this with an 'after' actor-network theory approach whereby interactions are characterised less by networked assemblages, and more by a fluidity of movement within relational space that more accurately reflects the oftentimes arbitrary and capricious forms of knowledge production. Secondly, with this theoretical backdrop in place, I outline the workings of a knowledge transfer project centred within the solar

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programme of an NGO in Rajasthan, India. I use this to reflect upon how certain kinds of knowledge are learned and expressed through different kinds of material assemblage. Drawing upon Law and Mol's (2001) metaphor of *fluid space*, I explore the emergent and contingent character of knowledge performed in the solar workshop. Knowledge in this sense adheres less to a functioning network topology as advanced by typical accounts of actor-network theory (see Latour 1987; 1993; Callon 1986; Law 1992), and more to a bricolage like performance of fluid knowledge-making; the form of knowledge that emerges being contingent upon the actor-configurations through which it is expressed. Terms such as abstract and situated, then, refer not to different kinds of knowledge, but rather to different kinds of practice.

Networks of development?

In recent years, the anthropology of development has witnessed a growing interest in the material-semiotic theories of what has come to be known, for better or worse, as *actor-network theory*. Actor-network theory, or 'ANT', is most closely associated with the various writings of the French theorists Bruno Latour (1986; 1988; 1992; 1993; 1996; 2005) and Michel Callon (1986; 1987; 1999), and the English sociologist John Law (1986; 1988; 1992; 1994; 2001). It is principally derived from Science and Technology Studies (STS) and conceptualises all social phenomena in terms of networks of 'actors' both material and human. The distinctive approach of ANT is to collapse typical ontological distinctions and traditional sociological dualisms of nature/society; agency/structure; human/material by drawing attention to their interlinked domains and the inherently heterogeneous networks of entities that comprise them. Thus, through a process of 'following the actors' at the micro-level, ANT can be seen to be levelling the ontological landscape, producing accounts of networks as they are performed in moments of practice. ANT, despite the name, designates not a theory, but rather a method of describing the *how*, rather than the *why*; *how* assemblages hold their shape, or *how* they fall apart. John Law (2007) characterises it as providing a 'toolkit' for telling interesting stories, as such it is descriptive rather than explanatory, paying no heed to truth claims, only outcomes.

ANT and its malcontents

Actor-network theory is a product of its time, arising from the theories of French post-structuralism in the late 1970s and early 1980s through its focus on material-semiotics and critiques of essentialisms and binary oppositions. This was combined with an attention to the work of Science and Technology Studies (STS) and their empirical studies of large technical systems (see Hughes 1983). These studies of large-scale technical systems entailed the crossing of multiple ontological borders, from the natural world to the affordances of technical objects and designs. STS itself drew upon the sociology of scientific knowledge (SSK) in particular the 'strong programme' of the 'Edinburgh School' and its assertion of the 'symmetry' of knowledge claims. This postulate holds that all scientific knowledge claims whether treated as 'true' or 'false' be treated the same way; that is, as derived from and produced through social circumstances. ANT however distinguished itself from other forms of sociotechnical network approaches by according equal agency to non-humans.

The principle of symmetry was extended to what has come to be one of ANT's most infamous concepts, that of 'generalised symmetry'. Generalised symmetry holds that all actors, whether human or material, be treated in the same way, with humans accorded no special attribute of agency; rather, agency is generated through the network of relations itself and is not presupposed. Such a position, philosophically radical as it is, is derived from empirical studies of laboratories and research centres, of 'science in the making', that observed the equal importance that humans, texts and objects play in the construction of actor-networks (Cressman 2009:4).

This last point has proved to be the most difficult for supporters and critics alike to accept as it grants equal status to non-humans in the functioning of an actor-network. What it does not do however, despite claims to the contrary (e.g. Golinski 1998), is grant agency to objects, but then neither does it grant agency to humans: "Purposeful action and intentionality may not be properties of objects, but they are not properties of humans either. They are the properties of institutions, of apparatuses, of what Foucault called dispositifs" (Latour 1999:192). What Latour is referring to is the inherently distributive character of all actions, whether of human or non-human origin. The ability of a human to 'act' is enabled through distributed chains of countless others, many of which are rarely perceived let alone acknowledged. It is through our enmeshment in these fibrous networks, Latour argues, that our ability to act is made possible.

Classic ANT accounts of human-material assemblages of the kind outlined above, have been somewhat superseded in recent years by an *after* actor-network theory approach (1999) that dispenses with an all-embracing network modality and instead embraces *spatial formations.* In their various inquiries Law and Mol (see Mol and Law 1994; Law and Mol 2001; Laet and Mol 2001) have perhaps been exemplary in this regard in shaping this new understanding of networks as *fluid* like. Thus in relation to scientific findings, they argue that facts, instruments, objects and theories form particular patterns of relations when held stable within a network which implies a particular 'form of spatiality' (Law and Mol 2001:611). Mol and Law thereby create sensitivities to different formations leading to more broadened forms of spatiality that take account of the oftentimes arbitrary, fluid-like and capricious forms of relational space. Thus, when objects are described by the spatial formations through which they perform as opposed to essentialised properties of their component parts, then we are better able to appreciate how knowledge, theories and models are constructed and become durable over time, and also how they move between different locations. This conception further allows us to discuss the character of objects and alliances without giving way to an overly managerialistic (Star 1991) focus or succumbing to materialistic conceptions of objects, for as Laet and Mol (2000) note in a discussion of the spatial properties of a water-pump (discussed below), it may act as a provider of clean water, and as a community and nation builder but it does not mean that it can perform any spatiality; it is bounded by certain constraints related to its spatial formation.

In the following account I draw upon this more expanded view of human-material interaction to explore the enactment of knowledge practices within the solar programme of the Barefoot College, an NGO situated in the arid state of Rajasthan, India that I spent fifteen months in conducting ethnographic research from 2008 to 2010. The explicit aim of the solar programme is essentially knowledge transfer: to provide relevant skills training in the maintenance of solar PV devices to village women from communities across Africa which are to be installed at a later date upon their return During this time I participated within the solar programme as a 'solar trainee' learning the skills of the 'Barefoot Solar Engineer' (BSE) for six months alongside a diverse group of women from seven different countries in Africa. Language differences were played down in the workshop, with a 'learning-by-doing' approach emphasised throughout. From a research perspective this had its pros and cons. Moving one's body in the same way as my immediate participants, learning as they did, making the same errors and experiencing the same toils, frustrations and elations brought about an unprecedented level of insight. On the other hand, such a diverse group of language bearers necessarily entailed a limiting of verbal understanding and communication, the traditional form of social research conducted through interviews and conversation. I was perhaps fortunate however in this regard to be assisted by several translators during the course of my research many of whom were participants in the training themselves. This augmented the experiential side to the research underway to engender a multifaceted research process.

The Barefoot College: learning-by-doing

The Barefoot College is a renowned community based development organisation, established in 1972 in the small village of Tilonia, central Rajasthan, India. It was initially founded to help develop self-reliance and sustainability in local communities through an integrated and practical approach to development. The principle idea was to combine the knowledge of urban professionals with rural skills and traditions in order to help local people identify and address the issues affecting them in a joint venture. This collaborative, needs-based approach to development led firstly to a two-year ground-water survey of the surrounding area, constructing water hand-pumps where appropriate. Eventually, health and education programmes were established, and were later followed by rural industries and agriculture.

With its emphasis on sustainability and appropriate technologies, the centre adopted solar photovoltaics as replacements for unsafe and inefficient kerosene lamps. Initially employed in the midwifery and healthcare section, photovoltaic lamps and lanterns were gradually put into practice throughout the organisation. Over time, the centre developed competence in the maintenance and repair of the systems themselves and with external funds began solar electrifying remote communities in India, providing skills-training to community members for the system's upkeep. This mirrored a general movement within the College of moving towards a 'barefoot' training model, inspired by the Chinese healthcare workers of the 1960s who were trained in basic healthcare to assist their own communities. Eventually, the solar programme became the largest contributor to the organisation, providing much needed funds and exposure and eventually leading to the solar electrification of over five-hundred villages in ten states across India. The centre remains the first, and so far only 'campus' in India that is run solely on solar photovoltaic energy.

The solar section is by far the largest section at the College, both in size and income, and employs the most workers. It is split between the new campus and the old - the new campus housing the main administration block and a workshop, the old campus comprising the storage blocks and training centre. Both today are busy hubs of activity. In the old campus training centre, groups of women from the Least Developed Country list (LDC)[2] churn out dozens of circuits by the day; in the new campus, orders are placed, shipments arranged, and the inescapable Indian bureaucratic system attended to. During the cooler winter months, large bus parties of school children and tourists on educational visits are a common sight; independent travellers in 'local' clothing seek answers, journalists and academics seek interviews, while donors, government ministers and the odd celebrity seek to be wowed.

It was not always like this, however. The solar section emerged as a small, experimental project to solar electrify the community health centre through a donation of solar panels by a Danish development agency in 1984. Prior to this, lighting was provided, like in much of rural India, by way of kerosene lamps. Further grants and donations led to the extension of the solar programme to thirty schools in the 'night school' programme allowing children, who graze cattle and help their families during the day, to study at night under the light of solar lanterns. With a donation in 1988 of a seven kilowatt solar system, the College moved to becoming the first, and still only, 'campus' in India to be fully solar electrified. Solar power today provides forty-five kilowatts of energy, enough to run thirty computers, five-hundred tube lights, photocopying machines, a pathology lab, a dental surgery, milk booth, and radio broadcast equipment.

On-campus proficiency in solar PV and an increasingly visible national profile through the efforts of the Director, Bunker Roy, led to grants and awards from government and development agencies for the solar electrification of further villages in remote areas of Rajasthan. These small-scale projects acted largely as demonstration projects for the viability of using photovoltaics for the electrification of remote communities. Feedback from differing user experiences and environments led to continued improvements in lantern circuit design and efficiency of system use. Over the next ten years, increasing experience, improvements in design and decreasing costs led to a snowballing movement as further government grants provided funds for projects in Jammu-Kashmir, Sikkim, and Himachal Pradesh. Projects in collaboration with the United

[2] Least Developed Country (LDC) is a term given to a country, which, according to the UN, displays the lowest indicators of socioeconomic development of all countries in the world. The current criteria utilised by the UN for the identification of LDCs are: a low income criterion; a human resource weakness criterion; and an economic vulnerability criterion. http://www.un.org/special-rep/ohrlls/ldc/ldc%20criteria.htm (Accessed: 30/09/10).

Nations Development Programme (UNDP), the European Commission (as it was then), and the Asian Development Bank followed.

As the College's profile expanded and solar went mainstream, the Director stepped up his efforts as a spokesperson for the uniquely decentralised, community-centred approach to solar promoted by the College. Relationships and links were established with international NGOs, a process amplified and made easier through the then novel, yet growing, use of internet-based communication networks. The College eventually became host to participants from partner NGOs, acting as a demonstration project itself in sustainable, community led development, providing training and know-how to individuals from, among other countries: Afghanistan, Costa Rica, Uruguay, Tanzania, and Kenya.

In 2007, a Government of India representative visiting the campus, convinced of the effectiveness of the programme, recommended that the College apply for Government funding under the ITEC (International Technical Economic Cooperation) and SCAAP (Special Commonwealth African Assistance Programme) programme as an official partner in their South-South development cooperation scheme. Established in 1964, the ITEC programme aims to provide relevant skills and capacity building to approximately five thousand participants each year from partner countries in fields where India has developed expertise. Over forty-five institutes from government and private sectors offer a choice of over 200 courses, both short-term and long-term, in areas of relevance to 156 ITEC/SCAAP partner countries.

Under the ITEC scheme, the Government of India provides funds for the "software": air fares, accommodation, materials, food and training costs during the duration of foreign nationals' stay in India; partners and donors provide funds for the "hardware": photovoltaic solar home systems, including batteries, lamps, and lanterns, plus six months of spare parts and equipment necessary for a Rural Electronic Workshop (REW).

Prior to travelling to India, the communities to be solar electrified are selected by the Director of the organisation in consultation with local NGOs of the host country. Villages are chosen based upon their low socio-economic status and remoteness from central grid electrification. Women, in the 40-50 age bracket, preferably grandmothers who are either semi-literate or illiterate are favoured due to their roots in the community and unlikelihood of migrating upon their return to seek employment elsewhere; a problem previously experienced with men and young women. For the same reason, no certificates are issued upon completion of the training to further hinder movement away from the receiving community. Two women from each receiving village are selected to provide support and comfort to each other during the training and upon their return.

The first group, or 'batch', as they are termed in the Barefoot literature, of ITEC/SCAAP funded women arrived on September 15, 2008 and completed their training in March, 2009. They were thirty-four women from seven countries: Malawi, Tanzania, Ethiopia, The Gambia, Rwanda, Uganda, and Bhutan. Since this first group of trainees arrived, groups of women from the Least Developed Countries index list have arrived every six months to be trained in the repair and maintenance of solar home systems. I formally joined the second group of women to arrive for training in March, making thirty-five including myself in total: five from Djibouti, seven from Senegal, seven from Ethiopia, three from Mozambique, three from Sierra Leone, three from Mali, four from Sudan, and two from Russia[3].

Solar apprenticeship

The training begins soon after the women arrive. They are granted one or two days to settle in, get a feel for the campus, undergo a medical check-up, get tested for eye glasses, and be measured up for new clothes and footwear before commencing work.

Table 1: Sequence of training curriculum

Sequence of training curriculum	
1. Establishing a common terminology	Learning English terms for electronic colour code: colours and corresponding numbers Learning tool names
2. Calculating resistance values	Metal film resistance (M.F.R) Carbon film resistance (C.F.R)
3. Lamp circuit	Learning terms and recognising all component parts Assembling and soldering circuit Testing circuit Assembly of lamp body and wires
4. Transformer and choke coil winding	Production of which continues throughout training period
5. Lantern circuit	Assembling and soldering circuit Testing circuit Assembly of lantern body and wires
6. Charge controller circuit	Assembling and soldering circuit Testing circuit Assembly of charge controller and wires
7. Practical demonstrations and tasks (these are carried out intermittently throughout the six month training period)	Testing of deep cycle battery acid levels Connecting appliances to correct battery terminals Installing and connecting solar panels Assembling circuit board holder Testing appliances with volt-meter

The electronic colour code[4], used to indicate the resistance value of resistors and other components, is the first group of words learned. Each number from 0-9 represents a particular colour on the electronic colour code, which is marked in bands on the resistors[5] themselves. For example, black = 0, brown = 1, red = 2, orange = 3 and so on.

[3] The two Russian trainees completed their training in the Northern field centre of Ladakh, Jammu-Kashmir, in order to avoid the searing summer heat of Rajasthan.
[4] The electronic colour code is an international colour coded system used to indicate the values or ratings of electronic components. It was developed in the early 1920s by the Radio Manufacturers Association and commonly uses colour-coded bands, particularly on resistors, to indicate resistance values.
[5] A resistor is an electronic component that determines the flow of current in an electrical circuit. They are common to most electronic equipment.

The trainees must therefore not only learn a new group of words but must also make a cognitive link between certain words, certain numerals, and certain visually recognised colours. Teaching takes place through a rote-repetition style of pedagogy. The master trainer, standing at the front of the class, points to each colour on a wall chart and states the colour name in English and its corresponding value. The whole class then repeats in unison. This is repeated several times over the course of the morning. The rote repetition of colours and numbers continues throughout the first week of training with variations such as pointing to a number or colour and waiting for the correct response from the class thrown in. Each trainee is also expected to step up to the front of the class and repeat the colour and number in English. The trainees are further provided with coloured pens to copy the chart into their notebooks. Those who are illiterate seek assistance from the master trainers or are helped by fellow trainees.

The teaching of resistance values is followed by the learning of different tool names to be used by the women. Each tool that the women will use - from nose-pliers to volt meters to soldering wire - is held up in front of the class and the name repeated slowly and clearly by the master trainer. A list of all the tools is further chalked up on the board. Each trainee is encouraged to draw pictures of the various tools and write the names in their notebooks.

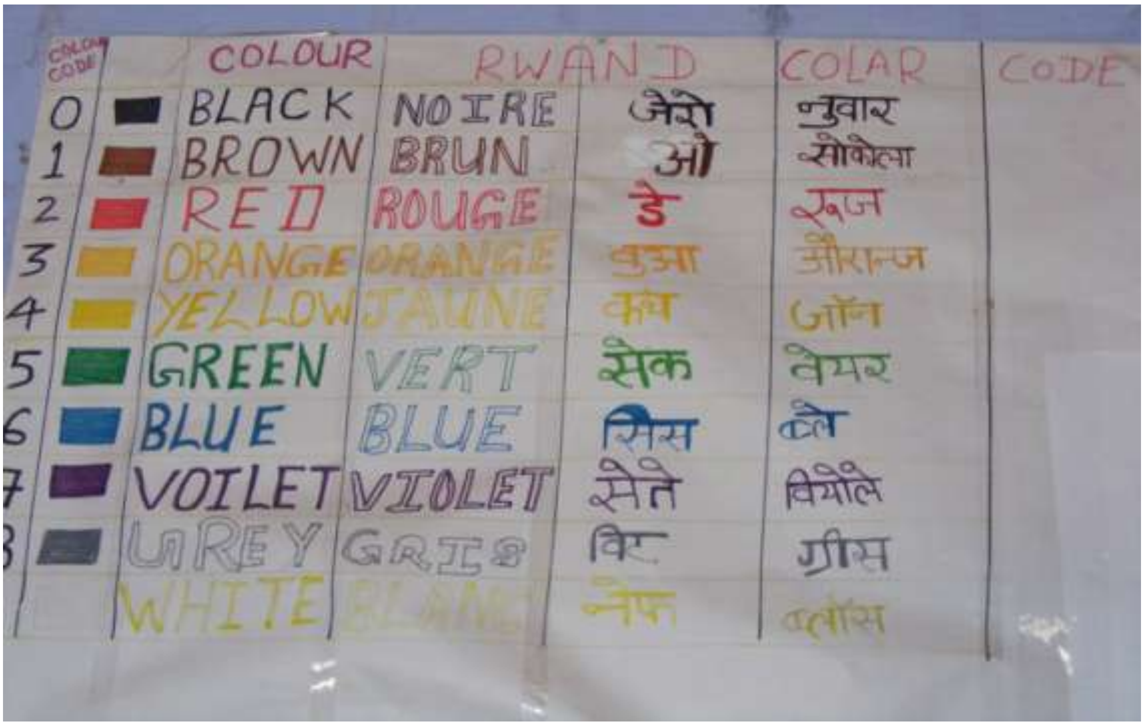

Figure 1. One of the wall charts displaying the resistance colour code in English, French and Hindi.

The naming of resistance values and tools continues for several days until everyone feels comfortable. The women are further encouraged to continue learning and memorizing in their free time. While the trainees quickly pick up the more tactile aspects of the training, such as manipulating and handling wire-strippers, sockets and lamp casings, with ease, the theoretical aspects of the training cause some confusion, not least because of the communication difficulties. Each resistor used in a circuit is marked with four bands of colour representing its resistance rating. The first two colour bands represent resistance values, the third colour band the decimal multiplier and the fourth the tolerance value.

Each group of women are given several sets of tools that they will use over the course of the following six months. In these early days, while learning the names of the tools, the women, the majority of whom have never encountered many of them before, pick them up, manipulate them, try them out and generally get a *feel* for them while learning this new terminology. Other skills learned during the first month include production of transformers and choke coils and assembling of lamp and lantern bodies. The correct use of the tools subsequently follows with their application. Each technique, such as soldering or wire-stripping, is first demonstrated by the master trainer before the trainee tries it for herself. Through the process of learning-by-doing, they quickly learn what each tool is capable of, and the particular tasks each one is suited to.

Material aids to learning

To help aid the learning and knowledge transfer process, the College introduced a solar maintenance manual in 2008. Printed in English, this manual is generously illustrated with photographs and drawings of every component, tool and piece of hardware that the trainees will use. Two manuals for each trainee have been produced; both are identical in content, listing the training process in codified form with detailed explanations for the use and maintenance of each of the main devices that the women will work on, plus a "trouble shooting" section towards the end. The only difference between the two manuals is the inclusion of blank spaces alongside each photograph and paragraph of writing for the insertion of words and summaries in the women's first language. All of the women, both literate and illiterate, had purposefully left the spaces blank so that members of their communities, upon their return, could help in the translation process. This, they stated, was not only a practical exercise in accuracy, but also a way to try and include the villagers in the process so they could better demonstrate what they had been doing while in India. The manual thus acts as an inscription device for knowledge transfer between different geographical and cultural locations.

Other devices to aid in the transfer of knowledge across language barriers include wall charts and colour coded wooden props. The wall charts are displayed in prominent positions around the room of the workshop. Each chart displays the number and corresponding colour of the electronic colour code. Next to each block of colour is the name of the colour in the language of a participating country followed by the name in the Hindi Devangari script for the benefit of the staff. Other charts around the room include common Hindi phrases written in the Devangari script, their spelling in the Latin alphabet, and their meaning in English. Props to aid in the learning process include small pieces of wood painted in the colours of the electronic colour code with the relevant numbers marked on each side. The pieces are wired together giving the trainees a more tactile experience of handling, and hopefully, learning the code.

It would be a mistake, however, to portray the learning environment in the workshop as one of structured and well-informed pedagogy. Much of the theory is simply lost on the non-English speaking and illiterate trainees who account for the majority of the intake. While the nonlinguistic (Bloch 1991) embodied skills associated with using tools and components can be picked up by observation and mimesis, the descriptive, theoretical knowledges associated with calculating resistance values and diagnostics require a shared platform of communication.

Daisy, forty-eight years old and a mother of eight from Uganda, was one of several English speakers in the first ITEC sponsored group. Despite her excellent English, she told me that communication remained the most significant obstacle to learning despite being told by the Director of the College when he visited her village, that they did not in fact need language to learn in the workshop. Daisy spoke eloquently about the frustrations of wanting to ask the trainers questions relating to the functioning of the circuits but being hindered by a lack of shared language, or how the answers given when she did manage to communicate were rarely what she asked. Further, the lack of a clear structure or outline to what they were learning meant that with one month left, they were still picking new points up.

Daisy, who with the other Ugandans arrived at the campus on September 25, ten days late due to problems with their visas, described her first day in the workshop:

> "So the next day on the 26th we just started class, that was very strange because not understanding anything, *anything*, even their English we could not understand a word… it was just showing us the tools that we are going to work with. But the way they were calling and pronouncing the tools, we did not imagine it was English. It was difficult because these people have no work-plan, because, if you are going to teach somebody something you have to tell them that "this thing is like this" but for us when we came late, we were just given those small PCBs, you fix this, you fix this, not knowing where we are to fix, so we are just gambling, gambling until we catch up. They had us speaking English, but how can you do something without explanation (laughing)." (Interview transcript 8.02.09)

Daisy explained that the only way they learn without a shared language and competent teachers ("If I ask the same question four times, I won't see that teacher again"), is through trial and error, trying what works and what does not: "When we measure the voltage of a circuit using the voltmeter, it should display 12V, if not, we keep trying and trying and experimenting until it does" (Daisy Interview transcript 8.02.09).

Following Ingold, we can refer to skills as certain capabilities of particular human subjects, given credence by particular communities, in particular times and places (Ingold 2000:315). As such, they are context specific in time and space. Furthermore, skills are not to be understood as techniques of the body acting upon a world 'out there'. Rather, skills are to be understood as particular aptitudes and sensibilities that develop in a mutually constitutive interrelation between person and environment (Ingold 2000:321). Skills are generated by, and in turn generate the bearers and the surrounding environment in a mutually reciprocal fashion.

Thus my field notes record the women's, and my own, growing confidence as we progress from hesitant beginners to dextrous experts. Assembling circuit boards is a case in point. Much of our time in the workshop is spent manufacturing the circuit boards that will eventually be used in the actual lanterns and lamps that are sent to the participating countries. Our workshop is part learning environment, part assembly line. We move from one circuit to the next, never spending more than a few days on each before moving on. The first circuit board that I assembled was a messy and frustrating affair. The small components irritated me, the task of reckoning where they went even more so. My hands felt ungainly and clumsy, and in the heat, the small pieces slipped between my sweating fingers. With patience and practice, however, the process gradually got easier. My fingers, previously unwieldy and graceless, acquired a deftness of touch as they grasped and manipulated the small components. My eyes picked out the correct resistors, diodes and jumper-wires quickly and assuredly in what was previously an unrecognisable clutter of multi-coloured bits and pieces. The tools now pass easily and comfortably between my fingers. A material interaction of eyes, hands, tools and components work together and combine together in a fluidity of movement. Circuits are built as knowledge is added and altered. A *topology of fluidity* (Law and Mol 2001) is one that flows and conducts with more or less viscosity between different material assemblages.

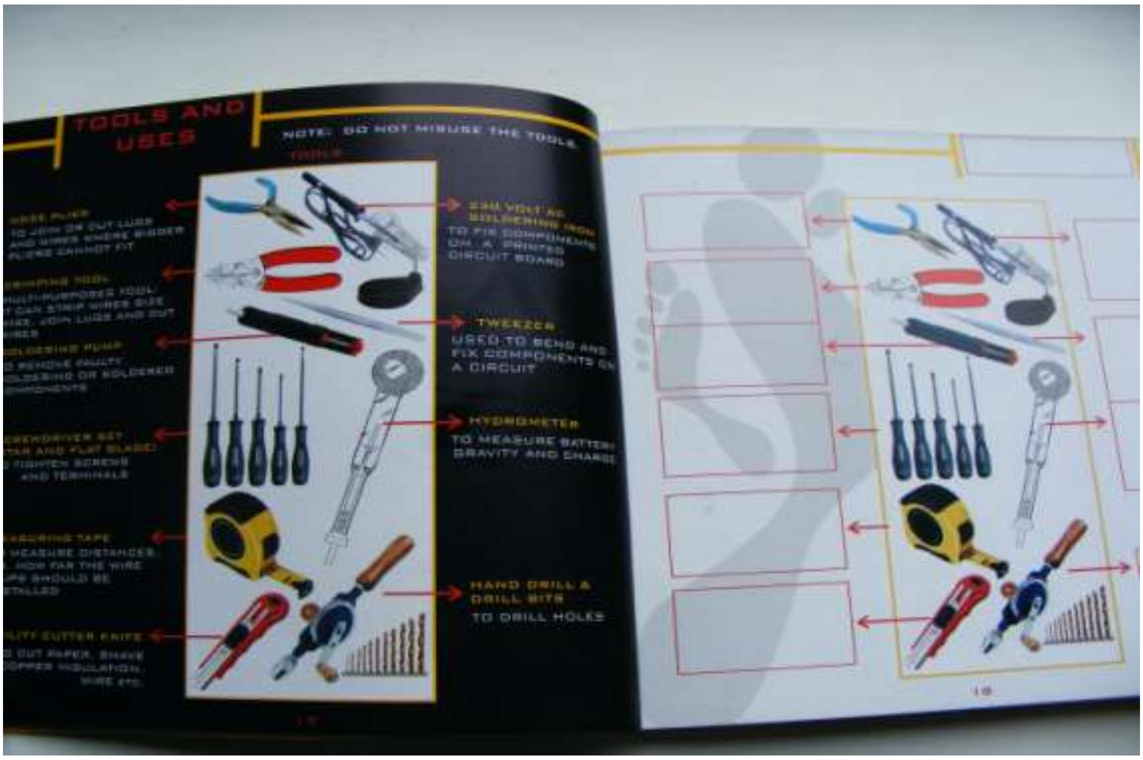

Figure 2. A page from the solar manual displaying blank spaces for the translation of tool names

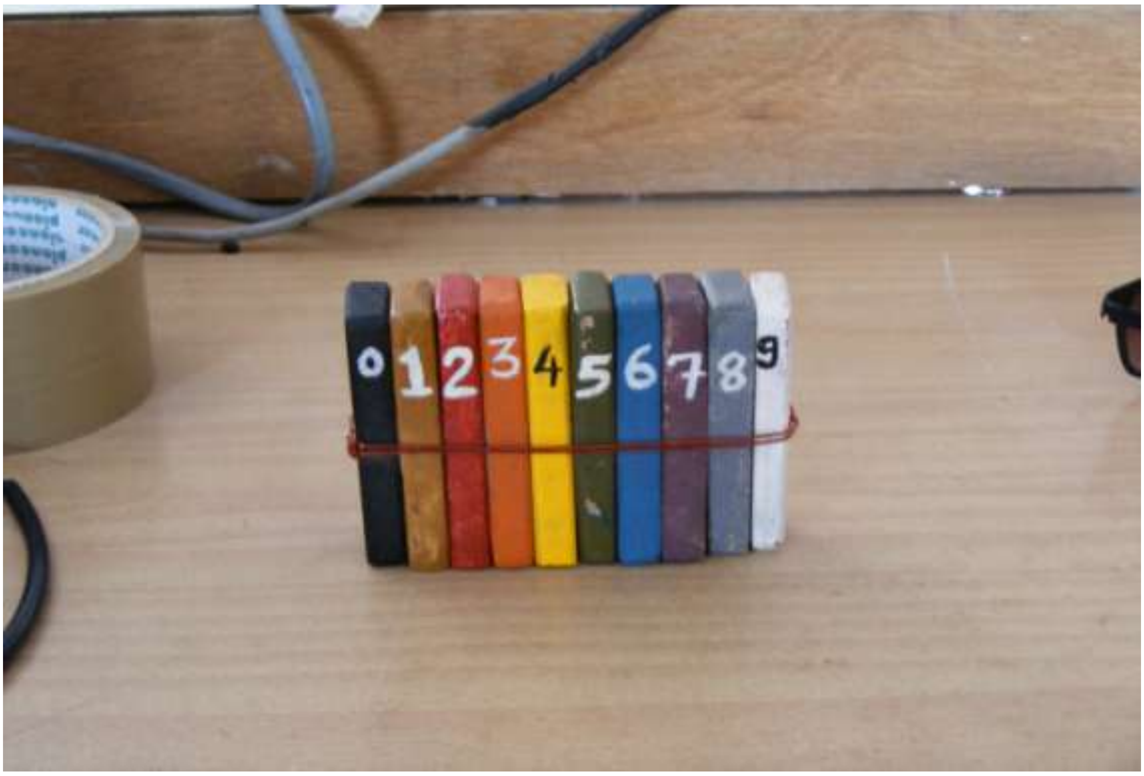

Figure 3. Colour coded learning props

The circuits

After establishing a common terminology, the class moves on to the lamp circuit. For most, if not all of the women, this will be the first time that they have encountered an open circuit board. The lamp circuit, or inverter circuit, comprises fourteen components in all, and is the simplest of the three circuits that the women will learn to assemble and test. The lamp itself is a nine watt, twelve volt Compact Fluorescent Lamp (CFL). The College buys in the component parts of the lamp: the lamp housing, wires, circuit boards, components, tubes and switches, and assembles them on-site. Since the College lacks the resources to design circuits themselves, consultants with relevant experience are approached to design circuits based on their needs of simplicity, durability and ease of repair.

Each component is held up and named while completed circuits are handed around the class for the women to examine. They are then instructed to copy out a diagram of the circuit into their notebooks. The next few days are split into rote learning and theory in the morning with practical, hands-on learning in the afternoon. From here, lamp circuits are slowly assembled by the women. At first, each component necessary for its completion, e.g. capacitors, transformers, heat sinks and diodes, is handed out individually to the women. These component parts are then threaded through particular points on a printed circuit board (PCB). The women learn where each component is placed either by comparing their work-in-progress with a completed circuit board or by referring to printed hand-outs listing the component parts. For example, on the lantern circuit board, points "R1", "R6" and "R14" each indicate resistors to the value of 10kΩ represented by bands of brown, black, black and red. The women then find the relevant components and points and thread them through. At this early stage of training, the master trainers check that each component is in the correct place before the trainees solder it into place. Later, with more experience, the trainees solder independently without the need to consult staff. The training progresses from the distribution of individual components by staff, to packets of pre-arranged components, and finally to the trainees selecting the components themselves.

The production of the lamp circuit is also completed conterminously with the assembly of the lamp body itself. The ability to assemble the wires, switches and casing of the lamp as a fully fabricated unit not only provides much needed skills for future installation and repair, but also generates confidence and familiarity in the handling of tools and equipment, which to many of the women is still considered the preserve of men.

The fourteen-component lamp-inverter circuit is proceeded by the seventy-one component lantern circuit, containing both an inverter and charger, and followed by the eighty-one component charge controller circuit which regulates the electric current that is drawn from or added to the battery. The circuits are tackled by level of perceived difficulty and complexity: as component numbers increase, concomitantly, the potential for faults also increases. Once each circuit has been completed, they are tested on the power supplies.

Testing

When a circuit has been completed, it is connected to a power supply for testing. The bench-mounted digital dual-power supply unit provides the means to regulate output voltage (measured in volts) and current (measured in ampere, shortened to amps) at a wide variety of adjustable settings for the testing of electronic circuits. Output settings are displayed on LED controls with "coarse" and "fine" settings giving precision adjustment. By regulating the voltage or current administered to a circuit, the trainees are able to test whether it is working to proscribed standards. The first circuit that the trainees learn to test is the lamp inverter circuit. The lamp is first of all connected to the output terminals of the power supply in the "volts" setting and the "course" regulator turned to 12.2V. We flick the switch and wait for the read-out. If the lamp is working correctly, the C.F.L tube will flicker on and start glowing, indicating that it is working as expected. The power supply reading is then switched to "amps". If everything is working as expected, the lamp will display a reading between 0.75 and 0.85 amps. If the power supply displays a value lower than 0.75 amps, the lamp will glow only partially, while a value higher than 0.85 amps will over-consume the battery charge. If the expected read-out is not attained, or the lamp does not illuminate, a process of trial and error diagnostics begins until the problem is resolved. In most cases, a low ampere reading is the problem that can be corrected by opening up the transformer in the circuit and inserting a small piece of plastic between the core halves to produce an “air gap”. Air gaps are introduced when adjustments are necessary to increase the current in a circuit.

If the lamp continues to give a faulty reading after an air gap has been inserted or the transformer tightened, other, common faults are searched for in a “trouble-shooting” manner. The most common flaw, aside from incorrect readings, is faulty soldering. Soldering wire has to be clean and neat with no overlap between the soldered circuit and the adjacent circuit. If the soldering is judged to be satisfactory and all the components are held in place, the women are next instructed to make sure that the wires of the transformer are in their correct place. Again, if they are judged to be aligned correctly, the wires of the transformer and the choke coil are then inspected for possible oxidation and de-soldered and cleaned using either acid or a wire brush, if found to be oxidised. They are then re-soldered to the circuit board. This trouble-shooting process continues until the circuit is judged to be working as expected. Other common mistakes include the wrong value of transistors or incorrect resistors. Yet the components are not only limited to transistors and condensers, the components of the functioning circuit network also refer to the soldering skills of the trainees and the ability of their eyes to pick out the correct parts.

In the above example of learning to construct circuit boards and test them, the knowledge exercised in the task of generating circuit fidelity is predominantly produced from ‘knowing that’, rather than ‘knowing how’. Trainees must know the meaning of certain indicators to deduce why the lamp may be malfunctioning. It is an either/or scenario that resembles a typical network spatiality, or as we will term it, a circuit spatiality. Knowledge is transferred, or not, between circuit components, along conductive pathways. If the components are functioning as expected, then network fidelity is preserved and it becomes an immutable mobile (Latour 1987). Network coherence hinges upon the stability, the firmness, the immutability of the various actors, or components, for it to function. Each component of the circuit plays an essential part in its overall functioning. If just one component in the network fails, then the circuit itself fails as a whole. Yet the components are not only limited to transistors and condensers, the components of the functioning circuit network also refer to the soldering skills of the trainees and the ability of their eyes to pick out the correct parts. The failure to dextrously solder or accurately pick out the correct circuit component results in the collapse of the circuit. By the nature of the material assemblages thus, there is much less room for slippage, for mistakes and for incremental growth. The network either holds or it does not.

Circuits and conductivity

The above account of workshop life demonstrates the decidedly patchwork approach to learning being performed in the workshop. Learning takes place across a diverse assemblage of human-material relations, each overlapping with the next as new meanings and understandings are co-produced incrementally and improvisationally. As new portions and fragments are drawn into and expanded in the course of learning, so the knowledge forms themselves are altered and transmogrified. Learning, as Ingold (2000) has convincingly argued, is a social process that takes place in a richly structured environment of human-material relations, less transmitted than grown anew in different contexts.

We can liken this process, after Laet and Mol (2000), to a *fluid* form of learning. In an innovative study of the Zimbabwe Bush Pump 'B' type water pump, Laet and Mol explore what makes it an 'appropriate technology'. They argue that its 'appropriateness' is defined by its 'fluidity', that is, of its boundaries, its working order, and its maker. For the Zimbabwe bush pump, despite its materiality and solidity, its rigidity is also fluid, flexible and, in a word, accommodating. Its adaptability in travelling to 'unpredictable' places is down to its ability to continue working when bits and pieces fall off, get worn down or are altogether replaced with different parts. The pump's component parts can be tinkered with and changed at length by local people, yet 'the whole' continues to hold its shape and pump fresh water.

As Laet and Mol discuss, the success of the pump cannot be defined by binary oppositions, since the success as a water provider and community-builder encompasses a variety of gradations. 'Good technologies' are those that incorporate the potential for their own breakdown and have the malleability to deploy alternative arrangements. From an actor-network perspective, the pump, in all likelihood, would be described as a failure because of its inability to hold its shape. The bush pump, as Law and Mol (2001) discuss in a later article, is not an immutable mobile, but a *mutable mobile*. It is a failed network. Yet, this very mutability, its fluidity as both a material object and as a network through which social relations are performed, are the reasons for its 'success', leading the authors to conclude that a fluid object is perhaps stronger than one which is firm.

Laet and Mol's metaphor of a fluid object closely resembles the kinds of knowledge-performing practices being performed in the workshop above. Knowledge-performance describes the uniquely hybrid forms of socio-material assemblages enacted in the workshop: solar manuals, coloured learning props, resistance posters, circuit boards, soldering irons, transformers, choke coils, power-supplies, muscles, skills, dexterity, identities, solar power, government ministers, NGOs, and international development efforts. All of these different elements are combined and performed in certain ways to produce particular consequences, of which the generation of knowledge is just one network.

Knowledge-performance also, however, brings to mind the very situated character of knowledge generation. Performances, by their very nature, are necessarily enacted in particular places and involve undeniably material practices. Moreover, a performance, as Law and Singleton (2000) note, is never an end in itself, it can never attain "closure"; its network robustness relies upon the sustained performance of actions in a feedback-loop of network-sustainability. In a circuit, current must continuously flow along the conductive pathways for the circuit to perform its assigned function. Similarly, if knowledge networks are to be maintained, they depend on regular enactments. This leads us to conclude that performances never exist in the abstract;

rather, they are always performed somewhere, someplace, including abstract knowledge itself (2000:775).

To talk of performance, however, leads us to ask what kinds of *spaces* they are enacted within. Actor-networks, in their original incarnation, are performed in two kinds of spaces. In the first, as noted above, they are performed and situated in Euclidean dimensions where they move through X – Y – Z coordinates (Law and Mol 2001) bringing to mind terms such as zones, regions and territories. In this instance, the actor-network holds its shape within a particular web of relations as an *immutable mobile.* Thus learning takes place through a hybrid pattern of material relations in a workshop, a particular place, located in a particular geographic and topographical area.

In the second kind of space, knowledge is performed in a *network space*. The notion of 'network' however, as Latour (1997) notes, does not imply a likeness to connectivity, distance or proximity. Instead, network space is a space of *associations.* Associations suggest the relationality of network assemblages rather than connections in geometrical space. When a network metaphor of association is deployed, it allows us to dispense with geographical classifications of space as defined in terms of measurement. Thus, distance and proximity, small-scale, large-scale, inside-outside, local and global have no meaning in a network of associations. These spatial 'tyrannies' (Latour 1997) are rendered redundant. A spatiality is formed from a hybrid pattern of associations that is not *a priori* defined as social, or natural or technical.

Thus in this original conception, knowledge participates in two spaces: network space and Euclidean space. The two spaces combine together to perform the network, or not, as the case may be. This either/or network spatiality, however, has been superseded by more broadened forms of spatiality in recent times that recognise the sometimes incremental push and pull, the slippage and overlaps of different networks. Some knowledge-performances adhere less to a binary, network-metaphor and more to a gradual, transformative, incremental spatiality much like Laet and Mol's bush pump. Knowledge from this perspective, like an apprenticeship, is gradually transmuted and grown into as it is performed (Ingold 2000), its boundaries may morph and change, yet its shape is largely maintained.

Thus, we can identify two kinds of knowledge being performed in the workshop; in the first form, knowledge *flows* with more or less viscosity. A fluid-like spatiality, or, to continue the circuit allegory, we will turn to the metaphor of learning *conductivity*[6]. Conductivity allows us to account for the ways in which knowledge and learning is a transformative process that takes place across different actors, and is shaped by the material properties of those actors. This is not, however, to fall back on a materialist conception of objects, but it does, as Laet and Mol (2000) argue, acknowledge that objects have material properties that constrain what kinds of configurations can be

[6] Electrical conductivity is a measure of a material's ability to conduct an electric current. Electrical conductivity is shaped by the material properties of a conductor, its geometric dimensions in space, and its temperature.

performed. Bringing a community together by digging a well is a quite different gathering, they point out, to the one that meets to bury a neighbour (2000:237).

Likewise, just as a particular conductor shapes the rate at which electric current passes through it, so knowledge is transformed and transmuted by the actors (components) through which it is performed. So while electric current is shaped by the properties of the conductor that it flows through, its current-like qualities, that is, its shifting and flexible boundaries, allow it to be performed in different configurations while still holding its overall shape. In this view, forms of knowledge are generated and transmuted in the context-specific engagements in which it takes place, which leads us to conclude that fluid knowledge is coterminous with learning, each being shaped by the other in a mutual coalescence of performed action. From this perspective, conductive knowledge is not transferred or transmitted; rather, it flows in different spatialities, never the same from one context to the next. It circulates among humans and materials with more or less viscosity as learning takes place, always moving and morphing, never static.

In contrast, the second form of knowledge resembles a typical network spatiality, or as we will term it, a circuit spatiality. An electric circuit is an interconnection of electrical components such that electric charge is made to flow along a closed path (a circuit), usually to perform some useful task. A circuit board is an apt analogy of an actor-network. It also allows us to visualise the heterogeneous make-up of an actor-network, containing as it does a medley of transformers, resistors, heat sinks, condensers, capacitors and others. An electrical circuit therefore provides us with a tangible example of the different spatialities through which it operates: as a network, it is an interconnection of electrical elements; as an actor within the network of the device that it is part of, in this case a solar lamp; as an actor within a solar technology discourse; as an actor within the efforts of the College to establish itself as a transnational manufacturer and capacity-builder of solar technologies; and as a community builder within African communities.

Does this mean, however, that knowledge, as performed in the workshop, can be categorised as either a conductive (fluid) spatiality or circuit (network) spatiality? The answer is of course both. The trainees learn through a circuit spatiality of relations. They are guided first from the establishment of a common platform of names and terms, through to their first experiments with handling tools and components, to assembling their circuit boards, and finally to testing and installation. Within this framework, however, lies a fluidity and flexibility of movement, of trial and error experimentation within a richly structured social environment (Ingold 2000) that gives the trainees the room to learn and try different things out. Of course, this may not be intentional, as Daisy's experiences testify, but as anyone who has tried to learn a new skill can attest, one can only learn so much from others; knowledge and skills must ultimately be interpreted and engaged with by the individual actor as they generate new meanings in the light of previous experience through heterogeneous interactions. Knowledge here is active and dynamic, continuously generated anew in different contexts through a mutually constitutive interrelation between person and environment rather than a passive and inert transfer of knowledge.

Spatialities of practice

When Latour called forth and exclaimed that we must “follow the actors themselves” (Latour 2005), I often think he is misinterpreted for promoting a kind of anthropocentric, trans-local approach to fieldwork. Of course, actor-networks can indeed cross geographic boundaries that can necessitate some multi-sited fieldwork hopping; yet, this is not a necessity. His earlier exhortation to “trace the associations” (1997), while not projecting the same allure, is perhaps a closer approximation of the actor-network project. As we noted earlier, associations perform particular spatialities through their own performance in space. The two go together, each shaping and being shaped through their dynamic becomings in a coalescence of action. Certainly, the implication is that – by their materiality - different patterns of relations perform different spatialities. Thus alcoholic liver disease (Law and Singleton 2000) performs a particular spatiality through the materiality of liver cirrhosis, hepatitis B, blood sugar levels and the effects of alcohol. A bush-pump performs a number of different spatialities, from provider of clean water to community builder; nevertheless, it does not imply that it can perform *any* spatiality. For however fluid it may be, it is still limited by certain boundaries, certain *affordances* (Gibson 1979). Similarly, learning with particular tools, and in particular environments, shapes the way that knowledge is generated and re-produced. Some networks, as we saw, rely for their continued stability on a circuit-like spatiality whereby knowledge is transferred between actors without much in the way of translation. In the testing stage of workshop learning, we identified the knowledge to ‘know that’ as resembling a circuit-spatiality for there is no negotiation or slippage inherent to its functioning. The network either holds, or it does not. Whereas in the learning of skills to dextrously manipulate soldering irons and thread components through the circuit boards, we identified the knowledge of ‘knowing how’ as resembling a conductive spatiality, one in which there is room for manoeuvre, for slippage, and for growth.

When knowledge is recast in terms of varying spatialities, as differently structured patterns of relations, rather than distinct ontologies, we are better equipped to challenge problematic divisions such as knowledge that is expressed in words and numbers, and knowledge that is embodied in skills and ability. Knowledge in this instance is conceptualised less as an entity, either as skills and expertise exclusive to the bodily habitus or as facts and information embedded within a text, and more as the outcome of an action performed through certain patterns of relations, be it bodies, texts, or materials, then the division separating skills from explicit knowledge becomes one of network spatiality, rather than a marked difference in kind. Due to their transformative nature, skills are better conceptualised within a fluid, or conductive spatiality; meanwhile, declarative knowledge and the materials through which they are performed subscribe more to a network, or circuit spatiality. As we have seen, however, there are gradations of movement and different materialities from different spatialities (e.g. 'fire space' Law and Mol 2001), some of which are perhaps better served by other metaphorical devices.

By 'tracing the associations', we can therefore explore and describe the different spatialities performed through different practices and patterns of relations. Different formations perform different spatialities, but all are ultimately situated and performed in practice.

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