Actor-networks in Engineering Education, a project approach

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Abstract **-** Actor-network theory represents a way to look at *things,*very different from traditional approaches. Convinced that actor-networks can provide an excellent mindset to deal with innovation in engineering education we present a concise background on the topic oriented to this knowledge area. We deal with knowledge, learning, contexts, and actor networkingwithin situated cooperative environments. We deal with the articulation of planned approaches and policies, providing ideas to explore contexts in which we can improve people'sinvolvement and design some innovative strategies and artifacts. We address the conciliation of sensibilities that normally wouldn't be able to cooperate.We try to imagine a space of translations and negotiations that facilitate the formulation of problems as a combination of detoursand extensions, constructing alignments to a learning goal.

Keywords **–** Actor-network theory, alignment, innovation in engineering education, translation, extensions and detours

I. INTRODUCTION

We can detect some tensions in the area of Engineering Educationand we believe the answershouldbethrough the negotiated alignment of different factors, like in a confluence of requirements. In fact, each tension provenience means a will to make things better, sothese tensions represent positive inputs to the aligning process. One of the challenges is to make the causes of these tensions work together, in order to createvalue and enhance resultsin practice. *Knowledge*, *learning*, and *actornetworking*, are some of the elements that need to be considered to construct such an alignment. These three elementsdon't belong to the same category, but they are crucial to the process and theyneed *conciliation*. This conciliation is our main driver to indirectly contribute to the results we intend. This conciliationdemands*cooperation*, requires*planned approaches* and depends on *policies*. In this paper we intend to speculate ona possible design of such anapproachto facilitate both alignment and conciliation in the process of engineering education. We begin by"burning" some ideas exploring the conciliation of wills and addressing some ANT concepts. We than explore the conciliation in terms of an ANT framework. Then we extend our ideas trying to explore a modus operandi. Finally we extend again our modus operandi into an action proposal. This action proposal is very simple and intends to be mainly illustrative. Finally we draw some exploratory conclusions and statements.

II. BURNING IDEAS

Rather than adopting problem solving as the model for theorizing learning processes in engineering practices and education, researchers on this field should view theory construction as sensemaking [1]. In our approach, valid for students, teachers and professional practitioners, we would translate theory construction into conciliation, as we need to integrate *what*and *why*, problem formulation, problematization in ANT terms[2], with the how, problem solving. These two processes reshape each other, in the sense they construct alternative realities that trigger innovation, they 'socialize'[3] between themselves and create knowledge. These alternative realities constructed by this "socialization of things" can be addressed as ongoing extensions and detours in a pathway of evolution. We use the term socialization coined by Nonaka in an ANT way, that is, we are interested in the play of hybrid actors, not only human.

The combination of innovation and learning in a context of engineering design, formulating problems, constructing requirements, defining specifications, designing and doing things should exploreconciliation and is a reflective practice [4]. Socialization is a key step in the knowledge creation process.It is in the core of knowledge creation as externalization is a closing, anoutput, of the same process, the beginning of another cycle. Socialization and Externalization represent two modes on the knowledge creation process[3]. The interplay and shift between these two modes depends on processes of translations. Taking advantage of network effects, we are 'socializing' and creatingopportunities that trigger the creation of new knowledge, facilitating innovation. But for this network to besocial is not enough. That is why we considered the "socialization" of things instead of people.

In fact we may say that technology and society are two interwoved systems that reshape each other [5]. If we look at this interplay we are able to understand things in a different way. The attempt of conciliating these two realities is mediated by our knowledge, our filters, the way we look at things (paradigms), the way we translate our "realities", and finally our situation, or context of our action.

The approachwe needshould provide the alignemnt of technology and societybut for that effectshould not rely ona usual social network. Our approach favorsthe construction of actor-networks(networks of things) that interact constantly [6]. One of the differencesbetween a common social network and an actor-network is that in this late one actors are hybrids and not just humans (rules, equipment, processes, dependences of factors, restrictions, concerns).

In this sense the process of innovation is a process of translation that should mediate the engineering education process.Let us say that accuracy in 'our' translation is not what we fight for, on the contrary, the more creative our translation is, the more powerful it could be in terms of innovation. And translation is the kernel operation in any actor-network up to the point we can say that an actor network and translation are the same.

Learning is a necessary process in this system. But as John Locke (1979) [7]said,"No man's knowledge can go beyond his experience", which means that we need to address knowledge as action, and not as a repository of concepts.Locke almost alerts to the fact that you learn by doing, by reflecting on what you do, the way you do it, how and why.Learning is an integrative process, travels in networks,is driven by purposes, and allows sensible action.The knowledge virtuous cycle imposes that practice brings people and things together, instigates this 'abstract socialization' and facilitatesthe construction of new knowledge that in turn improves the ability of doing things better.

Creativity is highly dependent oncumulativetacitknowledge. Individual innovation begins with internalization, via combination, externalization and socialization [3]. Sustainability, either economic, environmental, and in engineering design, requires continuous innovation, supported by well-planned systems of knowledge management and learning, managed in integrative ways in situated spaces.Actor-networks are such a space (milieu) where transactions to render possible this chain of action (translations) occur and flourish. Actor-networks act as dynamic spaces of negotiation where the alignment of different influences (technological, organizational, and material) is continuously crafted. The type work produced is quite diverse, looking for alliances, enrolling and discarding actors (due process), managing black boxes, increasingsize and align, are some of the activities explored in the Actor-network Theory (ANT). The actors enrolled are teachers, students, developers, researchers, users, learning systems, companies, organizations, regulations,laws, and policy makers to reference only a possibility and give an idea of the heterogeneityaddressed.

ANT supports relations with material (relating things) and semiotic (working with concepts) without distinguishing between them. There is no either or situations, all things are integrated and conciliated.

From an actor-network perspective, every innovation involves a reconfiguration of the actor-network of actors through the enrolment of new actors and the discard of others. Innovation means translations crafted in the interacting of social and natural processes (things), playing with displacements of content and context, in ways that change practices and create the new. In this sense innovation is a complex process of co-evolution/co-production. Just as new ideas and concepts have to be inscribed into materials, practices, or products to make them durable and mobile, new technologies have to be translated into artifacts in order to gain sustainability, and new practices inscribed in behavior to establish standards.

III. CONCILIATION

Knowledge is a transient essence, in continuous transformation (translation), created in interactive processes among actors that only exist in action, inscribed in actors. Being intrinsically built by ongoing relations between hybrid actors, actor-networks can inscribe forms of knowledge in permanent evolution. In this sense we can adopt strategies of alignment oriented to goals. The management of such knowledge spaces (milieu) as depicted in Figure 1 is not however a traditional management, it is a complex responsive process[8]. Stacey argues that complexity theories are difficult to apply to management action and they can only 'serve as a source domain for analogies' [8]. Even Deming, known for the importance of metrics in quality oncesaid,"you can't measure everything of importance to management. And you must still manage those important things."[9].ANT also goes in a similar way when defying the general and academic notion that statements and "laws" are accepted by their resilience to tests(validation). ANT is not based on validating tests, not onessential statements and not even on generalizations of the truth[15].

Stacey assessment represents a very interesting approach we loosely couple with ours. But instead of absorbing from the complexity realm, we propose an inspiration of ANT. In fact we are translating an academic approach into the rich dynamics of ANT, conciliating both influences.

IV. MODUS OPERANDI

This conciliation occurs in a rupture *space*, an actor-network that evolves in a cyclic way and works as milieu to the articulation of two operations – association (joining new elements, new actors, and related to due process) and substitution, breaking with some of the presented proposals [10] and proposing something new and different. It is the articulation between these two operations that enrich the negotiation *space* and generate new proposals, with alternative new solutions. These new alternatives are aligned with the goal in the sense that they emerged within a situated context and actors are scrutinized by a due process. Figure 2 represents this situated context and the referred due process with which we intend to purify the space, not the actors in them. This purification is an alignment with the goal of the system, something that could be seen as effectiveness. The representation in Figure 2 is simple, abstract and metaphoric. In our approach, the goal or the result of the alignment is to improve learning conditions for the engineering mindset, which means enrolling more than pure technological actors.

As Professor 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 per cent; 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" [11].

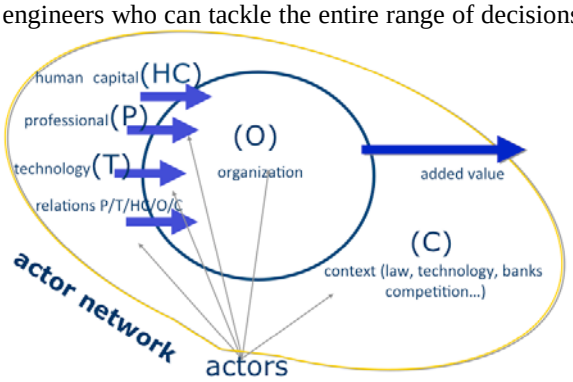

Figure 1 – Actor-networks as spaces of interaction

We think that to provide the necessary learning strategy and conditions we need to take advantage of this situated ambience.We need to explore some extensions and detours, meaning the triangulation of new artifacts, and even metaphors.That is,we address concepts and materials in such a way that facilitates the working out of new proposals and the sustainability of new practices. The extensions and detours here addressed are very important concepts explored in ANT but not born there. In fact, Paul Valery in 1895 already addressed the subject, as did Le Moigne later on, in 1995 [12]. The extension would be any addition that increases the area, influence, operation, form or contents of a situation, a community, or a system. The detour would be an operation in which using Obligatory Points of Passage (OPPs)wedrive other actors to converge.OPPscan be anything, an information system, an organizational rule, a dispatcher. Integrating them you resolve a problem, not in a direct way, but exploring indirect framingconditions. You are composing an actor-network for problem resolving in a constructed formulation.

Inside the situated context of Figure 2 we can see a ladder as a simple representation of the basic operations in an Actor-network. This representation is a Program of Action (PA) and registers the evolution of two types of translation, already addressed in the beginning of this section. The ANDtranslation/negotiation, along the horizontal axis, means agreeing and enlarging the critical mass of the network, reinforcing the network's aim. The AND translation is an association, in fact it joints new actors. The OR translation/negotiation, along the vertical axis represents alternative proposals, disruptive (creative) translations that create new courses of action. The OR translation is a substitution. These OR translations are the ones explicitly related with innovation, or the ones through which innovation emerges. But that doesn't mean that you cannot innovate by agreeing, exploring the AND progression.

Innovation is made of chains of these operations of translation, transforming through displacements, grabbing new actors (due process), while discarding some of them, passing through OPPs. In these progressions extensions and detours are experienced and architected.In an ANT context where actors are hybrids and can range from individuals to machines, passing through immaterial things like rules and laws, these extensions can be virtualization strategies able to allow us to experiment new proposals and the development of new problematizations. Problematization inscribes in this context in different ways, allowing new formulations of existing problems and new problems, and gathering allies to focus on a new goal for the system – double loop learning [4]. Extensions can also be the translations from one type of process to another, meaning the two types of translations explained [13]. New realities are normally and most often constructed through theextension and renewal of already existing ones.

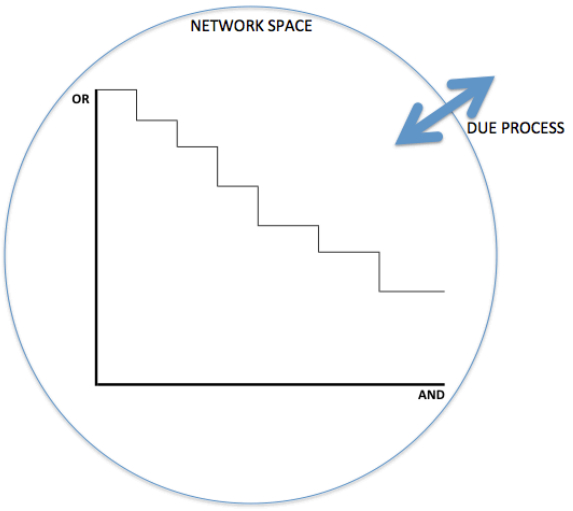

Figure 2 – Situated Context, space of innovation, purification

The concept of detour (from the Actor-Network theory) also means a strategic movement to explore alliances with other actors to envisage action with a purpose in a collective mobilization. In order to enroll other actors, OPPs needs to translate their common interests, collectively constructing a meaning for the action to take. It is important to understand that detours often propose a deviation from the original problematization, breaking with eventual previous plans.

According to Urry[14] all social relations maintain distances and are never static, evolving through circulations. There are always many circulations of actors in the translating process. In that sense social relations are developed through groupings of circulating relationships"relations are not fixed or located in specific places, they are constructed through 'circulating entities'"[15]. Circulating entities result in multiple 'connections' that cannot be conceptualized in terms of the dichotomies. All social relationships involve complex patterns of immediate presence and intermittent absence at-a-distance, which places technologies of the virtual in an excellent position to define situated learning conditions.

"ANT is not a theory of the social, it is a theory of a space in which the social has become a certain type of circulation", or better, ANT it is not a theory at all, but if it were a theory it would be "a theory that says that by following circulations we can get more than by defining entities, essences or provinces" [15]. In ANT terms and mindset the analytical focus is detoured from structural prescription to process deconstruction [16].

ANT deals with spaces of translation, with extensions, detours, and compositions, operated in terms of ANDs and ORs, as we have already seen, and not through structures. Sometimes longer and longer detours are necessary to dismantle obstacles, reformulate problems and construct new proposals [17]. Extending is necessary, but also risky.In fact, extending too much can promote dissociations that threaten the network durability, stability, and alignment.

In fact the *"secret"* idea is to capitalize to a center[18], reinforcing alignment, exploring durability and stability.To achieve that we need to arrange (discover, enroll) actors that speak on behalf of other actors,representing them, and translating their interests and motivations into aligned actions with aligned goals. These actors, the already mentionedObligatory Points of Passage or OPPs, are crucial to the building and sustainability of actor-networks. This representing role of the OPPs implies translationprocesses that, in ANT terms,we call calculation centers, or spaces to which action must capitalize. A special case of OPP is the Immutable Mobile (IM). IMs are particularly good on finding strategies and ways to capitalize to a center [18] and they are very important actorsto make things happen and, in situated conditions, provokethe emergence of innovation.IMs act as innovation triggers.

V. PROPOSAL

In terms of exploring our idea,defining strategies to deal with innovation in engineering education, we proceed in terms of "In the making, rather than ready made" [19]. Our approach is tentative and will try to enroll more people interested, able to make their own detours and extensions.

Trying to apply the conceptual framework we described we begin by emphasizing that in a situated learning community, that is, in a specific teaching class, we should begin to explore the comprehension that we are in a networked space of things. This network space should not be social confined. A lot of environmental elements and even inside group elements should be considered as actores,because they do act, limiting, or allowing operations and detours. To identify the relevant actors, hybrids by nature, in such a situation is fundamental to depict formulations and solutions.

Counter steering in terms of the dichotomy of formulating and resolving, we need to stress the crucial importance of conciliation. Conceiving conceptual exercises in which students are invited to formulate and reformulate problems, together with the exercise of resolving the correspondent situations is very important.

Joining new elements to the problems, new actors into the network, can attain reformulation. For example in a typical technological problem, if you promote a reformulation based on some simple economic details, you could help on creating a systemic view and a helpful sensibility to contingency.

Exploring the AND translation, that is joining new actors, we change the problem, creating a new space of

interaction in which you can entail substitutions, using the OR translation. Articulating both translations, AND/OR, you address new problems, you exercise reformulation and you create new things. Really important is to explore new elements interacting together (technological, social, material, conceptual).

Some of the extensions to explore are based on virtual strategies. Virtual strategies allow the experimenting side of things with limited resources and lower risk, and if you explore exercises on problematization, formulating and reformulating and resolving, you are addressing the scientific and conceptual side of the student's minds. Both strategies address what Allan Bromley so clearly addressed as an essential need (see section 4).

We should work on planning by identifying the relevant actors in a situated context, limiting the borders of the system, identifying contingencies, grabbing all the necessary elements and details, and only then pass to the next recurrent step, which is design. Remember the actors to identify are hybrids, not only humans, not only technological. The design we mention can be the formulation of a new problem, or the reformulation of an already formulated problem.

What is important in planning is not the plan but the reflexive path of knowledge creation that lets us internalize the detail and the whole in the different configurations and restrictions. This reflexive path entitles you to act in a situated context of action. These knowledge paths need tools to help on grabbing information about details.

The Wiki success is related to an interesting model of decentralization of the production, distribution of production responsibility. But in this decentralization you should care for the value.

Google page ranking model is excellent, innovative, probably the best, but it lets us find not the best, but the most well known [10]. The selection is made of tastes, opinions, and trends, that is, no assessed materials. Can we imagine a system that retrieves quality content? First of all we would need to define in an objective way what is quality information (quality knowledge), a fact that most reviewers of International Journals well demonstrate that is difficult and probably utopic. But lets imagine that it is possible, we need to decentralize in a situated quality, that is, we could not address the common web user but a selection. And this selection, being diverse, needs to have literacy on the subject or, even better, expertise. The idea is to have a search system in which you have not one hundred pages retrieved, but only one. If possible not even one page, but half a page, half for the best answers and the other half to explore educated guesses about the subject.

In fact there is nothing wrong with the page rank model, except that it should be segmented, using configurations that would allow the searcher to select the communities where from the information would be retrieved.

With this example we intend to stress that innovation in engineering education must be directed in different paths: learning contexts, socializing technics, educated practices, integrative and aligned policies, an information infrastructure, and supporting tools. All in one the learning contexts can comprehend all the things mentioned. But the design of tools to provide learning contexts should be performed by the members of the engineering education community (including students), as these tools provide an excellent edge to innovation.

And we should always recognize that a clear input for innovation is the detour, now in the sense of opening our minds and think differently, exercise lateral thinking[20]. So we need to motivate and enroll students on risking about the ways they generate ideas. We are frequently mind mapped to valuate reasoning's that give us more of the same, maybe this situationsare more controllable and less demanding, but we should promote, the contrary, out of the box thinking [21].

But in the sense that reinforcing innovation in engineering education should not be a collection of samples and experiences without direction and purpose, we need to reinvent policies able to trace the sense of global and systemic view, and to entail a common alignment.

Policies need infrastructure and in that sense some shared information management artifacts should be designed and developed. For example, a repository of ideas, experiences, and lessons learned is an obvious part of such a global system.

We need a composition of all the elements, infrastructure, policies, practices, tools, extensions, detours, in a conciliation way, that is, an actor-network should be our space of translation/negotiation.

Children play and experience a high level of creativity in playing. Playing is a space of translations and negotiations with a specific goal. It would be interesting to exercise the same degree of liberty that children experience at playing. Managing the goal exercising extensions and detours,we could enroll the actors in a situated learning space with the same kind of motive children have, to explore ludic situations in an aligned goal. To design technological problems with such characteristics could be a strategy of mobilization and enrolling. The fact that the actors, people, things, and variables of the problem, are hybrids could extend the formulation and reformulation and solving of technological problems into an extended, highly creative activity. The actor-network paradigm could help on these

constructions of socio-technical spaces of professional reality.

VI. CONCLUSION

First of all our reflection intends to be centered on a way of thinking, and not in specific solutions to a specific problem. We tried to formulate a conceptual way to discover new solutions, as these should always be situated in specific contexts. The explored way of thinking can keep the pace with the variety of eventual solutions that real life brings us.It is an approach particularly concerned with change, alternative proposals, and the construction ofsomething new. It is not a specific way of doing things, it is much more a state of mind to be able to discover and construct new realities.

Section 5 needs to be extended to become relevant, so our idea is work in progress. This paper intends to enroll more people in this type of approach.With more people we can develop communities exploring the potentialities of ANT in this specific domain of innovation in engineering education. If the paper is a contribution to this goal I would feel completely rewarded.

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