Actor-networking engineering design, project management and education research: a knowledge management approach

José Figueiredo
IST – Technical University of Lisbon
Management and Engineering Department
CEG-IST Engineering and Management Research Centre
Av. Rovisco Pais
1049-001 Lisboa
Portugal
jdf@ist.utl.pt

Abstract
With this research we invest in the integration of four important areas of knowledge interweaved within the sphere of engineering management research: Actor-Network Theory, project management, engineering design and engineering education research. Each of these areas represents a pole of a tetrahedron and they are all equidistant. Our approach has the ability and concern of putting them all at the same distance and with equivalent value, taking advantage of cruising fertilization among them. This entails a research in the frontiers of the engineering and the social where other elements emerge. In fact any technological system is a sociotechnical system and design and development must take this fact into account, which surprisingly enough doesn't seem to be completely accepted. This research is on the integration of knowledge and blurring of frontiers within these four areas. The actor-network embodies the change of settings and facilitates negotiations among heterogeneous actors, translating ideas and meanings and constructing innovations. Actor-Network Theory helps viewing the integration of these different areas as a fruitful integrative process of trade-offs and translations. This integrative process is intended to manage knowledge creation and serve as a context to a reflexive process of organizational learning and engineering academic learning. Narrative is a strategy we intend to use to facilitate the understanding of contexts and the circulation of common and emergent meanings.

Keywords: Knowledge, Actor-network, Design, Project Management, Engineering Education Research

1. Introduction

In this paper we address the four areas of knowledge identified in the title integrated in a space of knowledge management and organizational learning. We also address the use of narratives as an effective strategy to facilitate alignment, learning and decision making.

Actor-Network Theory (ANT) was created within the sociology of sciences (*École de Mines de Paris*, by Latour and Callon, followed by Law, from Lancaster, UK) and was essentially a retrospective approach which followed actors in past settings (Callon, 1986), (Latour, 1987; 1996) and (Law, 1986). ANT analysis focus in a very innovative way on the interpretation of connexions and negotiations among actors (heterogeneous actors like people, teams, organizations, rules, policies, programs, and technological artefacts), but tends to miss the enormous potentialities it offers in the processes of designing the making of technological artefacts. Despite Michel Callon's reference to "designing in the making" in the title of his chapter in the book edited by Bijker, Callon (1987), this approach is generally retrospective and revolves around reflection and explanations on how things could have been different if other actions had been taken. There are some attempts to put ANT into acting in "real time", for example in the information system domain, by Tatnall (1999) and Monteiro (2000), but these attempts are after all and again mainly ex-post. Anyway we can feel that Callon (2002) was himself already alert to some emergent potentialities of ANT. We may also think that Hepso (2001) was looking to more real action. But in fact these attempts were a dead end and our idea is that, more than in action or in the making, we should focus on using ANT in design and development of technological systems (Figueiredo, 2008). So, ANT needs to improve its abilities to be helpful in the making (design and development) of technological systems which entails the construction of sociotechnical systems. Although we used it mainly in requirements analysis and specification of technological artefacts in project management (Gonçalves and Figueiredo, 2008), ANT provides ways of looking into the making of technological systems from a different perspective. That is, ANT can be a new language of design. ANT embeds the social (social actors) and technology (technological artefacts also as actors) into the same network of negotiations and provides a view that can embody the bottom value of technology, integrating new relevant actors, discarding others, crafting specifications and requisites, that is, *purifying* the design of systems (actor-networks). Grabbing new actors and loosing some of the actors previously involved is a *due process* that provides open innovation, dismantling routines and closed specs.

Project management (PM), as a knowledge and research specific area has some internal contradictions. Some of them concern PM autonomy. If we focus on design we address project management in innovation contexts and we need to allow the braking of routines, as some traditional practices doesn't apply. Within engineering design, project management needs to assume new roles and some practices need to be reconstructed. That is why collections (bodies of knowledge) of best practices such as PMBOK (2004), a collection edited by the Project Management Institute, although widely used, are not considered significant enough in these more specialised realms of PM application. Goldratt's Critical Chain (1997), based on the theory of constrains (TOC), promises an alternative approach but it also has limitations and doesn't offer interesting alternatives to this specific problem (design). Also in specific areas of knowledge as for example information systems the world references explore alternative approaches, as James Cadle (2007) and Mark Fuller, Joe Valacich, and Joey George (2007) note. In this important field (information systems), methodologies as Rational Unified Process (RUP) and Agile increase their visibility. There are also some encouraging signs of new and complementary approaches in risk analysis, maturity studies, project collaborative tools design, project management in services, and system dynamics. We can see some emerging domains, like project management offices (PMOs), project portfolio analysis, multicriteria decision in risk analysis, agile project management (Ambler, 1999), and more. Overall then, we are convinced that addressing the project management in designing technological systems with an ANT approach provides a helpful view that can be applied from the very early stages of the engineering design act, requirement analysis and specifications (Ford and Coulston, 2008), right through its completion (Gonçalves and Figueiredo, 2009), i.e. all along the project life cycle (Figueiredo, 2008b). Project management is a transversal area of knowledge that also needs to integrate technology in its use, that is, needs to adopt a sociotechnical approach. Charles Rosenberg introduced the metaphor of ecology of knowledge that established constructivism as the dominant mode of analysis of science exploring knowledge embedded in material artefacts and skilled practices (Rosenberg, 1997). And the interplaying of the technical and the social is so dramatic in project management that the high rate of failure in project accomplishment is constantly addressed to social failures (communication, stakeholder involvement, team quality, leadership).

Engineering Design in the practitioner domain is at the very kernel of engineering activity. Design is context dependent and user oriented. Design needs specific skills, an inquiry mind able to understand the piece and the system in which it operates, a sociotechnical mind able to understand technology and its uses, an understanding of the organization, communication within the group and with the stakeholders, a hearing ability to understand needs, and permeable borders allowing things going out and others coming in through the borders of the system in design. Design operates in micro and macro mode, travelling through the boundaries of both modes. These two modes need to communicate and act together, with knowledge emerging from the interactivity of this process. Design fructifies in specific informal cultures, so to manage design projects the approaches needs more flexibility. Once again we stress that the actor-network metaphor is refreshing, as actors have freewill and free options resulting from negotiations occurring among them and without any frame limiting or imposing conducts and controlling their behaviour.

Engineering Education Research is for us, academics, a space of reflexion and action with a variety of inputs. What can we learn from practitioners, what can we learn from concepts and how can we apply them out in practice, how can we learn from both sides and how can we teach-learn from the interaction of these approaches. Namely we can address the two distinct modes of knowledge production identified by Gibbons (1994) as Mode 1 and Mode 2 (a context-driven and problem-focussed process more common in the entrepreneurial sphere). Can we act interplaying with both academic and entrepreneurial contexts? Can we engage in observing and playing ourselves around deploying strategies of knowledge production, of knowledge emergence and transference, addressing both Mode 1 (Jorgensen, 2008) and Mode 2, and understanding the tacit and cultural barriers that emerge and dissolve with the evolving of the actor-network, or the networked-actor? Can we take advantages of using the lenses of ANT to understand the mechanisms of knowledge production and knowledge emergence and how they relate with the design *value* and with the organizational learning and students learning?

What do these four areas of knowledge have in common? They all inhabit the as yet under-explored terrain where engineering and technology and the social sciences interplay, share domains and overlap fundaments. They all demand from the researcher more then a pure technological profile as they need a strong perception of the social. Allan Bromley, formerly Yale University dean once said "in the average engineering project, the first 10 per cent of the decisions made / effectively commit between 80 and 90 per cent of all the resources that subsequently flow into the project. Unfortunately, most engineers are ill-equipped to participate in these important initial decisions because they are not purely technical decisions. Although they have important technical dimensions, they also involve economics, ethics, politics, appreciation of local and international affairs and general management considerations. Our current engineering curricula tend to focus on preparing engineers to handle the other 90 percent; the nut-and-bolt decisions that follow after the first 10 per cent have been made. We need more engineers who can tackle the entire range of decisions." We need engineers that can cope with this, which means engineers with a design approach why of thinking and inquiry mind, a sociotechnical mind, communication skills, an understanding of the organization and social value.
This presents a major challenge, a need for researchers and engineers with a strong interdisciplinary sensibility and background, able to understand both the technical and the social. This integrative framework pretends to facilitate the emergence of knowledge in a design context and the management of this knowledge in aligned purposes. This approach also stresses the specific systemic paradigm of integration within a sensibility of border management and the inherent domain overlapping. This integrative approach also intends to explore the peculiarities of an ANT approach to engineering design and knowledge management, and to provide some refreshing considerations on project management and engineering education research.

2. Knowledge construction and learning

There is controversy about the different types of knowledge (tacit, explicit, soft, hard, informal, formal, and others) and how they can be constructed, captured, codified, used and "transferred". The New Production of Knowledge (Gibbons et al, 1994) explored two distinct models of knowledge production (we would say construction), Mode 1 (characterized by the hegemony of theoretical or, at any rate, experimental science; by an internally-driven taxonomy of disciplines; and by the autonomy of scientists and their host institutions, the universities) and Mode 2 (socially distributed, application-oriented, trans-disciplinary, and subject to multiple accountabilities, a context-driven process more common in the entrepreneurial sphere). These two modes are distinct but they are related and they co-exist, sometimes in the same evolving processes. We can say that in a business model mode 1 has only the first part (upstream) of the value chain, away from the market and practice purposes. The differences between these two approaches were recently characterized by Dias de Figueiredo and Rupino da Cunha (2006) as summarized in Table 1:

	Mode 1	Mode 2
Context	academic, scientific, prestige and uniqueness	economic and social applications, utility and profits for the stakeholders are the purposes
Dissemination	linear model, diffusion	problems are set and solved in the context of application, actor-networks
Research	fundamental/applied, exactly what does this mean? Knowledge is mainly for scientific purposes	fundamental and applied melt, theory and practice entangle, multiple sites. Knowledge is built and used in the context
Community	discipline based, homogeneous teams, university based, shared among fellows	transdisciplinarity, integrated teams, networks of heterogeneous actors
Orientation	explanation, incremental	solution focussed
Method	repeatability is important, reuse	repeatability is not vital, sometimes it even impossible
Quality assurance	context and use dependent, peer-review is the most important guarantee, refutability	context dependent: may involve peer-review, customer satisfaction
Definition of success	scientific excellence and academic prestige	efficiency/effectiveness, satisfy multiple stakeholders, commercial success, social value

Table 1. Adapted from Gibbons' Modes 1 and 2 of knowledge production

Sustaining our learning strategies in such differences and inscribing them into the design mind, with a sociotechnical and systemic approach, it is easy to agree that active learning and project-based learning are urgent strategies to adopt in the academia, in the engineering learning field.

"Active learning puts the responsibility of organizing what is to be learned in the hands of the learners themselves, and ideally lends itself to a more diverse range of learning styles....." (Dodge, 1998). Richard Felder and Rebecca Brent are among the most well known apologists of this learn strategy and curiously they mainly address the engineering arena "*Active Learning and engineering education are seen as a natural pair*", Richard Felder and Rebecca Brent (2003a e 2003b). In a similar approach we can also visit Michael Prince (2004).

Project-based learning is not new, it is a concept that showed up in the twenties namely with the experiences of William Kilpatrick, follower of John Dewey in his reflexive incursion into education systems. This kind of "teaching" is learning oriented as defined by Bolonha and involves students in projects all along its course in school in order they can construct competencies in the specific study domain, see Bess Keller (2007) and Graaff and Kolmos (2007).

To make it simple and picture like, when you are in a car discovering the way to a place you don't know in a quarter where you have never been, if you are driving you learn and probably you can reuse the knowledge you constructed in order to repeat the path, but if you are not driving, if you are just going in the car you can't. The difference in both cases is the way you are situated in the *system*. Similarly in an interesting book by Ivan Illich (1974) there was a citation of José Antonio Viera-Gallo, secretary of Justice of Salvador Allende saying "*El socialismo puede llegar solo en bicicleta*", which is a good metaphor on the same reality. Addressing technology Illich intends that the structure of production devices can irremediably incorporate class prejudice (Ivan Illich - Energy and Equity). Action and knowledge, as technology, are situated and socially constructed.

In organizational terms learning is a survival condition. Learning, knowledge production, organizational contexts, and culture are *things* (actors) we need to network in order to stimulate organizational creativity and innovation. No design activity is possible without the degrees of liberty of a situated context. Double-loop learning (Argyris and Schon, 1978), generative learning (Senge, 1990), adaptive process (Cyert and March, 1963), and the behavioural approaches are just a few among a myriad of topics that consolidated organizational learning as a discipline. Organizational learning focused originally on the practice of four core disciplines, or capacities, *systems thinking* toped as the fifth (Senge, 1990):

- systems thinking
- team learning
- shared vision
- mental models
- personal mastery

The situated context is constructed and often by special leaders that are able to motivate people and engage teams. Leadership is about change. A leader is a constructor of visions, realities, hopes, ways, means, and a flexible planner that plans and re-plans all the time (planning and organizing, doing and re-planning is a constructive practice). True leadership is earned, internally – in the unit, or the organization, or the community. Leadership could be seen as a "distributed leadership," meaning that the role is fluid, shared by various people in a group according to their capabilities as conditions change, (Mintzberg, 1977). Leadership, change, learning, and knowledge management are important topics in engineering design. And we need to understand different cultures. Addressing the cultural problem in a wider way Hofstede defined four/five cultural dimensions (power distance, uncertainty avoidance, individualism, masculinity – femininity, and long versus short term orientation) (Hofstede, 1980). In smaller teams the cultural differences can be addressed as psychological and social types and can be addressed as conditioned competences. And like this we are readdressed to organizational learning as managing competences.

3. Knowledge narratives

As knowledge is socially constructed and depends on interactions and negotiations among the different actors of the group or community, a way to create the appropriate conditions for translation is narrative.

Narrative is an interpretive approach born in the social sciences and gradually gaining recognition in various disciplines outside the social sciences. The approach is intended to enable capture of social representation processes addressing ambiguity, complexity, and dynamism of individual, group, and organisational phenomena. Context plays a crucial role in the social construction of reality and knowledge, especially in engineering design and organizational environments. Narrative can be used to gain insight into organisational change, or can lead to cultural change (Faber, 1998). Storytelling can help in absorbing complex tacit knowledge or can also serve as a source of implicit communication (Ambrosini and Bowman, 2001). Czarniawska (2004) researches on how narrative constructs identity, Abma (2000) on how narrative can aid education, Gabriel (1998) on how stories contribute to sensemaking. Narrative may also provide insight into decision making (O'Connor, 1997) or the processes of knowledge *transfer* (Connell, 2004) and (Darwent, 2000).

Narrative is inherently multidisciplinary and lends itself to a qualitative enquiry in order to capture the rich data within stories. Surveys, questionnaires and quantitative analyses of behaviour are not sufficient to capture the complexity of meaning embodied within stories. Traditional scientific theory adopts a rational and empirical approach to achieve an objective description of the forces in the world, and scientists attempt to position themselves outside the realm of the study to observe. In this way traditional science is kept within a narrow positivist frame, dealing with random samples and statistical analyses. Using the story metaphor, people create order and construct senses and meanings within particular contexts. Narrative analysis takes the story itself as object of inquiry.

In our integrative approach we think that narratives can be used as boundary objects, a notion Susan Leigh Star and James Griesemer (1989) coined. Boundary objects are plastic enough to adapt to local needs and constraints of the several actors using them, and steady enough to keep an identity (commonly accepted) across settings. These objects can be softly structured when in common use and become structured in individual-situated use. Boundary objects are normally explored (in the literature) within a geographic metaphor but they also make sense through temporal boundaries. When we report and explicitly express our lessons learned at the end (closing) of a project we are designing boundary objects to the future, in order we can interplay with them and through them with different communities (project teams) also separated in time.

Exactly as knowledge exists as a spectrum "at one extreme, it is almost completely tacit, that is semiconscious and unconscious knowledge held in peoples' heads and bodies. At the other end of the spectrum, knowledge is almost completely explicit or codified, structured and accessible to people other than the individuals originating it"(Leonard and Sensiper, 1998). Most knowledge of course exists between the extremes. Explicit elements are objective, while tacit elements are subjective empirical and created in real time by doing and questioning options. So does boundary objects, they can be abstract concepts or concrete facts. In this sense taxonomies are boundary objects as they represent an ontological dimension. Systems of classification are part of the building of information environments (Bowker and Star, 1999). Narratives too, they help on this travel of means, where means are common experience in progress. As they both represent means of translation we clearly agree that ANT ca help in the negotiation of these means at the very core of the knowledge construction and learning processes.

4. Knowledge management

The most usual panacea in knowledge management (KM) is about the knowledge to information *translations* that some consider as algorithms to convert knowledge into something transferable, into forms that can be handled, manipulated, stored and even automated. We do not agree with this rationalist - mechanic simplification. We align with the others that having different ideas among themselves simply don't agree with these functionalist and instrumental approaches (Polanyi, Hildreth and Kimble, Hargadon, Vicari et al…) and think that KM can only be addressed from a different paradigm. This paradigm believes technology is not sufficient. In an organizational environment technology is necessary, but not sufficient. But being necessary or sufficient we need to address technology as a sociotechnical thing, embedded in the way it is used, managed, designed and developed. We think that in order to address organizational knowledge and its management we can never separate technology from people and this applies to the full engineering process cycle (requirements analysis, design, development, test, maintenance, and, in terms of knowledge, use and reuse).

The design process should be situated in this full cycle. Organizational knowledge management should address knowledge construction as a socially emergent outcome that results from the *translations* within the actor-networks that includes technology, rules, people, cultures, and organizational communities.

Engineering design has to recognise that if the requirements are not situated in a context of action and use they cannot assure a *valuable* result, that is, the result of the engineering process (full cycle) can be compromised. That is the reason why an earlier stage of the processes needs to be addressed with specific care and a methodological approach. In our approach this early stage is addressed as an emergent actor-network that needs to create the appropriate conditions for translation in an aligned fashion through a process of *problematization*, *interessement*, *enrolment* (*inscription*) and *mobilization* (Callon, 1986). This actor-network should encompass not only the initial situational process, but the full engineering process cycle (ANT, Actor-network Theory). This actor-network acts as the tissue where (and within) design and knowledge is constructed and where this construction is nourished and motivated.

In this process our inquiry approach can use convergent thinking (the questioner attempts to converge on and reveal facts) and divergent thinking (the questioner attempts to diverge from facts to the possibilities that can be created from them, which requires the use of surprising alternatives, sometimes *out of the box*, using inductive and abductive types of reasoning) (Dym et al, 2005), so we need to develop qualities that allow us to integrate both thinking types.

In this subject we can understand the importance of divergent thinking in engineering design (Cooperrider, 2008) and Torrence (1988), and visiting Cropley (2006) we can explore the combination and productive interplay among divergent and convergent thinking. In these references we clearly address two domains: the knowledge domain and the concept domain. There is a huge difference between the two as concepts need not to be verifiable, a concept is a concept, but knowledge always does. Recently Hatchuel and Weil (2003) took along this reflexion and explored the creation of a concept dynamic tree, introducing a new theory. Hatchuel and Le Masson (2007), Hatchuel Le Masson and Weil (2006) developed what is called the CK Theory (where C states for Concepts and K for Knowledge). This theory basically explores the idea that organizations have two available sets – a knowledge base (K - knowledge) of disperse things (objects, facts, rules, knowing) and a space of intentional query about things that cannot be answered within the knowledge base (C - concepts). These two spaces, having different structures and logics, are both expandable, interdependent and they allow negotiations through each other. They are spaces of translation. Within these two sets, concepts leave C and are processed into K where new knowledge emerges, and other processes are sustained in K and move into C to trigger the creation of new concepts and so on. Theory CK "offers a unified model for creative and innovative design", Hatchuel Le Masson and Weil (2006).

We can bridge this with the collaborative design topic explored in Zouari (2007) because in the space of knowledge we have interaction and cooperation among the actors.

We can look at this space of action (knowledge, concepts and application of knowledge in practice) in terms of ANT. In the three views represented in Figure 1 the arrows represent translations from setting to setting. C and K are actor-networks of intangible assets only and A, the space of action and applications, is already a typical actor-network with all kind of heterogeneous actors. ANT can deal with the basic tissue of translation and dynamic capability of the boundaries of these three spaces. In fact, ANT's agnosticism and free association, and the fact that the actors are heterogeneous by nature allow us to tune across different spaces in either micro or macro views. And these travels in meanings represent strong roots for knowledge creation, learning and knowledge management.

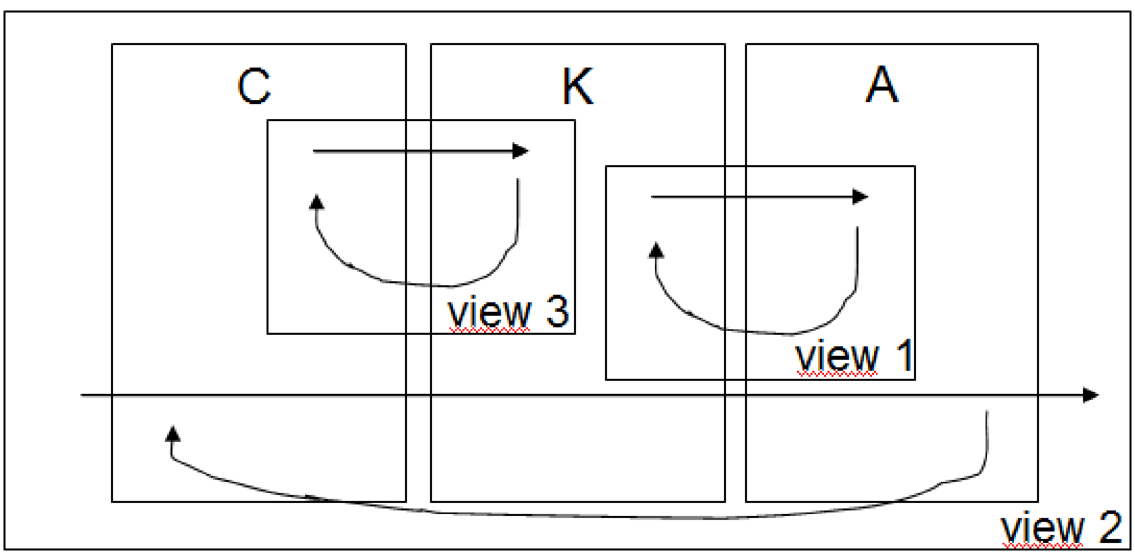


Fig. 1. Theory CK revisited

5. Knowledge, design and learning

In both practice and academia, we long ago passed from a teaching thinking modus into a design paradigm approach. We are mainly doing a choice on the way we think. In this way of thinking we need to construct systems as something that will work and we need to understand why, for what and to whom. In this way of thinking we get enrolled by purposes that are not only technical, they are user dependent, context dependent. We as designers should be concerned with *utility*, the bottom value. The best expected utility value, the best for our design purposes. Metaphors, analogies, divergences, thinking out of the box and serendipity are traditionally recognized ingredients to fuel creative thinking, so they must be considered as *design tools*. Design motivates involvement and learning, it motivates new things happening, it has a purpose of action, so it deals with decisions, knowledge production, a memory system and a learning ability. If you intercept more then one knowledge community then you mix and share motives, fears, problem solutions, analogies, associations and you increase again your own knowledge and both community's collective knowledge. The design approach, inserted in a sociotechnical chain of building artefacts, bridges the gap between the research concept and practice, (Romme, 2003). Design can be a methodology but mainly it is a paradigm (Van Aken, 2004), a way of looking into things understanding their qualities, looking at things in construction within a context. As seen in this loops of conceptual concentration, design is integrative and systemic. We address design in all engineering assertions but mainly in the assertion of "design as a discipline", as defined in Figueiredo and Cunha (2006). This discipline is central in every engineering branch (sometimes addressing one technology only) and particularly in the Engineering and Management domain where it normally involve more than one technologies.

6. Design project management

The mainstream research in project management has been criticised in recent years for its heavy reliance on the functionalist and instrumental view of projects and organisations (Hodgson and Cicmil, 2006). In fact we think projects do not exist as a given reality, ready made and neutral, but they are like networks of actions of interdependent actors through a process of negotiations and translations aligned to evolving shared meanings and goals. The target is moving and the reassemble of goals need to be a process of remaking and not only a steering exercise. In fact the project goal is constructed by the team (with the help of different stakeholders) and not only a cold spot in the horizon of our view.

What we just said is not easily accepted as in fact the mainstream, the project management body of knowledge (PMBOK), has for long emphasised the role of project actors basically as implementers, planning, doing and controlling what was mainly planned and mostly decided in a kind of closed time and defined territory. If we really think that in project management the most important role is the control of time, cost and scope and we think that this is enough, not foreseeing the other important roles actors interplay within the projects, then we are trapped by the classic mechanicists and ultra rational paradigm. So, broadening the scope of the very foundations of the project management discipline to include these new topics, less descriptive and rational, more intangible and more "open than closed", together with a systemic mind (and a sociotechnical mind), represents a new track that is not yet the common track, even if it is of crucial importance, mainly in projects involving innovation and design.

Unveiled in 2001 in Japan, P2P (Project and Program Management) was an attempt to address program conception, design, strategy management, architectures, communities of practice, and integration management of program execution. The major objectives of P2M are solutions to complex issues, accelerated innovation and trying to increase added value. Inscribed in a Japanese strategy, the sustainability of this approach to project and program management needs to be assessed. The Guidebook of Project and Program Management for Enterprise Innovation depicts the philosophy and paradigms behind the initiative.

We have two types of project management: operational and innovation driven. Operational project management pursues efficiency. Project goals and objectives are given by others. The basic concept of operational project management still is to define objectives such as scope,

costs, time and quality based on basic architecture design developed by others acquiring desired results in line with the intention of stakeholders while stressing business processes.
Innovative program and project management, as addressed in P2M, requires a paradigm shift from predefined project objectives to creative formulation of goals. P2M should address both formulation and complex problem solving while enhancing value through the community.
P2M is an interesting attempt to address creativity in project management but we must admit that some (basic and intangible) elements are and always would be in the centre of project success. Leadership and team building support to creativity and innovation in the operative work of a project management team are some of these elements. That is, the dynamics of creative success emanates from an ambience where generation and implementation of new ideas is stimulated. This ambience needs to be special and socially attractive, and with plain "windows" to the exterior, an exterior that must be invited to come inside whenever it seems possible and rewarding.

7. Conclusion

In an academic world dominated by mechanistic paradigms with positive approaches to the way research has to be conducted, some connections and interactions may seam irrelevant. We intend integration is important and we encourage the investment in systemic thinking, in training design thinking, in developing a sociotechnical mind, and in taking advantage of the actor-network metaphor. These seem to be success factors for today's (pos-industrial) engineering. And are these mainly important to the 10 per cent Allan Bromley referred (see section 1)? We would say no, they are important along all the one hundred per cent of the full engineering cycle and project management cycle. If this is so it must be internalized and some engineering education must take place in newer forms and subjects. And this effort needs to address the mechanics of mind, how it works and how your own values are crafted. Domains like communication, organization of work, psychology of people, organizational forms, an ethical mind, and many more, need to be integrated in the engineering design approach.
As in each day the importance of design in engineering (shorter production cycles, dynamics of technological innovation, reinforcing of competition) and the centrality of project oriented organizations increases (more and more firms are becoming project oriented, or are organizing themselves in a project logic) we need to focus our energies in these two broad domains. We exercised the Actor-Network metaphor in both of the domains, trying to demonstrate the advantages and the robustness of our thinking. Actor-Network is a way of looking into realities as landscapes and as trees, and this micro/macro ability is one of its advantages. But ANT can also address political tensions and power tensions that arise in design and project management situated teams.
The concepts presented in this paper are kind of *work in progress* as we are leading a project on this very subject that aligns the different community's collaboration and integration. Brown and Davis (2004) said the phenomenon of *culture shock*, the tension generated among different cultures, was an essential ingredient for enhancing learning and suggested that this should be directly managed when establishing the community's interaction. We think alike and claim that boundary objects are things to be considered in this creative and learning innovative process.

8. References

Abma, T.A. (2000), Fostering learning-in-organizing through narration: Questioning myths and stimulating multiplicity in two performing arts schools, European Journal of Work and Organizational Psychology, 9(2), 211-231.

Ambrosini, V. and Bowman, C., 2001, Tacit knowledge: Some suggestions for operationalization, Journal of Management Studies, 338(6), 811-829.

Argyris, C. & Schön, D. (1978): Organizational Learning. Reading, MA: Addison-Wesley

Bowker, Geoffrey C. and Susan Leigh Star, 1999, Sorting Things Out Classifications and its consequences, The MIT Press Cambridge, Massachusetts London, England

Brown, A., & Davis, N., 2004, Intercultural learning through digital media. In A. Brown & N. Davis (Eds.), Digital technology communities and education

Cadle, James and Donald Yeates, 2007, Project Management for Information Systems, Prentice Hall; 5 edition

Callon, M., 1986, Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay, Power, Action and Belief: A New Sociology of Knowledge, J. Law (ed.), Routledge & Kegan, London

Callon, M., 1987, Society in the Making: The Study of Technology as a Tool for Sociological Analysis, Bijker, W.E. and Hughes, T.P. and Pinch, T.J. (eds.) The Social Construction of Technological Systems, New Directions in the Sociology and History of Technology, MIT Press, Cambridge, MA

Callon, Michel and Méadel, Cécile, Rabeharisoa, Vololona, 2002, The economy of qualities, Economy and Society, Volume 2 May 2002: pag.194-217; Routlege – Taylor & Francis Ltd

Cooperrider, Bryan, 2008, The Importance of Divergent Thinking in Engineering Design, Proceedings of the 2008 American Society for Engineering Education Pacific Southwest Annual Conference

Cropley, A., 2006, In praise of convergent thinking, Creativity Research Journal 18(3): 391-404

Cyert, R.M. & March, J.G. (1963): A Behavioral Theory of the Firm. Englewood Cliffs, NJ

Czarniawska, Barbara, 2004, Narrative in Social Sciences Research, SAGE Publications Ltd.

Darwent, S. (2000), Story telling: An introduction to storytelling, IBM knowledge management.

Dodge, Bernie, 1998, Active Learning on the Web [On Line] Available: http://edweb.sdsu.edu/people/bdodge/ActiveLearning.html

Dym, Clive, Alice Agocino, Ozgur Eris, Daniel Frey, and Larry Leifer, 2005, Engineering design Thinking, Teaching, and Learning, Journal of Engineering education, 94 (1), 103–120

Faber, B. (1998), Toward a rhetoric of change. Journal of Business and Technical Communication, 12(2), 217-243.

Felder, Richard and Rebecca Brent, 2003a, Designing and Teaching Courses to Satisfy the ABET Engineering Criteria, Journal of Engineering Education, 92 (1), 7-25 (2003)

Felder, Richard and Rebecca Brent, 2003b, Learning by Doing, Chemical Engineering Education, 37(4), 282–283 (2003)

Figueiredo, A. D. & Da Cunha P. R., 2006, Action Research and Design in Information Systems, Two faces of a single coin, Chapter 5, Information Systems Action Research: Bridging the Industry-University Technology Gap, Ned Kock (Editor), Springer /Kluwer

Figueiredo, José, 2008, Reviewing the Actor-Network Theory, Encyclopaedia of Networked and Virtual Organizations, Book Chapter, a GI Global Publication edited by Putnik and Cunha, pp 1374 - 1380.

Figueiredo, José, 2008b, Cross-functional Emerging Domains in Engineering: Actor Networks and Collaborative Models, Organizational Learning and Knowledge Management, Proceedings of the IEMC Europe 2008, IEEE International Engineering Management Conference, Estoril, Portugal pp 469 – 473

Ford, Ralph and Chris Coulston, 2008, Design for Electrical and Computer Engineers, McGraw-Hill, Section 1.1

Fuller, Mark, Joe Valacich, Joey George, 2007, Information Systems Project Management: A Process and Team Approach, Prentice Hall

Gabriel, Y. (1998), Same old story or changing stories? Folkloric, modern and postmodern mutations, in D. Grant, T. Keenoy and C. Oswick (eds.), Discourse and Organization, London, Sage, 84-103.

Gibbons, M., Limoges C., Nowotny H., Schwartzman S., Scott, P & Trow M., 1994, The new production of knowledge: The Dynamics of Science and Research in Contemporary Societies, Sage Publications, London

Goldratt, E. M., 1997, Critical Chain, Great Barrington, MA: North River Press

Gonçalves, Abreu and José Figueiredo, 2009, Organizing Competences: Actor-Network Theory in Virtual Settings, International Journal of Networking and Virtual Organisations, Vol. 6, No. 1, 2009, pp 23 – 35.

Gonçalves, Abreu and José Figueiredo, 2008, Constructing scope in project management: an interpretive approach, Proceedings of the IEMC Europe 2008, IEEE International Engineering Management Conference, Estoril, Portugal, pp 485 - 489.

Graaff, Erik de, Anette Kolmos, 2007, Management of Change: Implementation of Problem-Based and Project-Based Learning in Engineering, Sense Publishers

Hargadon, A.B., 1998, Firms as knowledge brokers: lessons in pursuing continuous innovation, California Management Review, 40, (3), 209-227.

Hatchuel A., P. Le Masson and B. Weil, 2002, From knowledge management to design-oriented organisations, International Social Science Journal, Special issue n The Knowledge Society, n°171, UNESCO, pp.25-37

Hatchuel, A and Weil, B, 2003, A new approach of innovative design: an introduction to C-K theory, in ICED'03, Stockholm, 14

Hatchuel, A., Le Masson, P., et Weil, B., 2006, The design of science based-products: an interpretation and modelling with C-K theory, 9th International Design Conference, Dubrovnik, 15th-18th May 2004, D. Marjanovic, 1, 33-44.n

Hatchuel, A., et Le Masson, P., 2007, Shaping the unknown and the emergent: Design theory as a new source of management knowledge, European Academy of Management, Paris, 21

Hepso, V., 2001, The involvement of Human and Non Human Stakeholders, Combining ANT and Action Research, IRIS 23 - 23rd Information Systems Research Seminar in Scandinavia, Doing IT Together, Uddevalla, Sweden

Hildreth, P. and Chris Kimble, 2002, The duality of knowledge, Information Research, Vol. 8 (1), paper nº 142

Hodgson D, Cicmil S (editors), 2006, Making projects critical. Palgrave McMillan Publishing

Hofstede, Geert, 1980, Culture's Consequences: International Differences in Work-related Values, Sage

Illich, Ivan, 1974, Energy and Equity: Ideas in progress, M. Boyars Publishers.

Jesiek, B. K., Newswander, L. K., and Borrego, M., 2009, Engineering Education Research: Discipline, community or field? JEE vol 98, nº 1, pp. 40-41, January 2009.

Jorgensen, U., 2008, Engineering Design in Theory, Teaching, and Practice - The Construction of Design Synthesis and Methods and Contemporary Challenges, submitted manuscripts, Global Perspectives on Engineering, International Network for Engineering Studies Workshop, Lisbon 2008, http://www.inesweb.org/node/202

Keller, B., 2007, September 19, No Easy Project, Education Week, 27(4), 21-23

Le Masson, P., 2001, De la R&D à la RID, modélisation des fonctions de conception et nouvelles organisations de la R&D, thèse de doctorat de L'École des Mines de Paris

Latour, B., 1987, Science in action: how to follow scientists and engineers through society. Oxford: Oxford University Press

Latour, B., 1996, Aramis, or Love of Technology, Harvard University Press, Cambridge, Massachusetts & London, England

Law, J. 1986, On the methods of long distance control: vessels, navigation, and the Portuguese route to India, Power, Action and Belief, A New Sociology of Knowledge, Law, J. (Ed.), Routledge & Kegan Paul, London, Boston and Henley, http://www.comp.lancs.ac.uk/sociology/papers/law-methods-of-long-distance-control.pdf

Lucena, J., Downey, G. Jesiek, B. & Elber, 2008, S. Competencies beyond countries: The Re-Organization of Engineering Education in the United States, Europe, and Latin America. JEE, vol. 97, no.4, pp. 433-447. 2008.

Mintzberg, Henry, 1977, the Nature of Managerial Work, Harper & Row

Monteiro, E., 2000, Actor Network Theory and Information Infrastructure, Claudio Ciborra (Ed.), From Control to Drift, The Dynamics of Corporate Information Infrastructures, Oxford University Press, New York, pp. 71 – 83

O'Connor, E.S., 1997, Telling decisions: The role of narrative in organizational decision-making, in Z. Shapira (ed.), Organizational decision making, New York, Cambridge University Press, 1996, 304-323.

PMBOK Guide, 2004, A Guide to the Project Management Body of Knowledge, Third Edition, Project Management Institut

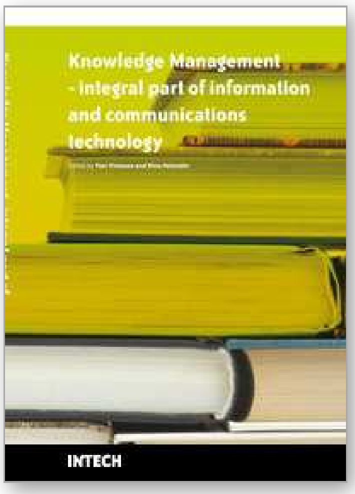
Polanyi, M., 1967, The tacit dimension, London, Routledge and Kegan Paul

Prince, Michael, 2004, Does Active Learning Work? A Review of the Research, Journal of Engineering Education, July 2004

Romme, A. G., 2003, Making a difference: organization as design, Organization Science: A Journal of the Institute of Management Sciences, 14 (5), 558-573.

Rosenberg, C., Toward an Ecology of Knowledge: On Discipline, Context, and History, No Other Gods: On Science and American Social Thought, revised ed., Johns Hopkins Univ. Press, 1997, pp. 225-239.

Senge, P.M. (1990) The Leader´s New Work: Building Learning Organizations. Sloan Management Review, Fall, 7-23.
Star, Susan Leigh and James Griesemer, 1989, Institutional Ecology, "Translations" and Boundary Objects: amateurs and professional in Berkeley's Museum of Vertebrate Zoology, 1907-39, Social Studies of Science, Vol. 19, pp. 387-420, Sage
Tatnall, A. E Gilding, A., 1999, Actor-Network theory and Information Systems
Torrence, E. P., 1988, The nature of creativity as manifest in its testing, RJ Sternberg (ed), The Nature of Creativity, Cambridge University Press
Van Aken, J. E., 2004, Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules. Journal of Management Studies, 41, 219- 246
Vicari, S., Krogh, G., Roos, J. and Mahnke, V., 1996, Knowledge creation through cooperative experimentation, In: Managing knowledge. Perspectives on cooperation and competition, edited by G. von Krogh and J. Roos, pp. 184-202. Thousand Oaks, CA: Sage.
Zouari, A., M. Tollenaere, H. Ben Bacha, and A.Y. Maalej, 2007, Can C-K theory apply to Knowledge-Based Engineering systems?, International Journal of Product Lifecycle Management (IJPLM), Vol. 2, No. 3, 2007



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This book is a compilation of writings handpicked in esteemed scientific conferences that present the variety of ways to approach this multifaceted phenomenon. In this book, knowledge management is seen as an integral part of information and communications technology (ICT). The topic is first approached from the more general perspective, starting with discussing knowledge management's role as a medium towards increasing productivity in organizations. In the starting chapters of the book, the duality between technology and humans is also taken into account. In the following chapters, one may see the essence and multifaceted nature of knowledge management through branch-specific observations and studies. Towards the end of the book the ontological side of knowledge management is illuminated. The book ends with two special applications of knowledge management.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821