

## Sociomaterial Assemblages in Learning Scientific Practice: Margherita's First PCR

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**Abstract** This paper examines the ways in which apprentice scientists learn how to work in the laboratory day by day, the hypothesis being that practical learning is part of the process of *becoming a scientist*. The paper's theoretical intention is multi-perspective, and unites various approaches: laboratory studies, practice studies, the corporeal turn perspective and that of communities of practice. The paper argues that learning is produced through the bodies of the apprentices. These embed a sociomaterial assemblage of heterogeneous elements, sustaining the collective laboratory work.

**Keywords** learning; corporeal turn; practice; assemblages; sociomateriality.

### Introduction

The paper proposes to discover how apprentice scientists learn to work in the setting of the laboratory. To achieve this scope, diverse research perspectives, all together oriented to the study of practical and situated learning, were examined and adopted. Among these, laboratory studies (Latour and Woolgar 1979; Lynch 1985; Knorr Cetina 1999; Latour 1987), practice-based studies (Nicolini *et al.* 2003; Schatzki *et al.* 2001), the corporeal turn perspective (Yakhlef 2010) and that of the communities of practice (Lave and Wenger 1991). The paper proceeds with a narrative description of learning in the research laboratory by focusing attention on Margherita, a novice, and the sociomaterial events she encounters in her process of incorporating practice.

The theme of learning laboratory practice, though not new, has been the focus of less attention (also from Actor-Network Theory and STS researchers) than “the production of scientific knowledge”, while I believe that learning daily

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practice in the laboratory is an important part of the trajectory of *becoming a scientist* and therefore deserves the attention of technoscience studies.

Research practice, in this paper, is intended as a sociomaterial activity situated in networks of bodies and objects, both involved in the (co)production of knowledge.

## I. Theoretical approaches

Learning is a *sociomaterial* (Orlikowski 2007) process that takes place in classrooms, lecture halls and workplaces. In educational (Fenwick and Edwards 2010; Sørensen 2009), professional and organisational fields (Lave and Wenger 1991; Gherardi 2000), learning is a social, situated and practical process characterised by the intertwining of heterogeneous aspects, both human and material, which connect people and things across time and space. This understanding of learning (Gherardi 2011) is based on the assumption that knowing and doing are inextricably linked, and that learning processes involve an equally inextricable intertwining of tacit and explicit knowledge (Collins 2010).

Learning is to be regarded as a complex and uncertain process of appropriation and translation (Callon 1986), which requires the commitment and participation of the subjects involved. Joining the laboratory, novices experience an initial phase of disorientation or breakdown. Entering the laboratory is like crossing a cultural threshold, in the sense of the knowledge acquired in the transition between two educational spheres: that of the university lecture hall and that of laboratory practice. The young apprentice scientists discover that scientific knowledge – which, till that moment they had learnt mainly from textbooks and university teaching – is rather a practical, material, social and relational process. During their first period in the laboratory they strive to distance themselves from a vision which perceives knowledge as being a codified, certain result, to one where knowledge is seen as a situated, local action, a relational effect which links people and objects (Latour 2005). Collaborating with a senior (and also working with other colleagues) leads the novice to an *all-practical knowledge vision*, far removed from the codified university variety. Knowledge acquired through laboratory practice is disarticulated, it becomes chaotic, vulnerable, subjected to experimental testing and questing for new order.

Theoretically speaking, the paper follows four main traditions of studies.

The first is that of laboratory studies and the cross-referenced contribution made by Science and Technology Studies (STS), Actor-Network Theory (Latour and Woolgar 1979; Lynch 1985; Knorr Cetina 1999; Latour 1987; Traweek 1988) and their applications in education and learning (Fenwick and Edwards 2010). The second is that of practice-based studies on learning and knowing in organizations (Nicolini *et al.* 2003; Schatzki *et al.* 2001), which have contributed to changing our vision from a stable, mental, individual, codified conception of knowledge to one where *knowing and learning* are emerging processes situated

and negotiated in sociomaterial practices. The laboratory is in fact a special educational setting which favours a curriculum activated and experimented through practice (Fenwick and Edwards 2012) and places the relational effects between sociomaterial events and researchers centre-stage, unlike scholastic and university contexts, which privilege a formal, codified knowledge.

The third tradition refers to theories that explicitly focus on the body in learning practices, the so-called *corporeal turn* (Yakhlef 2010). This contribution suggests that the body is cultivated through practice: the body is seen as a further link with the social, material world, and is also a go-between, a mediating resource in knowing and learning. Learning is corporeal and the body is both an object and a subject in daily working and knowing.

The fourth is that of Communities of Practice (Lave and Wenger 1991). In this regard, the paper aims at questioning and updating the concepts of *novices*, *experts* and *legitimate peripheral participation*. While sharing the theoretical perspectives developed by Lave and Wenger in their 1991 book, where learning is regarded as a form of social participation in situated contexts, the paper does not focus so much on the idea of community – i.e., a holistic, objectified, cohesive and homogeneous sphere where individuals are progressively integrated, gradually acquiring the resources available to their community – as on the idea that learning is based on the active and personal participation in processes of sociomaterial appropriation. As pointed out by Gherardi (2009), the label of Communities of Practice (CoP), especially in the interpretations proposed by Wenger over time (2002), has become a synonym for a welcoming, harmonious, non-conflicting place, where knowledge is a heritage, an outcome, a constantly ongoing process. The idea of CoP fails to consider both the materiality of practice (which is regarded as a mere result of an action, rather than the matter constituting the action itself) and the body working and acting, the agent producing and produced by practice. For this reason, as suggested by Gherardi (2009), it seems more interesting to reverse the concept and turn the idea of Communities of Practice into that of Practices of Community (PoC).

The paper aims to contribute to a multi-theoretical perspective on learning in practice, starting from the assumption that learning processes do not rely on a progressive and linear participation and inclusion in a community (as in the idea of legitimate peripheral participation - Lave and Wenger, 1991), but on a problematic, uncertain, demanding, daily appropriation and embodiment of sociomaterial practices.

## **2. The field of practice: entering the laboratory**

From a STS perspective, laboratories are interstitial spaces between academic and business organisations, basic and applied research, experience-based knowledge and codified knowledge. Scientific research laboratories are places where formal and explicit learning, informal socialisation, tacit knowledge and expert practice intertwine; places where knowledge is always a shared practice,

being the product of human and non-human assemblages. Like other professional settings, laboratories are spaces embodying a pedagogy of practice (Kaiser 2005). The processes by which researchers face problems, search for solutions, learn and embody roles, draw on established knowledge, create new knowledge and make themselves familiar with daily practices, constitute a daily pedagogy, which is not abstract or pre-established, it is not inside people's heads or in handbooks, but is embedded in the process of knowledge appropriation.

In order to describe the body (Yakhlef 2010) and sociomaterial practices of learning I will refer to observations conducted in a leading Italian research laboratory<sup>2</sup> working on stem cells. In this research lab, knowledge practices involve: learning to write; analysing, representing and interpreting data in laboratory; learning to understand the status of cells by observing them through the microscope; learning how to communicate at scientific meetings; learning how to discipline one's body in the laboratory (how to stand at the bench, how to stay under the hood, how to use technological devices, how to take care of non-humans, such as cells, molecules, etc.).

By observing the learning path of young University students, my aim is to show how scientific practice is learned day by day. The idea is to examine the experience of learning scientific practice in the transition between lecture halls (where knowledge is codified and stable) and the laboratory (where knowledge is still hybrid, vulnerable and malleable). Through the narration of crucial events concerning learning and apprenticeship, the paper focuses specifically on some of the basic processes (typical of scientific practice) directly involving the body: learning to stand at the bench; learning the gestures of practice day by day; learning how to recognise and treat valuable objects such as cells; learning to look at cell cultures (embryonic, cerebral, human and animal cells) through the microscope; learning how to register practical knowledge (keeping laboratory notebooks); learning to handle technological devices. All these processes require the construction of profound and tacit knowledge (Polanyi 1966), which is shared, processed, and embodied in bodies and objects. This corporeal knowledge will be observed while it is learned in practice, in personal, relational and material daily work.

Through the detailed account of how Margherita learns to carry out PCR tests in practice, the paper shows how the novice, although under the supervision of a senior researcher, immediately takes centre stage in the practice, thus supporting the texture of practices performed by more expert researchers. The hypothesis is that in research laboratories (as well as in other workplaces) newcomers are im-

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<sup>2</sup> The Laboratory of Stem Cell Biology and Pharmacology of Neurodegenerative Diseases is part of the University of Milan and is run by Prof. Elena Cattaneo. It is linked to several international networks and roughly 25 researchers (Italians and foreigners, post-PhD, PhD and students) work there. The laboratory is funded by: Telethon, Huntington's Disease Society of America, Hereditary Disease Foundation, European Union, Ministry of the University and Research, Ministry of Health, Banks such as Cariplo and Unicredit, Valdese Church. Articles on the laboratory have appeared in the following publications: *Nature*, *Science*, *Nature Genetics*, *Human Molecular Genetics*, *Journal of Neuroscience*, *PNAS*, etc.

mediately involved in the construction and organisation of established routines that constitute the crucial and ordinary texture of situated practices. Novices do not just stand and watch the world from the margins, gradually getting the hang of things through increased involvement, but are immediately cast into the practice in order to support and contribute to the work of the community. Novices are quickly called upon to enter into the heart of laboratory practice and soon become productive resources. They are *catapulted* into action and immediately realize that their daily practice is at the basis of all laboratory activities.

From a methodological viewpoint, I adopted an ecological vision, considering the laboratory as a wide, social and material space where apparently chaotic phenomena present regular, evident qualities. I progressively *zoomed in* practice (Nicolini, 2009) and focused on diverse seemingly exemplary episodes whose details might represent wider laboratory dynamics. I assumed an ethnographic perspective which required a lengthy period of observation. Then, little by little, I began to understand the macro-order of daily events and selected a series of practices to observe, choosing those which a novice learns at the initial stages (as in the case of the PCR, on which we will focus in the next paragraph).

For several days, using the *shadowing* technique, I therefore followed Margherita, a young novice and recent newcomer to the laboratory. About two months after having carried out the shadowing, I conducted a long interview with Margherita, reminiscing on my period of observation with her and asking her to reflect on her initial experiences with the PCR.

In the story we are about to enter, thus, we will observe Margherita as she becomes familiar with her work environment and moves from being an insecure, inexperienced novice, to an independent, reflexive and skilled researcher who has embodied laboratory practices.

### **3. Learning through practice: Margherita in the laboratory**

#### **3.1. Discovering the context**

Together with Margherita, we find ourselves at the beginning of the story, at the beginning of the internship, at the first impressions of the learner. Margherita begins her adventure, comes into contact with a world that is materially, spatially and temporally disciplined, finds durable and malleable objects, meets colleagues who will be her guides. The laboratory setting she finds herself in has a social and technological installed base. It is an already established environment, a learning field where she will have to inscribe her gestures, find her feet, learn how to correctly position her body and develop knowledge resources (Roth and Lawless 2002). Margherita enters a world where, as Lynch argues (1985), practices performed by the body are subject to time and turn into routines.

Margherita's first days in the laboratory took place in silence. At a superficial glance, Margherita seemed already at ease, though this is really what Merton defines *anticipatory socialization*. Margherita is not a *tabula rasa*, an empty vessel

to be filled: she has already been in another laboratory in the course of her university studies, where she learned how to manage diverse instruments and carried out all the tests used in molecular biology. Margherita, therefore, has some experience of the environment, and knows how to avoid getting in anyone's way, how to move agilely between workbenches and computers. She knows her place within the social and material space of the laboratory, but is also aware that every laboratory is a world in itself, a new, unknown and sensitive terrain to be explored.

In the morning she dons her white coat even though she doesn't exactly know why - for the moment it serves only to cover the embarrassment of her inexperience - while many of the more confident youngsters, but also their seniors, have a more relaxed attitude, donning it when they begin an experiment; when they approach a workbench with a purpose; when they enter the cell chamber; when they change a culture base or when they look through a microscope. In short, when circumstances require it.



Figure 1 – Margherita dons her white coat

These early phases of her learning path are similar to the tailors' learning practices described by Lave and Wenger (1991), with a short period of time defined as “way-in” during which Margherita observes, tries to make herself familiar with the work space, objects and people around her. The “way-in” phase is immediately associated with the “practice” phase, when Margherita starts getting the hang of the various segments of her work. In her first days, she is flanked by another young intern, Giovanna, a girl who has already spent several weeks in the laboratory. It is with her that Margherita begins *to find her feet*,

learns where instruments are kept, familiarizes herself with the *material geography* of the laboratory. She learns about the surrounding together with someone who has already elaborated a map of this reality and can share it with her.

At first, Margherita focuses on elementary but highly important matters: cleaning the workbench, discovering where the most commonly-used objects (such as the containers where events and materials crucial to the laboratory) are kept. She discovers scientific articles scattered around, the students' pipettes, begins to recognize the everyday gestures and experiments the first stages of acting (or rather, acting in its first stages). In a notebook, she writes down details of the information she begins to select: instruments' names, a telephone number, the names of suppliers, some notes on *primers*, the access code to the computer. Small but vital details to hang onto in these first days, in which she feels like she's holding her breath.

The space is densely populated by heterogeneous objects, which are there for theoretical and practical functions and will gradually be embodied and domesticated by Margherita. Scientific papers and notebooks will be her partners in the appropriation of knowledge. Margherita will learn how to write about her practice: she will describe in detail the use of the various devices and protocols, she will summarise the articles deemed relevant for the tests to be carried out, she will go through and file the articles that might be useful in the following phases of the experiments. Pipettes, hood, fridge, computer and microscope will be the instruments she has to gradually become familiar with. Primers, cells, DNA and laboratory animals will be other partners she will have to deal with, and ally herself with, in order to achieve the expected results. On top of that, there are also colleagues, peers and seniors with whom Margherita will share her process of socialisation, becoming familiar with the practice that is going to transform herself from a novice into an expert.

One morning I observe Margherita, watched over by the senior colleague she will be working with (Marta), carrying out her first PCR for an important project in which stem cell knowledge is applied to Huntington's Disease<sup>3</sup>. Margherita is introduced to the practice and is given the key elements to legitimately approach the tasks she has to learn. I therefore decide to follow Margherita's first steps in action.

### 3.2. Preparing for the first PCR

The Polymerase Chain Reaction (PCR) is a technique that has revolutionized molecular biology. It was conceived by the Nobel Prize winner Kary Mullis in the

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<sup>3</sup> This is a hereditary degenerative condition of the central nervous system, which causes patients to lose control of their bodies. This degeneration leads to dementia and death within 15-20 years after the appearance of the first symptoms. The illness usually manifests itself around age 40-50. There are 4000 diagnosed cases in Italy and it is believed that there are at least 12000 more that have not yet been diagnosed. The children of people who suffer from Huntington's Disease have a 50% chance of inheriting the defective gene.

early 1980s and allows scientists to amplify, clone, duplicate specific DNA sequences<sup>4</sup>. The history of the discovery of PCR, the DNA amplification technique, is made up of attempts, perceptions and manipulations, a practical history where the expert's body matters, as proved by Mullis' account of his research experience:

"Tonight, I am cooking: the enzymes and chemicals I have at Cetus are my ingredients. (...) There was nothing in the abstracted literature about succeeding or failing to amplify DNA by the repeated reciprocal extension of two primers (...). In September I did my first experiment. (...) One night I put human DNA and the nerve growth factor<sup>5</sup> primers in a little crew-cap tube with an O-ring and a purple top. I boiled for a few minutes, cooled, added about 10 units of DNA polymerase, closed the tube and left it at 37° (...). At noon the next day I went to the lab to take a 12-hour sample (...). The first successful experiment happened on December 16, 1983. It was dark outside when I took the autoradiogram out of the freezer and developed it. There, right where it should have been, was a little black band. A tiny little black band." (Mullis 2000, p. 9-20).

Mullis cooks, handles objects at different temperatures, weighs out ingredients, looks at results, uses his hands, his eyes, interconnects with objects, manages knowledge in practice. This is exactly what Margherita is about to do, as she gets ready for her first PCR. Those of Mullis and Margherita are stories of appropriation and discipline. Mullis followed his practical intuition and discovered what has today become an important routine in laboratory practices; Margherita instead approaches this routine as a discovery.

The aim of Margherita's first PCR is to evaluate whether the expression of a new gene, INSIG-1, probably involved in Huntington's Disease, is modulated or not by the presence of mutated huntingtin<sup>6</sup>. Margherita knows Huntington's Disease and she has already studied the molecular biology techniques she is now about to execute. However, she has to carry out a complex conversion. The codified knowledge she learned reading books and articles seems to disappear in front of the new complexity of a practice which now appears uncertain, unknown and mysterious. Margherita knows that what she is about to do is not an experiment or a simulation of a practice, she immediately gets to the heart of the action: what she is going to do, if done correctly, will directly contribute to the work of the laboratory. Margherita enters the practice by participating in the ordinary activities widely distributed in the daily life of the laboratory. The PCR practice is indeed a very common methodology in the daily life of the laboratory. It is a technique that is at the basis of almost all the molecular biology experiments, so much so that a more expert researcher, who had been working in the laboratory for four years and greatly enjoyed laboratory techniques and

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<sup>4</sup> Rabinow (1996) carried out an anthropological analysis of the birth and significance of PCR.

<sup>5</sup> The NGF (Nerve Growth Factor), discovered by Rita Levi-Montalcini between 1951 and 1952, is important for the development and maintenance of the sympathetic and sensory nervous systems. This discovery earned the scientist a Nobel Prize.

<sup>6</sup> Mutated huntingtin is the gene involved in the development of Huntington's chorea disease.

instruments, once told me: “I can’t bear to be away from PCR even for a single day!”.

Now, let’s follow Marta and Margherita as they approach the practice that the newcomer will have to learn.

With a quick hand-drawn diagram, Marta shows Margherita how the process they are about to start up will develop. Margherita dons her white coat and gloves and, following Marta's instructions, goes to the fridge to get ice for the biological samples. “First of all, clean the workbench and wash your hands, you have to get ready to manage the situation well” says Marta, and Margherita gets methylated spirit and begins to clean the workbench precisely and thoroughly.

Still following Marta's instructions, she also cleans the pipettes she will be using. Workbench ready, Marta says: “Let’s go to the computer to draw up a plan for carrying out the various phases of the experiment, an action map we can follow”.

While Marta and Margherita set things up for the PCR, all the others in the laboratory are otherwise occupied: at their workbenches, computers, using measurement technologies, quantifying, at the centrifuges, at one of the PCR machines, in the cell room, bent over a workbench or in front of a computer, waiting for the use of a machine, standing at work in the chemical hood or seated and reading with concentration, everyone’s material time is programmed.



Figure 2 – Margherita dons her gloves



Figure 3 – Margherita cleans the workbench



Figure 4 – Marta and Margherita prepare the plan at the computer

Having prepared the plan, they return to the workbench and Marta begins to explain what Margherita is about to do. “We have to get sterile tips, the ones with filters, and place the test-tubes in the racks they rest in during the experiments”, says Marta showing to Margherita how to number the rows of little test-tubes which will be used for the samples. They need to establish the number of samples to be used. Their action is mediated by inscriptions, and the procedure they are about to follow is not a way to precisely and accurately *control* the work, but an instrument, a resource to be used to simulate and guide the course of their action. Acting is Margherita’s principal cognitive and social resource: in her practical learning, which is made up of continuous assembling between things and self, activity and knowing are closely and intrinsically intertwined.

Back to the workbench, Marta starts explaining what Margherita is about to do: “You have to get sterile tips, the ones with filters, and then the test-tubes. The starting DNA is on ice and now we have to place the test-tubes in the racks”.

Then they take a second container with ice where they can put the test-tubes, primers and the various reagents.



Figure 5 – Margherita prepares the test-tubes

Margherita takes down quick details in her notebook. Nearly two hours have elapsed. Now Marta is explaining the steps, the dilutions to be made. Margherita prepares the pipette carefully, and Marta shows her how to use it: "See here, you have to go up and down, no, not like that, change the sterile tip" and shows her how to pick up and hold the pipette. "Now" – continues Marta – "having diluted the primers they have to be brought to 37° to be suspended better". Margherita prepares the test-tubes, makes a note of the dilutions they contain but continually asks for confirmation from Marta, who tells her: "First of all, put in the water, and if you don't touch anything you can use the same tip".

Margherita has to be very careful not to touch the rims of the test-tubes with the tip, as if she manages to do so, Marta tells her, she can continue to use the same tip, otherwise she has to throw the tip away and get another. Margherita notices that she has touched the rim of the pipette with the tip and says: "No, I've wasted one, I touched it!". She is able to feel that she touched the rim of the pipette with the tip, so her sensitivity has already developed. She has enhanced her situated perception skills. Similarly to Gina in Goodwin's study (2003, p. 166-170), Margherita is now able to infer what she is doing from her sensory perception: her body is now a sort of diagnostic instrument. "Let's get our sample now", says Marta to Margherita. Now there is an exchange of perceptions and sensitivity between them, they don't talk much: each of them, to a greater or lesser degree, knows what she has to do.

Margherita makes a note of what she has done until now in her notebook: that night she will go through them, but it's important to memorize the process, the direction, the chain of events in their order.



Figure 6 - Margherita and her notebook on the workbench

In conclusion, Margherita arranges the test-tubes and puts them back on ice. "Now we'll prepare the dilutions checking the measurements with the plan we prepared beforehand on the computer". Margherita needs to concentrate on the movements of her hands and the focus of her attention. Slowly, at first uncertain and then more and more sure of herself, encouraged by Marta, she proceeds. "Now we'll move on to loading the samples into the multiwall", says Marta as she

shows her how to pick up the Petri dish and warns her of the constant risk of contamination: “The Petri dish shouldn't be held between thumb and middle finger leaving the index finger suspended, but should be held using thumb and index finger, look, like this, never move your hands directly over the dish, organize your workspace well”.



Figure 7 – Margherita and Marta starting PCR



Figure 8 – The PCR machine

They load the multiwall onto the PCR machine and from then it will take two and a half hours to achieve results. After the loading, Margherita can relax and takes a deep breath, as if she had been holding it until then. She says: “You're there, a bundle of nerves and concentration, listen to me, I'm hoarse, I'm done in, but it's great”.

While waiting for the results, they place the primers back in the box and put the box in the fridge. Gently, Marta keeps on describing out loud what they need to do: “The aliquots already prepared and left over need to be frozen in a box at minus 20°”. While waiting, they prepare other things that might be useful in future work. The waiting time since the multiwall was uploaded onto the PCR machine has elapsed, so they now look at the results. Marta shows Margherita how to analyse them. Looking at the pattern of data obtained by the machine, she makes her see *again* the curve she had drawn at the beginning of the PCR process. Marta goes on: “Let's look at the results, so you can see what needs to be improved. From the graphs you can see whether this thing has been done well or not. Today we'll just have an overview of the results, tomorrow we'll go into details”. Marta turns off the PCR machine and Margherita asks her, worried: “Did we save the data?” Marta tells her, almost reassuringly, that the system saves data automatically. “Now we take the well plate, we bring it to 4°, we turn off the machine and then the computer. Tomorrow we'll perform an electrophoresis and we'll analyse it on an Agarose gel. If necessary, we can run a specificity test”. Margherita looks puzzled. She doesn't even know what an Agarose gel is... But this is something she will have to deal with tomorrow.

In this first phase, Margherita has tested the sensitivity of her hands, of her eyes, of her touch; she has started perceiving, hearing, seeing, trying to understand. In her dialogue with Marta, she has been engaged in an expert

communication and introduced to the most relevant area of the laboratory practice. She is a novice, but her participation is not peripheral: right from the beginning, she has got to the heart of an experiment that, while it is a routine procedure, is also fundamental for the project they are working on. She has started establishing relationships and becoming familiar with technological and bio-technological artefacts, such as pipettes, *primers*, centrifuge, computer, PCR machine, DNA, measuring instruments, and so on.

In critical moments, Margherita has learned through mistakes; her gestures are not repetitive and taken for granted yet, but her body is receptive. Margherita has plunged into the laboratory world, perceiving it, moving her body in a temporalised space, getting to the heart of a process of embodiment of objects and functions (Yakhlef 2010, p. 416). Her body starts being disciplined without her being fully aware of it. She is still quite tense, but she already feels the corporeal density of the practice she is becoming familiar with.

As already underlined by Lave and Wenger (1991) in CoP there is a shift from teaching to learning in practice: Margherita's access to the practice was not marked by explicit moments of theoretical teaching, but by learning a specific task while carrying it out.

Through her efforts, exemplified here by the episode of the PCR test, Margherita establishes a meaningful and passionate relationship with the materiality of practice: there is no knowledge beyond its practical application. Even developing dexterity in handling tips or creating new concepts is a practical exercise, a learning *effort* that also involves objects (Gibson 1979). Scientific knowledge, as shown in the above-mentioned episode, does not lie somewhere in people's heads or in metaphysical laws, but is constructed through the accumulation and fine-tuning of skills developed, embodied and sharpened to solve everyday problems.

### 3.3. Margherita some months later: between autonomy and attachment

Some months have gone by and Margherita has become totally familiar with PCR practice. She has inserted it in a wider context of work (and scientific) practices, with regard to which she is now completely autonomous. Now the PCR tests are in the order of hundreds, while at the beginning she did three or four a day. She has become swift and expert. Marta has been an excellent teacher, also because she tends to leave freedom of action to her collaborators, thus allowing them to develop their independence. At the beginning this autonomy was perceived by Margherita as a kind of solitude, but later on she realized that only in that way could she acquire competence in what she was doing and the way she was doing it. Several months later, I interview Margherita, so to ask her what has happened, what she perceived has changed in her acting in practice. Let's hear what Margherita has to say about the conquest of her competence:

"In time, I elaborated my work inside. Marta was there, but I knew that I had to do it alone, that I had to acquire dexterity in my hands and autonomy in my head. During my first PCR, I concentrated exclusively on what I was doing, I wasn't the least bit interested in why I was doing it, while today carrying out a PCR seems so simple, today it's easy, it gives me satisfaction, but there are phases in which you have to be very careful, you have to be precise, very precise, even the slightest mistake... in short, dexterity is all-important. Of course, if I do something wrong today, I'm immediately aware of it, I'm much more sensitive, I see my mistake right away. You acquire this sensitivity through time, I didn't realize this before, I was just concentrated on organizing my work, what I had to do first, what I had to do after that, through time I understood that the job I was doing had a scope and I started to piece the puzzle together in my head, and today PCR is only a small part of that along with others. At the beginning, I worked mainly in molecular biology, then I moved on to cellular biology and I was put in charge of carrying out the proliferation of the stem cells, the ES mouse cells. I started to do the differentiations, and although having the cells means more stress it's great. For months I've had to come here at weekends too... you learn to know the cells, how to behave with regard to them, what dilutions you have to make, when to make them, to understand whether they're well or not, all these things take time... I used to go home and think, I wonder how my cells are. At first Marta was with me and I made a note of all the steps I had to carry out. Of course, I looked around me, I watched the others, asked for advice about everything, about what to do, what to look for, even though all cells are different, each type of cell requires different treatment, some are more stable and need less attention, others are more delicate and need a lot more attention. Now I manage two cell lines, and each line needs specific care, some cell lines have to be changed every day, others don't, you have to understand them, observe them. Slowly, I started to understand how to treat them. I asked everyone: "How do you think the cells are?" I trained my skills and started to elaborate a complete picture of what I was doing. I realized that it wasn't just important how things were done, but also why they were done, why they had to be done in exactly that way, I moved my focus from my hands to my head and my whole body. At first I didn't consider the entire project, I focused on the details, the processes, on how to perform single actions, how to write them, report them, repeat them and then slowly you widen your vision and you see a bigger picture, you see the links between the various elements, between the actions you perform, the objects you use".

Now Margherita clearly masters a richer and more refined language. Instead of talking *about* PCR practice, she talks from *within* the practice, from the inside of it. She is no longer a mere participant in the practice, she has now developed a deeper insight into it. She has learned to move across a plurality of practices, she has also acquired competence in cell biology, she is able to distinguish different cell lines, develop her own work plan, and contribute to the others' tests.

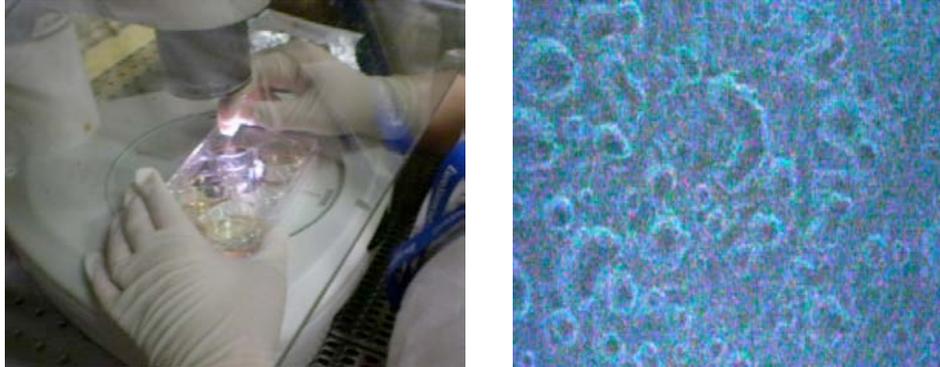


Figure 9 - Margherita and her cell line

When Margherita enters the laboratory, she meets an already established environment, and she ventures into this contest with her hands, her glance, her thoughts, as she slowly becomes familiar with objects circulating in the laboratory: DNA, cells, PCR, notebooks, protocols, primers, articles, papers, test-tubes. Thus her autonomy, her competence of movement and her ability in interpreting events, increase and, as she familiarizes herself with the material context, her attachment (Hennion 2004) to events grows. Margherita has now mastered not only “how things are done”, but her actions have acquired a rhythm, a fluidity which is apparent (for example) in her use of language. Autonomy manifests itself in a stronger link with all the human and material events.

## Conclusions

The aim of this paper has been twofold: firstly, that of placing the “corporeal turn” centre-stage in observing learning processes in laboratory practice; secondly, that of attempting to go beyond the peripheral conception of novices in practice (an idea central to Lave and Wenger’s approach), proposing the idea that novices find themselves at the centre of practice and sustain the daily sociomaterial texture of collective work in the laboratory.

Regarding the first point, one could say that Margherita is immersed in events guided by what Tarde (1985) defines *les lois de l'imitation*. In fact, she has to go through reciprocal imitation processes before achieving autonomy. She draws inspiration from Marta’s indications, but at the same time she copes with other processes tacitly (writing in the logbooks, keeping the practice in order, donning gloves and a white coat, managing the experimental timelines, etc.) Acting represents her sole learning plan, a plan which takes no single direction,

but rather permeates a terrain of constant relationships and connections between human beings and things.

In order to illustrate the type of link that binds Margherita to the events surrounding her, we could perhaps adopt the term *Wechselwirkung* (“interaction”) which is at the basis Simmel’s approach (1908). This concept regards the most elementary forms of connection in social life, a form of association which binds subjects (and action) together. It is, however, necessary to strengthen Simmel’s concept with the dose of materiality which it lacks. The concept expresses a kind of *reciprocal effect* between individuals in interaction. But the events Margherita is involved in are not related just to human interaction (as in Margherita’s relationship with Marta) but also to a sociomaterial time-space continuum which is constantly unfolding. She is actively part of a *mutual learning* process (Blumer 1969) in which the significance of actions is to be found in collective coordination, according to situated events. Margherita’s learning path takes place within a social and material space where she interacts with heterogeneous actors who develop the activity *with her*.

I chose to focus my attention solely on Margherita, but this methodological choice should not be misleading. Although Margherita is observed singly in her peripheral position, she is in fact surrounded by a more ample space filled with events which involve her and which she contributes to shaping. Her daily practice is closely linked to the practice of others: that of Marta (her senior of reference), for example, or Giovanna, the peer with whom she works and whom she continually asks for input, her colleagues in the laboratory who represent a relevant imitative source (in the open-space workplace, at the workbench, under the chemical hood, in meetings where results are discussed). Margherita builds a learning trajectory on her own, but the trajectory is built through *effectual reciprocity* with the heterogeneous elements she encounters in practice.

The story of Margherita is thus about situated learning, a process of knowledge (and knowing) appropriation which required a laborious work of embodiment. Margherita has domesticated herself, establishing a relationship with objects and learning to develop independence and awareness. Margherita’s change of posture, her gaining awareness and getting to the heart of practice are developed through a disciplined set of repeated gestures, through the embodiment of routines and sociomaterial relationships of daily practice. The docility, efforts and difficulties of this process of appropriation are the result of the intertwining of heterogeneous elements, as well as of a self-discipline (Kaiser 2005), which is the individual’s contribution to the learning process. The processes Margherita has aligned herself with, have produced an agent able to exercise active control over objects and rituals.

The episodes related to Margherita’s learning process show that there is no precise and pre-established order of events, no explicit set of knowledge to be taught: knowledge is rather situated in practice and inscribed in the instruments and in the steps by which a technique is performed. As in the case of the PCR tests, the practice is embodied by Margherita as a *craft knowledge* (in Bernstein’s words), a manual, bodily and practical knowledge (Sennett 2008). Margherita is

introduced to the practices of a context where knowledge is embodied and embedded in people's skills and competences, as well as in technologies, objects, rules, procedures. This *knowing in practice* (Gherardi *et al.* 2007) depends on knowledge experienced and developed in specific situations: it is not situated in abstract rules to be acquired, but is activated by physical stimuli and sensory perceptions (Strati, 2007). As a constantly evolving resource, knowledge is *encultured* in social dynamics, in sensemaking and in shared stories; it is related to heterogeneous processes and expressed in the specific language required by the context. Knowledge is also *encoded*, codified and conveyed by signs, symbols and traditional artefacts of codified knowledge (such as books, manuals, codes, procedures and forms of digital coding).

In Margherita's increasing relationships and connections with the field (the management of the workbench, the increasing dexterity in handling pipettes, the relationship with the cells under the hood, the knowledge of instruments and the adaptation of her senses to their use), she experiences an *agency* that is not performed and established individually, but based on a constant relationship with the material playground of the laboratory. The practical knowledge produced by this dense transindividual experience (Simondon 1958) leaves both subjectivities and objectualities unfinished, open to relationships and connections they establish with each other.

Margherita is now interconnected with a world of *objectual practices* (Knorr Cetina 1997; 2001) where material objects (as well as bio-objects) become part of her field of relationships. The materiality of laboratory life (Latour and Woolgar, 1979) is not cold and distant, but becomes absorbing and close: what used to be unfamiliar to Margherita is now conventional and her competent practice reflects her affiliation with the practical culture of the laboratory. Practical culture has been embodied by Margherita as an implicit practice, rather than as an explicit appropriation of normative domains: sometimes, practice precedes theory (Bruner 1996).

We are now able to see Margherita's training as a net of sociomaterial processes, rich of human and non-human elements. It is an *expert situated action* within a field where prescribed rules and standards of action have been established through time and continue to be elaborated day by day *via* researchers' bodies and through the density of sociomaterial relationships. In this sense, the story of Margherita shows that it is much more productive, from an analytical point of view, to develop a post-humanistic approach to learning. Through this theoretical sensitivity, in fact, we can witness how objects, technologies and space are no longer 'matters of fact' (objects in a static sense); they are rather 'matters of concern' in educational practices, for practitioners as well as for researchers (Landri and Viteritti 2010).

Finally, I have underlined how scientific work is an "expert practice" which deeply involves novices: as in the case of Margherita, in laboratories youngsters are often in charge of the routine daily events (caring for the cells on a day-to-day basis; checking infrastructures; managing minor accidents). Their seniors intervene to correct the course of events, to monitor the results, to programme

future steps, but novices govern the everyday laboratory life: they manage crucial routines, keep the workspaces tidy, keep up with the details of experimental work practices, do and repeat everyday tasks with the same care and meticulous attention. Without them, scientific work would lose both density and intensity. Their contribution is therefore in no way peripheral: they are at the very “heart” of daily practice. Of course, in order to gain full recognition, their practice must be firmly anchored to the work of their expert colleagues, whose developments in scientific work, by the way, are *founded* totally in the experimental practices the novices accomplish day by day.

In this process, novices and experts are reciprocally made part of a common process: both are involved in practical activities and are, to a greater or a lesser degree, co-producers of scientific practice.

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