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This special issue collects a selection of peer-review papers presented at the 8th International Conference INPUT 2014 titled "Smart City: planning for energy, transportation and sustainability of urban systems", held on 4-6 June in Naples, Italy. The issue includes recent developments on the theme of relationship between innovation and city management and planning.

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This special issue of TeMA collects the papers presented at the 8th International Conference INPUT 2014 which will take place in Naples from 4th to 6th June. The Conference focuses on one of the central topics within the urban studies debate and combines, in a new perspective, researches concerning the relationship between innovation and management of city changing.

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EIGHTH INTERNATIONAL CONFERENCE INPUT 2014

SMART CITY. PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM

This special issue of TeMA collects the papers presented at the Eighth International Conference INPUT, 2014, titled "Smart City. Planning for energy, transportation and sustainability of the urban system" that takes place in Naples from 4 to 6 of June 2014.

INPUT (Innovation in Urban Planning and Territorial) consists of an informal group/network of academic researchers Italians and foreigners working in several areas related to urban and territorial planning. Starting from the first conference, held in Venice in 1999, INPUT has represented an opportunity to reflect on the use of Information and Communication Technologies (ICTs) as key planning support tools. The theme of the eighth conference focuses on one of the most topical debate of urban studies that combines , in a new perspective, researches concerning the relationship between innovation (technological, methodological, of process etc..) and the management of the changes of the city. The Smart City is also currently the most investigated subject by TeMA that with this number is intended to provide a broad overview of the research activities currently in place in Italy and a number of European countries. Naples, with its tradition of studies in this particular research field, represents the best place to review progress on what is being done and try to identify some structural elements of a planning approach.

Furthermore the conference has represented the ideal space of mind comparison and ideas exchanging about a number of topics like: planning support systems, models to geo-design, qualitative cognitive models and formal ontologies, smart mobility and urban transport, Visualization and spatial perception in urban planning innovative processes for urban regeneration, smart city and smart citizen, the Smart Energy Master project, urban entropy and evaluation in urban planning, etc..

The conference INPUT Naples 2014 were sent 84 papers, through a computerized procedure using the website www.input2014.it . The papers were subjected to a series of monitoring and control operations. The first fundamental phase saw the submission of the papers to reviewers. To enable a blind procedure the papers have been checked in advance, in order to eliminate any reference to the authors. The review was carried out on a form set up by the local scientific committee. The review forms received were sent to the authors who have adapted the papers, in a more or less extensive way, on the base of the received comments. At this point (third stage), the new version of the paper was subjected to control for to standardize the content to the layout required for the publication within TeMA. In parallel, the Local Scientific Committee, along with the Editorial Board of the magazine, has provided to the technical operation on the site TeMA (insertion of data for the indexing and insertion of pdf version of the papers). In the light of the time's shortness and of the high number of contributions the Local Scientific Committee decided to publish the papers by applying some simplifies compared with the normal procedures used by TeMA. Specifically:

- Each paper was equipped with cover, TeMA Editorial Advisory Board, INPUT Scientific Committee, introductory page of INPUT 2014 and summary;
- Summary and sorting of the papers are in alphabetical order, based on the surname of the first author;
- Each paper is indexed with own DOI codex which can be found in the electronic version on TeMA website (www.tema.unina.it). The codex is not present on the pdf version of the papers.

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DILEMMAS IN THE ANALYSIS OF TECHNOLOGICAL CHANGE

A COGNITIVE APPROACH TO UNDERSTAND INNOVATION AND CHANGE IN THE WATER SECTOR

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ABSTRACT

In this paper we argue for the need to apply a cognitive approach to understand deep dynamics and determinants of technological evolutions. After examining main contributions from innovation studies to the conceptualization of innovation and change in complex socio-technical environments, we highlight the contribution coming from the application of the cognitive approach to evolutionary studies on technologies and we introduce the concept of technological memory as an interpretative tool to understand those changes. We discuss our hypothesis with reference to several observations carried out in different local contexts – Mexico, India and Italy – in relation to technological change in the water sector. In those cases deliberate attempts to substitute traditional technologies with modern ones led to interesting trajectories of change ranging from the collapse of old technologies to the development of multifaceted hybridization patterns.

KEYWORDS

Technological Evolution; Innovation Studies; Cognitive Approach; Technological Memory; Water

1 INTRODUCTION

Debates on sustainable technologies for urban and territorial management – being them related to water, transport, energy or any other major sectors – tend to be restricted to issues about how to support the transition to green infrastructures and more sustainable technologies. This means, on one side, a focus on key technological components and an evaluation of their technical performance, in order to support R&D efforts in sustainable directions and to "push" technological innovations towards greener outcomes; on the other side, this means a great attention to the identification of best possible governance, market and policy strategies to sustain a societal transition to them, i.e. their wider adoption within society. In all this technology tends to be treated like black-box, like something exogenously defined by engineering R&D efforts, on which society has, at most, the power to accept or reject it on the basis of its preferences.

Even if research on technological innovation has deeply tried to challenge that simplistic view by proposing social constructivist approaches to science and technology (Bijker et al, 1987; Bijker, 1995) and by giving a much stronger role to people besides their being passive consumers (Breschi and Malerba, 1997), technology is still commonly conceived of as linearly progressing along a technology-push approach to technological innovations. In this perspective, an heroic idea of technology, as resulting from the diffusion within society of radical inventions made by few, is still dominant (Shumpeter, 1934, 1942), as well as the idea of linear path of progress as proceeding from an old, backward technological past to modernity (Rostow, 1960).

But evidence from real case situations often shows the opposite, i.e. that technological evolutions are sometimes – if not very often – linked to the work of many distributed agents and thus follow a pattern nurtured by several micro-learning processes instead then pushed by large breakthrough events (Garud and Karnøe, 2003; Hendry and Harborne, 2011; Grassini, 2011). On the other side, they show that evolutions are rarely done along linear patterns of change, as they are marked by many returns and recombinations of traditional and new components and practices (for an account in the water sector see also Barbanente et al., 2012; Grassini, 2013).

While these observations have constituted the ground for empirical and theoretical research in innovation studies, research findings have rarely been linked in a more comprehensive theoretical framework of technology evolution. Moreover, a cognitive perspective in the analysis of technological change and innovation is still largely to be developed. In this paper we will try to address these issues by developing a cognitive frame to the analysis of technological innovations, with the final aim to help in shedding light on the functioning of the "black-box" of technology and its evolution.

In our discussion we consider technology as an organization of cognition-action abilities of individuals and societies aiming at reproducing their life and incorporating resources available to them. In particular, we will discuss the concept of technological memory as a medium to understand technological change (TC) in a cognitive and micro-organizational perspective and will try to address some major questions, i.e.: is TM a particular form of memory or does it comply with the dominant model of generic memory currently postulated?; what is the relation between social and individual learning in TM?; which influence does TM exert on evolutionary pattern of technological change?

This discussion will be done in relation to a case study about the evolution of water technologies in several local contexts, i.e. Mexico, India and Italy. Water technologies offer an exceptional stance in the above mentioned perspective, because of their centrality in the ecology of living beings. In this field, the centralized large-scale hydraulics produced by standard technical expertise is increasingly challenged by small and distributed hydraulics, bioregional, ecologically more resilient, produced by local common knowledge well adapted to the local environment (Borri et al., 2010).

In all three cases under examination in this paper, evolutionary technological patterns look particularly interesting since local socio-cultural and technological traditions at some points merged with external knowledge systems brought either by conquerors (this happened in the cases observed in Mexico and in India) or by more recently developed global/engineering science (this is the case observed in Italy). In all cases, complex trajectories of sociotechnical change developed, with traditional knowledge combining with other knowledge systems through multifaceted processes of domination and resistance. While these changes often led to the collapse of traditional systems, sometimes indigenous technologies resisted to the domination and evolved through interesting innovation and hybridization patterns, where tradition became not only a memory of the past but a generative force able to shape the future through innovation. In this process, cognitions and actions are strictly interwoven and activate new opportunities for change as a generative enactment process (Weick, 1995), where old concepts and routines are mixed with new ones.

The paper is thus structured as follows: in the next section we discuss major research findings in technological innovation studies with reference to systemic and co-evolutionary approaches to technological innovations and to the role of distributed actors in innovation processes. In the third section we then highlight potential and limitation of the actual application of a cognitive lens to understand technological change, thus introducing the discussion made in the following section about the concept of Technological Memory. Finally, in the concluding section we discuss key findings from the case studies, which are interpreted according to the TM lens.

2 EVOLUTIONARY PATTERNS OF TECHNOLOGIES

Innovation and technological change have been a core concern in economics as they have been traditionally considered at the root of economic growth (Schumpeter, 1942; Solow, 1957). In his book "The Theory of Economic Development" Schumpeter argued that development (at that time considered to be equivalent to the concept of growth) was the result of the innovative ability of the entrepreneur and his introduction of new methods of production (Schumpeter, 1934). In his writing technological change was considered to be proceeding through three stages, namely invention as the stage of generation of new ideas, innovation as the locus for the development of new ideas into marketable products and processes, and diffusion as the stage for new products and processes to spread across the potential market.

How to foster technical change and which are the determinants and effects of innovation and technological change have been highly relevant and intricate questions for economists since then, in the attempt to increase the rate of productivity of economic enterprises (Schmookler, 1966; Mansfield, 1968; Rosenberg, 1982; Griliches, 1984; Nelson and Winter, 1982; Scherer, 1986). The famous "technology push" model, which has been the basis for the development of the linear R&D model of innovation, is directly connected to Schumpeterian ideas and has been highly influential in the definition of policies to induce innovation. In this model, innovation is mainly proceeding from the engineering application of scientific discovery through manufacturing to the marketplace – thus having in R&D efforts the real boosts of innovation and reducing users to passive consumers of technological products. The demand pull model is but another version of this linear model of innovation, whose only difference from the other is the attribution of a more active engagement of users through market demand, which constitutes a source of new ideas to direct R&D efforts (Schmookler, 1966).

Both models paid little attention to the socio-cultural environment where innovation were supposed to take place, which was mainly narrowed down to a simple "selection environment" (Breschi and Malerba, 1997). They brought with them a powerful conviction that innovation and technological changes were a sort of "black box" (Rosenberg, 1982) proceeding as breakthrough events made by few talented innovators and that the growth of an economy was directly linked to the capacity to apply innovations and technological changes to increase its productivity. In this line, traditional entrepreneurship literature primarily attributed the success and failures of innovation activities to specific individuals (Gartner, 1988), mainly conceptualized as heroic individuals who have the ability to discover, create and exploit opportunities that lie beyond the reach of most.

At the same time, powerful economic theories postulated the existence of a linear progression of economic growth along a predetermined path from a backward past to modernity, with "take off" being deeply related to the capacity of countries to unload the traditions of the past and adopt modern technologies and models of production (Rostow, 1960). This strongly supported the transfer of technology as a key approach to spur economic growth within lagging behind economies. This quick-and-fix approach to the use of new technologies to solve complex development problems of developing economies dismisses glibly the achievements of the past (Agarwal and Narain, 1997) and underestimates and minimizes the many difficulties some of the new technologies have brought in their wake. This is particularly evident in relation to technological innovations for environmental management, where increasing critiques emerged highlighting the environmental as well as the social and cultural side effects of the application of the technology-push and the transfer of technology approaches (for the water sector see also Escobar, 1996; McCully, 1996; Postel, 2000; Shiva, 2001; Grassini, forthcoming).

At the same time, this conception neglected the differences of local contexts in terms of factor endowments and assets, including natural resources, knowledge and social and cultural capital. In so doing, the productivity of technological innovation along imitation curves run the risk to be significantly lower than that obtained from innovation efforts rooted in local factor endowments (Hicks, 1932). This is particularly evident in the field of natural resources management, where traditional technologies – which developed in close tune with the capacity of local population to exploit the potential of their endowments – undergo the tendency to be substituted by modern technologies ubiquitously transferred across the globe (Ahmad, 1966; Binswanger and Ruttan, 1978). On particular case of this tendency and a critique to its effect in wider terms have been recently discussed also in the field of water resources management (Kubursi et al, 2011).

Initial attempts to open the black box of technology and to show the more intricate and complex dynamics leading to innovation and technological changes were made within evolutionary economics, with its claim for a non deterministic description of technology development, the role of limited rationality of involved actors and the co-evolutionary linkages between technologies and organizational settings (Nelson and Winter, 1977, 1982; van den Bergh and Gowdy, 2000). The notion of "technological regime" (Nelson and Winter 1977, 1982) and of "technological paradigm" (Dosi, 1982), as an extension of the Kuhnian concept of "scientific paradigm" (Kuhn, 1962) to the technological field, were developed to explain the influence of cognitive routines shared by the technical community on technological trajectories of change.

The need to adopt a more systemic approach to technological innovations through a co-evolutionary framework of analysis encompassing technological artifacts as well as social, institutional and policy environment has been then reinforced by contributions within the field of history and sociology of technology (Bijker et al., 1987; Hughes, 1987), with the expansion of the concept of technological regime to accommodate the influence of a broader non technical community of social groups to the patterning of technological development (see the concept of "socio-technical regimes", Bijker et al., 1987; Hughes, 1987).

This emphasized the idea that scientific knowledge, engineering practices, and process technologies were socially embedded—i.e., seamlessly intertwined with the expectations and skills of technology users, with institutional structures, and with broader infrastructures (Kemp et al., 1998).

As a consequence of the acknowledgement of the multi-dimensional dynamics, which affect at the same time technology, user practices, policies and institutional structures through complex multi-actor processes, more complex frameworks for the analysis of technological innovations were developed within newly emerging research streams.

One of this is the multi-level perspective on socio-technical systems (Rip and Kemp, 1998, Geels 2002), with its focus on larger "socio-technical systems" (Geels, 2004; Geels and Schot, 2010) – encompassing at the same time material artifacts, techniques, but also knowledge related to them (Raven and Geels, 2010), networks of actors, and institutions (socio-cultural norms, technical standards, regulations) (Voβ et al., 2009; Farla et al., 2012) – and its attempt to develop a theoretical framework to explain the non-linearity of technological transitions by the interplay of dynamics at three levels: niches, regimes and landscapes (Geels, 2002). Another is the field of technological innovation systems (Hekkert et al., 2007; Bergek et al 2008), which applies methodologies coming from the analysis of National Systems of Innovation or Sectoral Innovation Systems (Carlsson and Stankiewicz, 1991; Archibugi and Lundvall, 2001), with its attempt to overcome the narrow concept of market failure as the only responsible for poor diffusion of innovations and to single out a broader set of system failures, which encompass institutional, infrastructure, organizational aspects (Negro and Hekkert, 2008).

These frameworks have been successfully employed in the environmental domain, where they contributed to contrast the simplistic and overenthusiastic faith in the "technology fix" approach for solving environmental problem, which could only provide partial and temporary solutions due to rebound effects or other unintended consequences (Farla et al., 2012).

In so doing, they have supported the birth of a newly formed field of research dealing with environmental innovation and "sustainability transitions" (Elzen et al, 2004; Geels et al., 2008; Smith et al., 2010), which specifically developed both detailed accounts of the formation of new socio-technical configurations, as well as frameworks for analyzing determinants of radically new modes of production and consumption. In so doing they try to find the way to sustain sustainable practices and technologies in their struggle against existing systems or "regimes" (Kemp, 1994; Geels, 2002) stabilized by various lock-in mechanisms that tend to lead to path dependence and entrapment (Unruh, 2000; Walker, 2000).

As a result of the application of the above mentioned analytical frameworks to the issue of innovation and technological change, several steps have been made in the direction to obscure long lasting convictions about innovations and technological changes.

One of them is certainly the idea that technological innovation only proceeds through heroic and breakthrough events, which is increasingly challenged by a growing body of research dealing with those cases where innovations are not based on any new dramatic and breakthrough inventions or scientific discoveries, but rather on the steady accretion of inputs from many actors (Garud and Karnøe, 2003; Kamp et al. 2004; Hendry and Harborne, 2011; Grassini, 2011). This in turn is leading to the re-evaluation of the importance of a multiplicity of learning modalities – learning by doing, learning by using, learning by interacting – besides the much celebrated learning by search (Kamp et al., 2004), and to the acknowledgement of inherent fragility of high-tech breakthrough development patterns deriving from the technology-push approach as far as they tend to overcome and to stifle multiple micro-learning processes from distributed agencies (Garud and Karnøe, 2003).

3 A COGNITIVE APPROACH TO TECHNOLOGICAL CHANGE AND INNOVATION

Although more recent contributions of innovation studies and contemporary framework to understand the evolution of complex socio-technical systems pay large attention to inputs and micro-learning processes made by distributed actors as well as to the contribution of several types of knowledge to the process, cognitive factors, including attention, memory, and reasoning, did not receive any systematic treatment in relation to technological change. By application of a cognitive lens to technological change and innovations we mean the attempt to link technological changes with the way individuals and groups organize their knowledge about technology and make decision and act in relation to it.

Cognitive approaches have received increasing attention within the broader field of organizational theory (DiMaggio, 1997, Walsh, 1995) since the seminal work of March and Simon (1958), which highlighted the cognitive foundations – assumptions about the future, knowledge about alternatives and perception of possible consequences of actions – brought by individuals to management decisions within organizations. These set of givens – or "frame" (Goffman, 1974) – soon started to be recognized as a key concept to explain the way individuals make sense of highly complex and uncertain environments and are able to make decisions and actions in relation to it (see also Argyris and Schön, 1978; Schön, 1983).

The importance of cognitive frames and routines (e.g. search heuristics, exemplars, interpretations,…), which are shared within a technical community, in guiding and orienting engineering activities in the technological change process started being recognized within evolutionary economics with the introduction of the concepts of "technological regime" (Nelson and Winter, 1982) and of "technological paradigm" (Dosi, 1982) as important determinants of trajectories of technological change. Similarly, social constructivists used the term "technological frame" to encompass the whole set of problem agendas, problem-solving strategies, search heuristics, theories, design methods, testing procedures (Bijker, 1995) owned by a certain community and acting as retention mechanism through which communities store accumulated knowledge (Raven and Geels, 2010).

The very concept of "technological frame" is quite recent and comes from the attempt to draw on the concept of cognitive frames (Tversky and Kahneman, 1981; Weick, 1995) and to apply it to the context of technology in order "to identify that subset of members' organizational frames that concern the assumptions, expectations, and knowledge they use to understand technology in organizations. This includes not only the nature and role of the technology itself, but the specific conditions, applications and consequences of that technology in particular contexts" (Orlikowski and Gash, 1994, p. 178). In their work Orlikowski and Gash (1994) used the concept of technological frame to understand the dynamics of technological development and change within organizations and to explain the differences in the nature and extent of the early use of an Information Technology within an organization in comparison to expectations of technologists. In so doing, this work shows an increase in the difficulties and conflicts around the development, use and change of technology when technological frames of key groups within the organization (managers, technologies and users) are different. It furthermore succeeds in combining research on frames, which are individually held, with research on institutional analyses, which are concerned with the shared, taken-for-granted systems of social rules and conventions that structure social thought and action (DiMaggio and Powell, 1991). In this work, nevertheless, technology is still mainly considered as exogenously brought in organizations, so the focus in not much on the roots of the innovation system but on the adoption of some technologies.

On the basis of this work, some scholars tried to use technological frame as an interpretative system to understand corporate strategies in relation to technology, and ultimately their linkages with a competitive dimension of the firm (Acha, 2004). Also in this case, the focus is on inter-organizational dynamics in relation to exogenously driven technologies, but the work is insofar interesting as it underlines the competitive advantage of the match between technological features and technological frames of key people within specific organizations.

One interesting attempts to use a cognitive perspective to explain patterns of technological innovation has been made by Paul Nightingale (1998), as far as he uses a cognitive approach to demonstrate that the application of science to produce technology can only happen through the mediation of tacit knowledge (Polanyi, 1967), i.e. the background of interwoven experience and the capacity to relate experience to it, and tacitly understood traditions of technological knowledge that co-evolve with technological paradigms. In so doing, he maintains that technological innovations are directly linked to embodied and socially embedded technological traditions, i.e. a set of beliefs, based on previous design experience, about how technology should function and how problems in the innovation process should be solved. Although his reasoning is applied to a very simple case of technology innovation, which does not encompass all complex dynamics rooted in micro-learning processed from distributed agencies which often nurture the cases of socio-technical innovations in the environmental domain, this research shows the importance of tacit understood traditions of technological knowledge, which are embodied in the brain and embedded in socialized practices.

Following the work of Nightingale, Kaplan and Tripsas (2008) applied a cognitive perspective to explain technical change by developing a co-evolutionary model of technological frames and technology. In particular, they identify technological frames as a source of variation in the era of ferment, framing activities as something helping the achievement of a dominant design when one emerges, and the intertwining of technological frames and organizational architecture in the era of incremental change as one of the reasons why transitions in those periods are so difficult. In this study the focus of the attention is still on individual cognitions, which are considered to be the drivers of technological change, although some implications are underlined about the way individual cognitions impact on collective understanding of technologies insofar they discuss the links between actor's technological frames and interpretative processes, collective technological frames and the evolution of a technology.

A more explicit considerations of a socio-cognitive perception within the study of technological transitions is made by Raven and Geels (2010), insofar they try to explain key steps of radical innovation emergence by adopting a socio-cognitive approach. In particular, they focus on a socio-cognitive explanation of the mechanisms of retention, variation and selection for the diffusion of the innovation. In so doing, they try to show how actions of different agents – being them producers, engineers, users, institutions, … - are shaped by expectations, understanding, assumptions made by each of them, which guide the way they interpret facts about technology and act in relation to them.

Our discussion of technological memory, which will be made in the following paragraph, builds on these attempts to include cognitive factors in the analysis of technological evolutions, but it will also try to overcome their almost exclusive focus on behavior, i.e. their main consideration of cognitive factors as interpretative tools to explain the behavior of distributed actors in relation to their interpretation of complex socio-technical contexts.

In so doing, we also root our discussion in the foundations of cognitive science, with its attempt to study representational and computational capacities of the human mind and their structural and functional realization in the human brain. As such, our work is indebted towards seminal works and deep transformations happening in the 1950s at the crossroads of psycology, linguistics, antropology and neuroscience, with the development of new approaches and methods in experimental psycology in

contraposition to behaviorism, the foundation of cybernetics (Wiener, 1948) and the cognitive revolution in theoretical linguistics (Chomsky, 1957, 1961), the emergence of computer science and neuroscience with the invention of artificial intelligence (Shannon and McCarthy, 1956; Minsky, 1961, 1967) and the use of computers to simulate cognitive processes (Simon et al., 1958, 1969).
Within this framework, in the following paragraph we will specifically reason about one of the cognitive functions, namely memory, and its implications for technological change and innovations.

4 TECHNOLOGICAL MEMORY AS AN INTERPRETATIVE TOOL FOR TECHNOLOGICAL CHANGE

Memory is a fundamental component of living organisms. If deprived of memory, for example, a living organism cannot find a destination in space, select safe food, tailor its behaviour toward others, perform correctly a learned task beyond instinctive skills, think and act usefully and normally in many other domains and occasions. Cognitive science, particularly neuroscience (Damasio, 2005; Edelman et al., 1992), has recently illuminated many potentials or constraints relating to the individual memory of the living, while the same cannot be said of social memory. Indeed, the very concept of social memory appears problematic and ontologically questionable, both because it is apparently based on nothing more than relations between individual memories, and because it is difficult to be experimented. In fact, a brain injury can be analysed experimentally in a living organism, today, by looking at the decreasing "knowledge-in-action" (Friedman, 1987) abilities of that living organism, whereas a social-memory deficit can not. On the other hand, as explained by anthropology and psychology, this does not obscure the great contribution of social memory in the construction of social organizations in which individual memories are embedded and develop. It is an inextricable link between the living and its social space of life, so important that its primitive absence (or more often a laceration) leads to alienation and the impairment of the ordinary knowledge-in-action abilities (Damasio, 2005).
Commonsense reasoning assumes memory as an important component of ordinary action abilities, but also as a minor component (or even counter-component) of extraordinary creative or action abilities (Weisberg, 1993). Probably the complexity of the memory-part of the brain deceives the common sense here, similarly to what happens in physical sciences when facing highly complex phenomena. Current literature points out how creativity, as an ability of organizationally and 'combinatorially' innovating past knowledge, is founded largely on memory (Bink and Marsh, 2000).
Newell and Simon have showed that human problem solving ability links to a cognition-action rule based memory gradually framed through interaction with the real world and education and accessible via an innate program (Newell and Simon, 1972). Anderson has supported the idea of a modular architecture of cognition having at its centre a long-term memory (dualistically oriented towards facts and procedures) and a working memory (Anderson, 1983).
Today, computer science gives a powerful proof of the critical role of memory in all the diverse knowledge-in-action abilities. It emphasizes the role of memory as essential base, together with reflexivity and intentionality (which operate just on individual and social memory), of the development of organizational and combinatorial abilities. The continuous expansion of memory and the increased accessibility to memory – e.g., through the process of multiple indexing (Schank, 1999) – provide even better performance on computers, with very high computing speed that eliminate the processing time of huge chunks of memory in which erudite (rather than creative) reasoning operations are carried out.

A library or an archive are examples of social memory deposits, whereas memorials are examples of physical deposits of individual memory. A civic library can be seen as an example of deposit of social local-based memory, which collects individual knowledge somehow built, developed, stored by individual agents as part of the social knowledge of that local milieu. The lack of a civic library and the presence of merely generic libraries (i.e., the lack of records of local, civic history in that place) makes it complex the reconstruction of knowledge and knowledge-in-action in that place. This is particularly true when those knowledge and knowledge-in-action have been peculiar and have not emulated other general knowledge and knowledge-in-action (Fagin et al., 1995).

The concept of knowledge-in-action makes it possible to avoid the divide between theory and practice, and it looks particularly fertile for the exploration of technologies and their changes. In this case, we are dealing with the physical (but even increasingly virtual) organization of knowledge and knowledge-in-action, which is presumably useful for the preservation and the transmission of a diffused social knowledge. If such a library is missing, yet the place may not be unable to preserve and transmit knowledge. This ability resists in conditions of experiential continuity: but it may annihilate because of great discontinuities induced by complex problems. Such discontinuities may cause those problems to be solvable not merely by using creative individual memories, but also and especially by relying on erudite social memories (Borri et al., 2009). The concept of technological memory is strictly connected with the above considerations.

In human individual agents, Hofstadter postulates the existence and the need of an "episodic memory", derived from experience. It is essentially built around problem-solving, around the development of episodes and events, and it would be a key deposit for future action and to solve a new problem from the knowledge of the solution to a connected problem. It is a deposit that kids fail to build up in their permanent, long-term memory, so that adults have little or no memories of childhood and related experiences (Hofstadter, 1995). It is a deposit with high value and hierarchical level in the scale of cognitive abilities, so that it is hard to build up automatic reasoners incorporating that ability ("the system must go through its own experiences just as a person does, and store them away for future use") (Hofstadter, 1995).

The conceptual memory evoked in the intelligent software Letter Spirit, built in the 1980s for the design of alphabets artistically consistent, seems to be particularly close to our concept of memory of technological concepts. These technological concepts have a particular social gist in a solution domain of highly complex social and relational problems, which are embedded in local/global chains and situations they cannot exist without (McGraw and Hofstadter, 1993).

The concept of technology and technological change is a highly social concept: within it, memory is essential but it is a social memory, constituted by the interplay of individual memories. Let's consider the case in which an entire generation of individuals, who made a certain technological experience, goes away, leaving a range of technological experiences impossible because of that departure. Then the episodic memory would have no way to activate and could only resist in the individual memories of the next generation, as a 'second hand' wreck of primitive knowledge (or memory). This would in turn cause a decay of memory due to lack of reinforcement, and in further generations that episodic memory might vanish altogether, turning into legend. In this context, the Mexican case studied here is a fair witness of such scenario.

Also the Memory Organization Packets (MOPs) and the Thematic Organization Points (TOPs), postulated by Schank (1982), are directly connected with the concept of technological memory evoked by us.

It is helpful to use a concept of linguistic memory (Schank, 1980) to support the concept of technological memory. In fact, as in technology, apparently also in language an interruption of social abilities (language, local dialect) may occur, so involving the disappearance of one or more generations of speakers of that language in that place. It is like the loss of a living species: if it disappears at all, then we should hope that an akin variety exists somewhere, in order to transplant it and re-activate the lost language. If it does not disappear completely, then a deposit of individual memory can support the reconstruction of other individual deposits and (through interactions) of a social language deposit able to evolve, to adapt, to solve and declare new problems, etc.

As far as our individual agent's memory is concerned, we could speak at a lower level of abstraction about musical memory, mathematical memory, aesthetic memory, sensorial (smell, taste, touch, etc.) memory. They are individual memories, whereas technological memory is a primarily social concept because it refers to an essential apparatus of social resources and cooperations, without which the *techne* on which the *logos* is inserted is impossible, like an ambitious promethean dream.

5 EVOLUTIONARY PATTERNS OF WATER TECHNOLOGIES IN SELECTED CASES

Interesting insights about how technological memories evolve together with technologies themselves and about their individual and communitarian use come from some observations on the evolutions of traditional technologies in very different local contexts, namely in Mexico, India and Italy.

In the Mexican cases[1], we observed the evolutions in relation to a prehispanic technology, jagüey, which is an artificial water reservoir carved in the soil near the hills, where water is diverted through natural or artificial channels. Its use strongly rely on the capacity of local community to maintain it, as desilting of channels and reservoirs as well as proper cleaning of the runoff surface need to take place. The memory of this technology thus include elements of construction, maintenance and use.

A main change in the knowledge-in-action about this technology happened with the arrival of the Spaniards and the colonial period, which produced what some authors have called a "mestizo architecture" (Castro, 2006), i.e. a syncretistic process where previous existent technologies merged with overseas experiences leading both to the introduction of completely new elements like the aqueducts and the renaming and refashioning of already existing devices for water extraction such as wells, aljibes [cisterns], and jagüeyes.

Within this period of breakthrough events, when abrupt changes were introduced within the water field, with the promise to bring abundance and prosperity as well as to ease the use and maintenance of water technologies, technological memory of the specific jagüey technology underwent deep modifications. A survey was made to understand the prevalence and use of jagüey as a main water source for small rural Mexican communities and the main features and diffusion of technological memory within two villages in Mexico, namely San Antonio and San Martín in the State of Puebla (Torregrosa et al., 2010). This survey revealed how that technology and its memory persisted and reproduced across time only when they represent a culture in action, i.e. they are part of culture and everyday life. In particular, although jagüeyes generally tended to disappear in Mexico as water coverage due to piped water or other modern technologies increased, significant differences were noted in the two cases. In particular, in the case of San Antonio an important fraction of the male population was found to still understand and be able to reproduce the technological principals at the basis for the construction of the jagüey – at least in theory as most of them never constructed a jagüey. On the contrary, in the case of San Martín the chances of reproducing this

1 Case studies in Mexico were analyzed within the research project ANTINOMOS, "A knowledge network for solving real life water problems in developing countries: Bridging contrasts", funded by the European Commission under the Sixth Framework Program, thanks to the joint efforts of the international consortium and field research made by the Latin American Faculty of Social Sciences (FLACSO) team (Maria Luisa Torregrosa, Karina Kloster and Jordie Vera).

technological system are scarce, the only knowledge remaining is related to the maintenance tasks and not to the technological principles for its construction.

These difference were explained with two factors, which are related to the way technological memory was built and the way it is currently linked to knowledge-in-action. In relation to the origin of technological memory, a key difference comes from the fact that while in San Antonio the jagüey was built at the beginning of the twentieth century by grandparents of current village dwellers, so that these have a strong memory of the construction of that technology as it was linked to stories told in their childhood and to names of people they perfectly know as previous members of the community, in San Martín, local dwellers obtained that technology through land endowment in the 1940s, so they did not build it and do not have any memory of its construction (Torregrosa et al., 2010).

Secondly, it's worth mentioning important differences in the actual use and reproduction of that technology in the two villages. In San Antonio jagüey recently underwent a process of innovation and change as a small dam for reducing silting of the system and a biofilter to increase quality of water taken from the jagüey were recently constructed thanks to the support of the federal government and the cooperation of villagers. In so doing, local dwellers reinforced their knowledge about the system and their memory about its use through individual and collective actions for the evolution of the system. On the contrary, in the case of San Martin, where the population has grown and differentiated, the introduction of piped water has carried along the disuse of the jagüey for human consumption. In this case the culture in action in correspondence with the use of the jagüey and its memories are disappearing.

In India we observed the evolution of water tanks, which constitute a traditional and widespread water storage system for individual and communal use in urban as well as in Templar complexes. They were traditionally built underground, with retaining walls made of bricks or local stones and held together by silt, and were receiving rain water from roofs and terraces through a system of copper gutters and downspouts. They had a small opening on the roofing from which you to draw water with buckets.

The evolution and memory of this technology was observed in the old city center of Ahmedabad, in the Gujarat State, where large tanks with an average storage capacity of 25.000 lt had been built in the past. A survey made by the municipality showed a huge diffusion of this system, with the presence of about 10.000 cisterns within the old town, out of a total of about 70.000 houses, although more detailed investigations carried out on the site allow to assume the presence of an even greater number of tanks (AMC, 2000; Grassini, 2003). They were mainly individual systems, directly put under the premises of each house, with the opening in the internal courtyard of the house, in the near vicinity of the kitchen.

A main breakdown in the knowledge-in-action of this system happened between the 1940s and 1950s due to several events. On one side, the order of the British government to seal those systems at the time of the Indian struggle for independence, in order to avoid that they could offer shelter to any rebels (AMC, 2000). On the other side, the beginning of piped water supply through the newly built aqueduct system within the city, which took place in the 1950s and led to the definitive abandonment of these ancient systems in favor of a system, which was conceived of as more efficient and not needing any individual nor communal effort for maintenance.

As a consequence, at the beginning of 2000 all tanks within the old town were not in use, and a vast majority of them were strongly compromised by their recent use as damp sites. The memory of that technology was very superficial within the community as they did not have any link to knowledge-in-action neither in relation to the construction nor to the maintenance needed to ensure that only clean rain water could be stored and kept of a good quality.

Despite these limitations, at the beginning of 2000 a pilot project started for the rehabilitation of 11 tanks within the old city center, with the aim to demonstrate the re-use potential of those systems. It was indeed a top-down and elitist project, which was promoted by a cultural association guided by the State Ministry of Health, which was himself a resident in the historic center, with 100% funding from the Heritage Cell of the Ahmedabad municipality. The project thus resulted in a mere rehabilitation of the physical structures of the old technology, which was completely detached from any change in the broader socio-technical system and in the technological memory held by local community. Technological memories and perceptions of this technology remained completely unchallenged by the project, thus rehabilitation did not make any substantial change in the deep understanding of water technologies within key local actors.

The last case under scrutiny is related to deep technological changes produced in the water field in the Apulia region, in Southern Italy, in the last Century. The history of water management in this region is the result of a complex interplay between a slow evolution of traditional techniques and breakthrough events of deep technological change, which erupted at the beginning of the XX century with the construction of the current largest aqueduct in Europe.

The construction of this titanic engineering effort, which attracted attention from all over the world and made Apulia suddenly start its run towards progress and modernity (Viterbo, 1954[2010], Masella, 1995), created an abrupt break between past and future. This was done, on one side, in terms of physical infrastructures, as the spreading pipelines were rapidly leading all traditional techniques, mainly based on rain water harvesting (especially underground tanks in urban areas as well as in rural contexts), to disuse and collapse. But this also had important implications in terms of deep perception of water and its use by the local population as far as it made local people believe that technological change could definitely free them from scarcity and from the old thirst, beyond any environmental limits and foreseeable constraints, and let them forget their backward past to embrace prosperity and progress. In this idea, technology became a sort of black-box, a saving tool, whose construction and functioning was fully devoted to engineers and technical people. This quickly led to a decay, among local people, of technological memory about traditional water use and techniques, and made them embrace new practices and patterns of water use derived from a concept of water as abundant resource (For a more detailed account of the evolution of water technological systems in Apulia and their interpretative process see also Grassini (forthcoming)).

An analysis of the processes which made this change happen and its wider consequences in terms of the conception of technical progress and changing relationships between local communities and the environment showed how the different conception of technology and its role for progress produced deep changes not only in the way people related to new – imported – technologies, but also in the way they used traditional technologies – whenever they persisted and did not go defunct, like in the case of wells. While in the past their use had been mainly related to subsistence and individual purposes, the diffusion of mechanized systems for water extraction made that technology become one pillar of the widespread attempt to guarantee abundance of water for modern production systems.

The idea that the rise of the water supply was an undeniable right, especially for the population of a region that had long suffered from lack of water, and the underestimation of the impact that the spread of modern techniques for water extraction from underground aquifers could have on aquatic ecosystems led to subsume completely those technologies and their functioning within the newly imported socio-technological regime. This is a well known mechanism related to knowledge evolution in contexts where traditional knowledge merge with other knowledge systems giving rise to several combinatorial possibilities: primary-level practices and facts learned from external knowledge may be subsumed under secondary-level interpretative concepts from pre-existing systems; conversely, newly-acquired secondary-level concepts may be adopted to explain practices of the existing systems (for an interesting account of this mechanism in the case of tree management technologies in India see Brodt, 2001, 2003) or, as in the case of the Apulia region, re-organize existing practices to new aims and purposes within new socio-technical trajectories of change.

6 CONCLUDING REMARKS

We have evoked the concept of TM starting from evidences presented by some case studies of water technology in environments in which traditions and memories still resist to innovations and standardizations. Meaningful cases are the water technology of the Mexican jagüeyes, the Indian tank systems and several traditional technologies observed in Italy, whose actual persistence or interruption is due to complex and multifaceted processes of technological evolution. In those cases, micro-learning processes and the distributed inputs of a multiplicity of agents collide with breakthrough events suddenly imposed by conquerors or by modern science. Since the ancient ages, in arid climate countries, water technology presents extraordinary examples of specific organizations devoted to designing, constructing, and managing complex and ambitious works. The gradual minor adjustments that have been brought to the original forms of these works through infinite replications in different places and times suggest that social forms of cognitions and actions interacted with individual contributions, granting a blend of mutual learning and transfer of memory and creativity.

With the gradual disappearance – for many reasons – of the productive and market organizations on which certain techniques are based, technological memories referring to them begin to suffer transformations and sometimes become unusable. One such example in the field of architecture is related to the construction of large roofings in the Roman Empire. While in Rome during the Empire age a semisphere of more than 40 metres of diameter was built for the Pantheon's dome in a very sophisticated way with extremely light prefabricated clay pieces settled in concentric circles and linked by high resistance and extremely light mortar, covering large spaces without intermediate supports became impossible for the next 1.500 years, until the reinvention of a different building solution (much less sophisticated: heavy masonry, made of bricks reinforced by big ribs) with the Gothic dome designed by Filippo Brunelleschi for the cathedral of Saint Mary in Florence (Petrignani, 1978). In this case, the disappearance of the Roman political and productive organization operationally annihilated a technological memory. Building history and techniques in exceptionally wide perspective were presumably perfectly known by Filippo Brunelleschi in Florence or by Andrea Palladio in Venice: the two giants of architecture presumably shared the sectoral TM which was needed for emulating the Roman technique of covering large spaces but they did not have anymore the ability of making it operational.

In the light of the above simple considerations, thinking on one side to the Newell's and Simon's memory model (abilities as gradually formed by series of condition-action rules) (Newell and Simon, 1972) and on the other to the Anderson's one (factual memory plus procedural memory) (Anderson, 1983), the idea is that TM is labelled in relation to its own essential attributes like facts, procedures and judgments. Then it becomes clear how parts of TM learnt through experience within a tradition, or through descriptions from others, can be gradually abandoned till the eventual cancellation or be more probably qualified with obsolescence and impracticability attributes.

Let's come back again to the difference in TM between the big Roman constructions and the constructions built in the ages to come. Perhaps the giants of technique and creativity in the Western world ignored some operational details of those constructions, for example the preparation of special pieces and mortars, and therefore they could not design them even if hypothetically they belonged to a still practicable activity. As a matter of facts, individual memories make sense not per se but within social chains of context-based practicability, they are made by transmission rings cut and interrupted by disappearance of individuals, organizations, resources, and examples (Severino, 1988).

As a consequence, TMs are constituted in the agents through direct or indirect (i.e., diffused outside from local origins) experience, and can:

(i) be limited to simple passive cognition of facts and procedures ("I know that a certain technique exists" or "I saw that technical device while functioning", or "Somebody described to me that technical device but I never had a chance to use it") or

(ii) become part of an active inclination of the agent as a direction given by him/her to other agents (political agents can tell other agents to adopt that technique: they have to learn it immediately, if they do not know it yet), or, further,

(iii) become part of a life that uses that technique ("I am a user of that technical devices, should they have functionality problems I should be able to repair them" or "I saw that technical device functioning, while giving me water availability for long time", or, in the end,

(iv) become active ability ("I very well know that technical device as I had the chance to build it" or "I was present when this technical device was built and started its functioning" or "I know how to create this type of technical device here", or "I am a user of this technical device", or "I am not a user of this technical device but I could be a user of it in the future").

In a process of technical imitation, consisting in introducing an exogenous technique into a place, we witness a process of technical change, where an ecological variant is built. Its inspiring principles (ontological concepts and relations) remain substantially fixed, although they are linked to the way the imitator conceptualized that technique or to the way that technique was represented to the imitator (through a technique description by an informed agent). Therefore in technological transfer and use of TM it is important to distinguish general principles from local applications.

TM, in our view, cannot be effectively constituted, however, when the principle of functioning and applicability of its components (techniques) is not enough clear in detail. In this case, the techniques are not memorized or are destined only to passive action memories, and commonsense warns us against their possible superficiality and political orientation ("Use that technique, it has a lot of positive credentials!"), in that it can prove to be a disaster because of a too scant knowledge. So our answer to the question if TM is a particular form of memory or it complies with the dominant model of generic memory currently postulated is that operational TM is constituted by facts and explanation about facts from which actions come down: it is not a mere if-then-type memory of events and of phenomena in which causal relations are relaxed.

Furthermore, TM is constituted selectively. Selection has large stitches when human agents perceive by intuition that a large filter is essential for them, because capturing more technical memories increases their survival abilities in the future inevitable solitary confrontations with those technical problems. Selection has narrow stitches when human agents perceive by intuition that even if they do not understand those technical problems they could delegate the problem solving to others (see the Nozick's hypothesis about the emergence of a technical rationality more and more inaccessible for non-specialists) (Nozick, 1993).

In all cases examined in this paper, the construction of technological memories within local communities can help explaining the difference in the performance of technologies and in their actual evolution and use within different contexts. In the Mexican case, for instance, we have a water technology, the jagüeyes, which presents a problem of TM tragedy in a village community under the push of exogenous innovations (water engineering of the Spanish conquistadores vs water engineering of the Mexican natives). In one case,San

Antonio, TM was diffused in the whole set of community agents and linked to knowledge-in-action abilities, so that the whole society of the individuals of the village contributed to maintain the jagüeyes and became active protagonists of that technique and agents of the related TM; in case of San Martin, TM never constituted an active ability but was mainly restricted to passive cognition of facts and procedures, eventually leading to the collapse of the system. The spread of TM within the first village also explains the capacity of those villagers to adapt the ancient technology to their new needs, thus having the old components of the technology as source of innovation and technological change.

This would also confirm the concept of cognitive difference between passive or active participation in practicing a technology. In all cases we examined, innovation potential proved to be very closely related to the persistence of technological memory, which constitutes the roots of technological trajectories of innovation and change, like in the Mexican case of San Antonio. On the contrary, where memory vanished local communities proved to be unable to have any role in innovation processes and became only passive recipients of externally induced technological changes, which were mainly condemned to failure as in the Indian case.

NOTES

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