# 1. Management of emerging technologies for economic and social impact: an introduction

**Dimitris G. Assimakopoulos, Ilan Oshri and Krsto Pandza**

## PREAMBLE

From February 2010 to January 2014, the European Union (EU)-funded Management of Emerging Technologies for Economic Impact (ManETEI) – Marie Curie Initial Training Network, brought together a diverse group of leading European business schools, research institutes and industrial partners to investigate the challenges associated with the management of emerging technologies for economic and social impact.

Individual research projects progressed broadly in two directions. The first group of researchers embraced the notion that technological and organizational innovation unfolds in complex settings where a myriad of actors (companies, governments, universities and wider public) collaborate and interact in order to translate technological advances into solutions with impact of economic progress and social well-being. They followed the already recognized notion that innovation frequently depends on interplay and networking of many organizations and communities across different industries. Such ecosystems of interdependent organizations and scientific and technological communities are characterized by the wide dispersion of adequate knowledge that needs to be integrated and coordinated through collaboration and networking. This group could be further divided into researchers who investigated strategic challenges for policy makers in shaping technology development and those who centred their research on exploring collaborative and networking practices in technological and regional innovation networks.

The second group zoomed in and investigated how individual companies organize their innovation processes and identified what constitutes organizational capabilities that help organizations to capture value from emergent technologies. This group consists of researchers who investigated the foundations of organizational capabilities for technological innovation and those who explored how emerging technologies (mostly information and communication technology-enabled) help companies to strengthen their innovation capabilities.

The book is organized in four parts. Each part includes four chapters. Part I explores foundations of organizational capabilities for technological innovation. Part II explores collaboration and networking for shaping the emergence and progression of technologies. This is followed by Part III, addressing strategic challenges for policy makers that influence the sustainable and responsible development of technology. Part IV is less concerned with the technology dynamics; it investigates how emerging technology supports organizational capabilities and how novel technologies affect work and communication practices.

In the rest of this introductory chapter we discuss, in four sections: the changing conceptions of managing innovation and emerging technologies; the role of collaboration networks and communities in the process of emergence of emerging technologies; and then in the last two sections we discuss how emerging technologies relate to broader discussions on open innovation and changing work practices in organizations, with a particular reference to ICT innovations.

## THE CHANGING NATURE OF MANAGING INNOVATION

Innovation is a word on everybody's lips. However, it often means different things to different people. Policy makers responsible for channelling governmental funds into research have recently rebranded science and technology policy into innovation policy. This should remind academic scientists and technologists that their inventions require transformations into something with value and impact. The wider public mostly experience innovation through improvements in products, new gadgets, and by consuming news about technology (mostly internet) entrepreneurs and their journeys from a garage to riches. For scientists and engineers, innovation is essentially a scientific discovery or engineering problem-solving. For managers in companies, innovation stands for new products and services that support the competitive advantage of their companies. They represent a group most likely sensitive to the fact that innovation requires strategic intent, appropriate structures, coordination and incentives, yet they still mostly believe that innovation is about a link between investment into research and development (R&D) and the number of new products and services introduced to market. For economists, innovation is about studying the relations between measurable inputs into a national innovation system and quantitative outputs captured in conventional national accounting. This suggests that different constituencies are united in seeing innovation as a set of inputs and outputs.

Innovation, however, is much better portrayed as a process: a journey (Van de Ven et al., 2008) characterized by temporal and relational complexity as well as extreme uncertainty. It encompasses the emergence of novelty and patterns among activities and events that enable the transformation of novel ideas into new products, services, organizational forms or industry that create value for customers and, more broadly, for society. This process resists stabilization and continuously develops in directions that challenge established theories and the very practice of innovators. In order to make sense of complex innovation processes Garud et al. (2013) divide the process into phases and levels. Innovation progresses from invention through development towards implementation and could be analysed on a level of a firm, multi-organizational networks and wider communities.

This multifaceted and multilayered nature of innovation is even more profound if the process that connects the emergence of technology and grand societal challenges is concerned. The twenty-first century poses major challenges to protect and enhance the quality of life, economic wealth and social stability (Pandza and Ellwood, 2013). It is deemed that advances in emergent technology fields offer opportunities to address the challenges in areas such as health, energy, environment, agriculture, transport, security and education, and that these in turn create business opportunities. Two influential reports were published at the beginning of the twenty-first century to guide policy makers and research funders when making research policy decisions.

A report sponsored by the USA National Science Foundation and edited by Roco and Bainbridge (2002) introduces nanotechnology, biotechnology, information technology and cognitive technologies (NBIC) as four general-purpose technologies that, through convergence, enable improvement in human potential. The Nordmann (2004) report that was supported by the European Commission (EC) focuses on nanotechnology, biotechnology and information communication technology (ICT). Nanotechnology is the understanding and control of matter at dimensions of roughly 1–100 nm, where unique phenomena potentially enable a huge variety of novel applications. Biotechnology explores and exploits chemical and physical processes and structures in living systems that are traced to their material basis in cellular and genetic organization; it has applications in health, medicine, agriculture, food and energy. ICT is the study, design, implementation, support or management of computer-based information systems, particularly software applications and computer hardware.

Schmidt (2007) highlights some major differences between both reports, especially in respect to understanding interdisciplinarity. The NBIC report argues for a holistic view of technology based on transformative tools, the mathematics of complex systems, and unified cause-and-effect understanding. By contrast, the European approach to emergent technologies assumes that nanotechnology, biotechnology and ICT are not the only enabling technologies[1] capable of supporting each other (Nordmann, 2004: 39). It recognizes and supports the contribution of the social sciences to emergent technologies. The report explicitly suggests integrating social science research into emergent technologies, which could then be promoted alongside science and technology research. By recognizing the social and dynamic nature of emergent technology-driven innovation, the report implicitly calls for management and business studies research that uncovers insights into the socially complex processes that lie between investment into emerging technologies and social impact.

The business and management studies literature has already contributed significantly to the understanding of technological and organizational innovation and its impact on firms' competitive positions. There is a general understanding that changing technological paradigms create environments of uncertainty and instability. It is also argued that the higher the complexity of innovation, the bigger the influence of non-technical factors on the adoption of technology (Anderson and Tushman, 1990). In the context of emerging technologies, this implies that non-technical, socio-economic factors warrant special consideration from the policy, practice and social science points of view. The knowledge about emerging technologies is also widely dispersed across disciplinary, sectoral, institutional and national borders. Knowledge about technology is therefore integrated, diffused and utilized in a complex technology innovation system (Carlsson et al., 2002), which can include individuals, firms, universities, research institutions, venture capitalists and public policy agencies (or parts or groups of each).

Building on the tenets of the sociology of technology (Knorr-Cetina, 1999), Garud and Karnøe (2003) emphasize the importance of distributed agency in the wider social construction of technology progression. From this perspective, it is impossible to distinguish between the social and technical spheres; technology itself, understood as a complex mix of social and technical elements, becomes a level of analysis. New technology is viewed as a driver for the dynamic emergence of new industrial architectures, disintegration of established industries, and changes in relations between co-specialized firms (Jacobides et al., 2006). Nanotechnology potentially enables applications that will spread through different industries (Rothaermel and Thursby, 2007) and may prove fruitful for studying the influence of emergent technology on emergent and established industrial architectures.

Literature on technology dynamics has traditionally been concerned with competitive dynamics between incumbent and new firms. The notion of disruptive technology (Christensen and Rosenbloom, 1995) emphasizes the difficulties incumbent firms face when emergent technology threatens to make their core capabilities obsolete. The emergence of ICT certainly had disruptive effects on areas such as music and media distribution and publishing. On the other hand, biotechnology shows that interfirm competitive dynamics could take the form of productive co-existence between different firms of the kind characterizing biotechnology firms and the pharmaceutical industry. Interfirm competitive dynamics introduce two additional perspectives on emergent technology innovation. Competitive interactions in the context of emergent technologies often switch into a collaborative dynamic, in which members of innovation networks, orchestrators of innovation ecosystems (Dhanaraj and Parkhe, 2006), strive to integrate and share the knowledge to foster innovation. The notion of open innovation (Chesbrough, 2003) highlights the relevance of externally available knowledge, but also creates challenges to establish appropriate business models to capture value from collaborative endeavours for large global firms.

The networked nature of technological and organizational innovation and dispersion of relevant knowledge challenges firms' dynamic capabilities (Eisenhardt and Martin, 2000). Established firms face the challenge of absorbing relevant external knowledge to accelerate their knowledge trajectories or create new knowledge paths in high-velocity industries. On the other hand, new technology-driven firms, which have established an identity based on their competency in a particular aspect of emergent technology, need transformative capacity (Garud and Nayyar, 1994) to transfer emergent knowledge into a potentially immense variety of applications.

Last but not least, individual agency is deemed to be instrumental for the process of technological innovation. Opportunity-seeking behaviour is a critical element of technology entrepreneurship (Shane and Vankataraman, 2000) and managerial agency is essential for competitive survival in the context of high uncertainty. This resonates with the recent call to understand better the role of managerial agency in creating new organizational capabilities (Barney and Felin, 2013; Gavetti, 2005). Moreover, entrepreneurial behaviour is not solely contained in entrepreneurial and established firms, but is also instrumental for initiating action and creating novelty in non-profit organizations such as universities, research policy institutions and community supported organizations.

## COMMUNITIES AND NETWORKS IN EMERGING TECHNOLOGIES

Emerging technologies addressing grand societal challenges increasingly stem from neither any single company, nor a unique organizational setting. They stem from collaboration and networking within and across diverse communities, networks and regions bringing together and integrating knowledge and expertise in Europe and worldwide (Chesbrough et al., 2011; EC, 2012; Curley and Salmelin, 2013). Emerging technologies have progressively engaged a large number of organizations and people, which do not only compete, but also collaborate, forming diverse networks across all kinds of boundaries: geographical, institutional, demographic and disciplinary (Assimakopoulos, 2007; Schweer et al., 2012; Boudreau and Lakhani, 2013). In their process of emergence, emerging technologies also raise several challenges – technical, social and economic – that open up tremendous opportunities for solving the most complex and challenging problems of our era, while at the same time they create formidable barriers in understanding and managing precisely this process of emergence.

Students of emerging technologies need to acquire an in-depth understanding of an array of complex knowledge bases underlying the origins of emerging technologies vested in multiple scientific and technological communities (Constant, 2002). Such an understanding seems a vital requirement before any meaningful policy or strategy intervention is put in place for managing their emergence. As scientific and technological subject areas have become vastly complex, knowledge is accumulated in huge databases of publications and patents (Leydesdorff et al., 2013). The organization of collective knowledge in subject categories, patent classifications and the like seems a necessary evil for bounding disciplines and associated communities of experts in silos of vested interests. Experts and knowledge workers need first to absorb 'disciplinary' knowledge before they start transcending boundaries, collaborating for innovation and emergent technology across boundaries. Recent research has also shown that experts are rewarded if they broaden their expertise in several knowledge domains, and both publish and patent their knowledge in an intricate interplay of scientific communication and intellectual property protection (Murray, 2002; Meyer, 2006; Breschi and Catalini, 2010). As a result they have to make choices about whether they socialize and engage in multiple relevant communities involved in the social shaping of emerging technology, maintaining multiple memberships and appreciating different professional values and beliefs in the process of engaging with these communities.

Nowadays a cross- or multidisciplinary understanding of emerging technology is challenging to achieve on an individual basis. This is often grasped at the collective level, by both pre-existing and new emerging technological communities, professional associations, committees setting standards (Rosenkopf and Tushman, 1998), and securing both continuity and change in terms of pre-existing and emerging technologies (Assimakopoulos, 2000). Membership in multiple communities raises its own challenges as each subject area and scientific or technological community has accumulated a vast body of knowledge that unavoidably creates cognitive dissonance to outsiders. It also fosters patterns of collaborative behaviour that often embed and to some extent lock in experts to networks and communities where they talk the same language and share the same interests, values and beliefs (Bechky, 2003).

Nonetheless key actors and institutions in an array of communities try to shape the technological evolution of emerging technologies and socially construct their deployment and use. A myriad of actor networks (Latour, 2005) have tried for decades to create and take stock of necessary research infrastructures, testing scientific discoveries, and carrying out trials for new solutions in terms of diagnosis and treatment (Rosenberg, 2009). For example, in developing and diffusing new therapies for cancer there is a basic requirement for carrying out trials that they may last five to ten years minimum for establishing mortality rates or/and quality of life after treatment, before government administrations approve them for adoption and use with 'real' patients.

Key enabling technologies (KETs) also call for smart public policies and specialized clusters (EC, 2012; Wilkins et al., 2013), where orchestrators build interorganizational networks with small and large 'anchor' firms, leading universities and public research laboratories, as well as related supporting innovation services. The distributed nature for emerging technologies therefore requires the development of business models at the ecosystem rather than the organizational level of analysis, highlighting the interdependencies among emerging technologies, co-evolutionary ecosystem dynamics and the performance of key firms (Adner and Kapoor, 2010; Agouridas and Assimakopoulos, 2014). In a sense, key actors within such ecosystems need to develop dynamic capabilities and manage dispersed industrial architectures, global supply chains and distant markets, and co-create with lead customers.

Last but not least, as emerging technologies are diffusing across different geographies and cultures, they are reinvented from a broad range of actor networks who give situated meaning to such technologies based on different local interests, traditions and scientific and technological practices. Historians of science and technology as well as the field of social studies of science and engineering have highlighted the social construction of large technological systems for the past few decades (Hughes, 1983; Geels, 2002). We endeavour here to unravel the socio-economic impact of such emerging technologies for all kinds of stakeholders in order to manage them more effectively in their early critical days.

One of the main findings that cuts across several chapters of the book is the need to create, share and manage knowledge and research infrastructures at the network and community levels of analysis. This is characteristic of much European research and innovation since the early 1980s, when the first collaborative EU research and technological development framework programme was funded by the European Commission (EC) in the area of ICT (Georghiou, 1999; Assimakopoulos et al., 2004). No one organization or discipline on its own can solve these highly complex problems arising from practice (clinical or otherwise). 'Mode 1' knowledge production is rather limited scientific knowledge triggered and produced within disciplinary boundaries and scientific paradigms. 'Mode 2' knowledge production in the 'triple helix' of university–industry–government relationships has rather been the norm for more than 20 years (Gibbons et al., 1994). 'Mode 3' knowledge production in the 'quadruple helix' of innovation systems, including non-profit, non-governmental community-supported organizations, is the latest non-linear network innovation model, appearing in the early 2010s (Carayannis and Campbell, 2012).

## EMERGING TECHNOLOGIES AND OPEN INNOVATION IN ORGANIZATIONS

The focus on innovation networks for managing emergent technology exposes intriguing questions of how organizations organize internally to search for adequate knowledge dispersed through wider networks. The openness (Chesbrough, 2003) suggests that organizations need to attach equal importance to knowledge generated outside the organization and knowledge produced within organizational borders. Managers within organizations are well advised to tap into the rich pool of externally available knowledge, at the same time paying serious attention to internally generated knowledge that resists commercialization through existing business models or current market channels. This focus on collaboration and the open nature of innovation has exposed questions of: (1) how organizations organize internally to search for adequate knowledge dispersed throughout an innovation network; (2) which strategies are required for capturing value in open innovation contexts; and (3) how new internal organizational structures emerge as a result of the need to participate in and benefit from innovation networks.

Many innovation networks are driven by grand societal challenges (for example, sustainability, environment, health and ageing), which increases their institutional diversity. Transnational institutions, national governments, local authorities and professional associations accompanied by organized members of the public play a powerful role in shaping the innovation efforts that aim to translate social challenges into growth opportunities. The changing nature of innovation in such issue-driven innovation networks requires the investigation of very complex interactions between agglomerations of organizations, groups and individuals. This further challenges the internal organizational design of innovating firms, their strategies and organizational capabilities. The societal issue-driven and open nature of innovation in emergent technology innovation networks radically shifts the logic and understanding of firms' innovation strategies and the organization of innovation processes.

Openness and the resulting knowledge complexity, interdependency and dispersion alter the logic of how innovation processes within a firm are strategically managed. These characteristics of emergent technology-driven innovation networks demand a simultaneous search for technological knowledge, development of organizational capabilities and creation of new business models. The openness of the innovation process suggests that knowledge and solution-providing competency is extremely widely distributed. Innovative organizations are, therefore, challenged to organize their search processes for the integration and recombination of distant (less familiar technologies and markets) and often very fragmented knowledge domains (Afuah and Tucci, 2012). New organizational structures are emerging that enable coordination across organizational borders, yet those that support open innovation processes are not sufficiently studied. The search for highly distributed knowledge is additionally complicated, because firms are not only searching for external knowledge that supports the development of their products or services. Many technology-enabled new products or services are themselves complex knowledge architectures (for example, cloud computing) with numerous firms contributing their competency only at a component level. If firms are facing architectural innovation (Henderson and Clarke, 1990) – components change only incrementally, but interdependencies among them alter radically – then search, no matter how distant, cannot only be focused on finding knowledge that supports improvement of a component. It also needs to provide adequate knowledge to understand the innovation on the level of the entire system. Architectural innovation changes competitive dynamics, division of capabilities and industrial structure, yet it is less studied how firms should organize their search activities in order to successfully shape emerging architectural innovation. In such circumstances it is unlikely that a network of contributing organizations will form a well-structured supply chain. Networks of organizations that attempt to shape complex architectures of new products or services are more akin to ecosystems that do not always have a clearly defined central actor. This suggests that firms need to organize their search activities not only to acquire adequate technological knowledge, but also to develop new organizational capabilities and business models in order to influence the direction of architectural innovation, differentiate themselves within the complex product or service, and capture adequate value from within the emerging industrial architecture.

It is intriguing that emerging research insights from the ManETEI project suggest that many technology-driven companies are reluctant to label collaboration with external partners as 'open' if new knowledge supports the existing core products. Regardless of whom they engage with or how uncertain or radically different the relevant technology is, collaboration is rarely described as open if it directly contributes to improvements of core products or technological competency. It is indicative, however, that companies use open innovation strategies when exploring integration of their products into radically new product or service architectures. Here, technological advances in products are of secondary importance to how a product fits into emerging product or service architectures. This is even more pronounced if the emerging industry architecture lacks a central firm to orchestrate integration efforts or when collaboration is needed between companies from different sectors to create a complex new product or service architecture. Companies have to develop new organizational capabilities to navigate emergent innovation networks that aspire to create complex architectural innovation from a variety of innovative products (for example, smart cities). In such an architectural innovation context it is unproductive to distingush between product, process, business model (Teece, 2010) and organizational innovation (Birkinshaw et al., 2008). Organizations often experiment with all these innovations simultaneously.

The institutional diversity of societal issue-driven innovation networks increases the number and variety of constituencies involved in innovation and changes the ways innovative firms organize their innovation processes to navigate multiple institutional logics (Thornton et al., 2012). The institutional diversity of the innovation process is recognized in the innovation management literature, inspired by insights from the sociology of technology (Garud and Gehman, 2012). Configurations of interdependent actors include not only firms and public research institutions, but also governments, regulators, professional associations, organized public and end-users. Such institutionally complex innovation networks are theoretically conceptualized as organizational fields that bring together various constituencies with often disparate purposes and institutional logics. It is often characteristic for such organizational fields to be driven by a central issue (for example, sustainability: smart cities) and not necessarily by a particular technology or market (Hoffman, 1999). Societal issues that drive institutionally diverse innovation ecosystems challenge firms' existing capabilities, yet it is rarely studied how developments at the level of an organizational field impact upon innovation strategies and capabilities at the level of an individual firm. It is even more scarcely investigated how an innovative firm organizes in order to shape and influence developments in an issue-driven innovation ecosystem, where the interactions are not only limited to interfirm or industry–university collaboration, but also include close interactions with governments, regulators and the wider public.

ManETEI researchers have identified the emergence of new organizational forms (for example, technology platforms supported by the EC) as typical meta-organizations (Gulati et al., 2012) that combine elements of interorganizational networks with structures and hierarchies as characteristics for single organizations. The ManETEI focus on exploring interactions between an individual firm and members of the wider organizational field is timely, because innovation managers with strategic responsibilities often participate in initiatives such as setting standards and collaborative technology development (for example, SEMATECH consortia), that bring together institutionally diverse constituencies. Moreover, they interact with governments, municipalities and the wider public in order to gain information, generate social and reputational resources and influence the direction of innovation. It is indicative that such interactions between institutionally diverse members often happen within new organizational forms such as European Technology Platforms (European Commission, 2004) and private–public partnerships that require adequate managerial skills and organizational capabilities in order to influence the agenda and support the strategic intent of a company that participates in such meta-organizations.

If innovation ecosystems are characterized by different degrees of institutional diversity and complexity, interdependency and dispersion of adequate knowledge, it is possible to argue that different capabilities and different internal organizational structures are needed within a single organization. This suggests that heterogeneity of external innovation ecosystems could be accompanied by internal heterogeneity of innovation structures. ManETEI researchers have identified that technology-driven companies are themselves becoming complex networks of internally distributed innovation initiatives. These decentralized groups are becoming increasingly autonomous in collaborating with external partners such as universities and technology-intensive small and medium-sized companies. ManETEI research has identified two intriguing and interrelated consequences. Firstly, complex organizations introduce new organizational units that specialize in supporting autonomous innovation initiatives undertaken in collaboration with external partners. Secondly, innovation management becomes a new profession distinct from R&D activities. This very intriguing trend enables the study of new organizational interdependencies (Siggelkow, 2011) and professional identities that influence the emergence of autonomous actions within complex organizations involved in innovating with emergent technologies.

## WORK PRACTICES AND EMERGING ICT

For as long as technology has existed, it has affected the way people performed their work. In the beginning of the twentieth century, technology helped to automate manufacturing lines, resulting in the specialization of the workforce and efficiencies for car manufacturers. One hundred years later, ICT has emerged to enable collaboration and coordination between dispersed teams, redefining the grounds upon which distributed work can be carried out. However, such advances in ICT were not free of challenges, and indeed were at the centre of the ManETEI project. Various aspects such as geographical distance, time zone and cultural differences associated with global distribution have been examined as causing problems for globally distributed software teams in achieving successful collaboration. Indeed, a growing number of studies have reported problems regarding collaboration in distributed work, such as coordination breakdowns, lack of understanding of a counterpart's context (Cramton, 2001) and different language competencies across remote sites. Other studies have argued that globally distributed work may exacerbate the chance of misunderstandings, lack of trust (Jarvenpaa and Leidner, 1999), asymmetry in distribution of information among sites (Carmel, 1999), difficulty in collaborating due to different skills and training, and mismatches in information technology (IT) infrastructure.

By and large, the practices proposed in the literature have focused on two possible routes to ensure effective and efficient collaboration and coordination between remote sites. One stream of research has advocated for the division of work that minimizes the need for intersite coordination and, therefore, communication and synchronization (Herbsleb and Mockus, 2003). To achieve this, it was recommended that tightly coupled work items that require frequent coordination and synchronization should be performed within one site. Clearly, such a view highlights the importance of ICT as supporting the integration of components across sites.

Another stream of research has promoted the idea of rich and intensive interactions between various sites, supported by ICT and face-to-face meetings in which counterparts develop social and cultural contextual knowledge of their remote peers as part of enabling coordination and collaboration. This view, in contract to the former one, advocates the use of ICT as a communication tool that enriches coordinative activities via contextual knowledge, thus supporting distributed work.

The contrasting views presented here offer new avenues to understand the links between ICT and work practices. Arguably, firms cannot eliminate coordinative efforts through the practice of division of tasks between remote sites. While excessively investing in coordination activities may erode the advantages that distributed work may offer, such as low-cost locations and the utilization of time zones to speed up product development.

There are, therefore, two possible explanations through which the relationships between work practices and ICT can be further explored. First, understanding how socialization takes shape in such settings. Second, exploring the notion of 'expert systems' and how codification plays a role in such systems.

**ICT and Socialization**

Collaboration and team performance depends, to some extent, on the socialization of dispersed team members (Govindarajan and Gupta, 2001). Socialization refers to the process by which individuals acquire the behaviours, attitudes and knowledge necessary for participation in an organization (Ahuja and Galvin, 2003). Through socialization, the norms, identity and cohesion between team members develop, enabling team members to effectively communicate and perform (Hinds and Weisband, 2003). Most studies refer to organizational socialization as a process that is based on interactions between a newcomer and members of the organization (for example, colleagues, superiors or subordinates). Through such interactions an employee is taught and learns what behaviours and views are customary and desirable at their workplace, and becomes aware of those that are not, as well as acquiring the knowledge and skills needed to perform their job. While such a socialization practice is supported by human interactions when team members are co-located, distributed teams may face spatial, cultural and time zone challenges that may prohibit them from socializing.

Socialization in globally distributed teams, therefore, may take place through two key mechanisms. One is the application of ICT and the other is through face-to-face interactions. In terms of the application of ICT, various electronic media will be needed to support connectivity between remote sites and facilitate socialization. Additionally, generic collaborative technologies (for example, Groupware) will be needed to enable remote counterparts to connect and communicate. The most commonly suggested collaborative technologies are social media, e-mail, chat (for example, instant messaging), phone / teleconferencing, videoconferencing, intranet, group calendar, discussion lists and electronic meeting systems. More recent studies have focused on integrating collaborative technologies into an integrated development environment in order to offer solutions that deal with breakdowns in communication among developers in dispersed software development teams.

However, while ICT plays a role in socializing, face-to-face meetings are also important for the development of distributed teams through the establishment of interpersonal relationships. Furthermore, such meetings were found to positively affect team collaboration and team performance, mainly through the enhancement of interactions between team members. However, such face-to-face meetings are sporadic, short, selective and formal, therefore suggesting that their impact on socializing remote counterparts is likely to be minimal.

Recent studies have indeed acknowledged the difficulties in socializing through human interaction in distributed settings and therefore proposed the need to 'reacquire' norms, attitudes and contextual knowledge by combining social media with short-term visits, a term coined 're-socializing' (Oshri et al., 2007). Re-socializing in distributed contexts takes several steps in which both human interactions and the application of ICT play an equal role in moving the distributed team from introducing each other through social media means, meeting up for a preliminary meeting, but also renewing social ties via short visits and interactive social media platforms.

## Transactive Memory and ICT

Socialization may increase remote counterparts' awareness of the islands of knowledge existing within the team; however, this may not suffice to effectively transfer knowledge between the sites. Indeed, studies have demonstrated repeatedly that, despite advances in technologies, ICTs do not prevent breakdowns in the transfer of knowledge across distributed sites (Cramton, 2001). While ICTs are critical for knowledge transfer processes in distributed teams, a neighbouring stream of studies has considered human-related factors, such as trust and interpersonal ties, which may act as facilitators for knowledge transfer between remote counterparts. But collaboration also requires remote counterparts to be aware of their peers' expertise and their mastery. In this regard, ICT are unlikely to support developing awareness for mastery, but rather assist in encoding, storing and retrieving information from and for experts when needed (Wegner, 1995).

Indeed, a transactive memory system (TMS) has been defined as the combination of individual memory systems and communications (also referred to as 'transactions') between individuals. The group-level TMS is constituted by individuals using each other as a memory source. Transactions between individuals link their memory systems; through a series of processes (that is, encoding, storing and retrieving), knowledge is exchanged. Individuals encode information for storing and retrieval, similar to a librarian entering details of a new book in the particular library system before putting it on the shelves. Through encoding, knowledge is categorized (that is, assigned labels that reflect the subjects of the knowledge) for systematically storing the location of the knowledge, but not the knowledge itself. Then, individuals store this information internally (building their own memory), or externally (storing it in ICT or indirectly in other people's memories). And lastly, information about the location of the knowledge or expertise is retrieved when someone else asks for it (Nevo and Wand, 2005).

Retrieval thus consists of two interconnected sub-processes: person A asks person B for information; person B retrieves the information. As Nevo and Wand (2005: 551) put it simply: 'knowledge is encoded, stored and retrieved through various transactions between individuals'. Wegner (1995) explains that for a TMS to work, three corresponding aspects to encoding, storing and retrieving should be considered. Creating a TMS that supports collaboration between team members is perceived to be less challenging than in distributed contexts (Oshri et al., 2008). Globally distributed teams often experience changes in membership that negatively affect the long-term development of a TMS. Furthermore, in many distributed settings, team members do not have any prior experience of working together. Their distributed mode of operation decreases communications and increases the possibilities for conflict, misunderstanding and breakdowns in communication. In teams that do not carry out joint training or arrange face-to-face meetings, the development of shared understanding is even more challenging because members of such teams do not stand on common ground. How then can a TMS benefit from ICT, thus enhancing collaborative practices in distributed modes?

Studies suggest that, similarly to socialization, there is interaction between human interaction and artefacts which creates the conditions for the development of a TMS in distributed contexts. Indeed, both personalized and codified directories are created during memory processes in a TMS which supports the encoding, storing and retrieving of information when remote counterparts exchange knowledge (Oshri et al., 2008). ICT and digital artefacts provide standard templates to capture information about individuals involved in knowledge exchanges, and central project repositories serve as storing artefacts to ensure the ability to retrieve information upon request.

Furthermore, we find that the three transactive memory processes – that is, encoding, storing and retrieving – play different roles in shaping a work practice such as knowledge transfer. Firstly, the development of collective expertise – that is, encoding – acts as a process for defining the procedure through which knowledge will be transferred. During the encoding, parties negotiate the meaning of knowledge (that is, the subject and location of the knowledge) following either a codified, standardized approach or by relying on an embedded routine developed within the organization. Secondly, the management of expertise – that is, storing – creates a pointer to the location where the knowledge is stored and from which it can later be transferred. In this regard, creating a pointer involves the actual storing activity during which remote counterparts attach particular labels to the knowledge stored within them or in a digital artefact. These labels, including for instance contextual information, make it possible to negotiate and clarify the meaning of this information, and its subsequent retrieval from its place of storage. And thirdly, the coordination of expertise – that is, retrieval – concerns the integration of knowledge by bringing together experts through search mechanisms and interpersonal contacts. For knowledge transfer to take place, teams rely, on the one hand, on the procedures and shared meanings established through encoding processes; and on the other hand, on interpretation and the use of labels attached to the transferred knowledge during the storing process. The coordination of expertise – and thus knowledge transfer – can be supported by relying on either the codified or the personalized directories, or both.

The question that we may pose at this juncture is: to what extent do personalized or codified directories matter to a certain practice such as knowledge transfer? Indeed, it would be wrong for either of these memory systems to be perceived as 'better' or 'worse'. In line with Cook and Brown's (1999) observation on epistemologies of knowledge, codified and personalized directories are best seen as two complementary, rather than competing, memory systems. Absence of the codified or digital directories would deprive the teams of shared methods for encoding, storing and retrieving information, which may strain the personalized directories beyond feasibility. Leaving out the personalized directories, on the other hand – for instance, due to high personnel turnover rates – would leave the project with independently working individuals who would find it difficult to agree on collaboration standards. In this regard, groups develop meta-routines that interlink the two types of directories. Further, there is a 'generative dance' (Cook and Brown, 1999) between these two memory systems that contributes to the transfer of knowledge between remote counterparts. The codified directories depend on interpersonal 'norming' processes for defining standards, templates and procedures. The personalized directories extend the codified system by offering additional avenues in cases when documents provide incomplete knowledge about a task. In these cases, individuals know who to contact and how to retrieve information. Evidently, the development and use of a TMS may change over time. During initial phases of the project, rudimentary parameters of transactive memory are defined (for example, which sites and individuals are responsible for which tasks and knowledge domains). These are extended and refined when people work together over prolonged periods of time, renegotiating meanings and regenerating learning around the knowledge transfer process.

The two explanations offered here about the relationships between work practices and emerging ICTs have been captured in the ManETEI network. Cloud services, as a recent example, pose serious challenges to firms' business models, in particular those that rely on a product business model, requiring such firms to reorganize their operations to consider a service-based business model. Similarly, the digital games generation, who bring gamification skills to their work, are shaping the way they interact with work artefacts and what would motivate them to perform. In this regard, the research carried out by ManETEI researchers is advancing our understanding of the complex relationships between technology and work practices, and how these two evolve over time and recursively shape each other.

## NOTE

1. The report coined the term 'Nano-Bio-Info-Cogno-Socio-Anthro-Philo-Geo-Eco-Urbo-Orbo-Macro-Micro-Nano'.

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