Contextual Analysis of Remote Experimentation Using the Actor-Network Theory

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Abstract: Distance learning is promoting the adoption of several and new technological resources in education. The Internet is a proof of this trend, providing students with the ability of accessing better pedagogical contents from everywhere at anytime. This is usually supported by the so-called Virtual Learning Environments (VLEs). However, the increase of the bandwidth together with improvements in terms of the devices' processing capabilities for accessing services/tools through the internet, has contributed to the appearance of the Remote Experimentation (RE) concept. Currently adopted by several Science and Engineering (S&E) courses, RE is classified as a sub-domain of E-learning and as an extension of the traditional VLEs, since it provides all the facilities required for remotely accessing laboratorial experiments, giving both students and teachers the ability to control real experiments by using a simple device (e.g. PC, PDA, smart phone, etc.) connected to the internet. Traditional (in-place) laboratorial experiments can now be remotely controlled with more flexibility, reducing place and time restrictions usually present in a real laboratory. In addition, technological evolution is contributing to many changes in several domains, which has alerted us to the importance of contextualizing RE as a network of interconnected actors, with distinct characteristics and interests. This represents a huge challenge that is fundamental to analyse, since society, and more particularly the educational context, is faced with several unpredictable influences from technological innovations that may contribute to the adoption of various educational solutions some of which may not have been validated, particularly in S&E courses. Hence, this paper focuses on an analysis of RE based on the Actor-Network Theory (ANT) in order to understand the existing relationships between human and non-human (technological and/or conceptual) actors. The paper begins by contextualizing RE as an actor-network in an intersection of several contexts, namely the social, technical and educational. Further on, we map the actors and their associations. An analysis of the inclusion of a new actor into the RE actor-network, namely FPGA-based boards for accommodating Instruments and Modules (I&M), which are usually applied in remote laboratory infrastructures, is dealt with in the final section of this paper.

Keywords: Remote Experimentation, Remote laboratories, Weblabs, Actor-Network Theory, Technology adoption.

1 Introduction

Analyzing a specific domain requires understanding all the internal and external social influences that promote its sustainability. When technology is involved, the challenges are huge, since technological evolutions pose several and unpredictable changes. This is usually caused by innovation that in most situations is viewed as an added value, but in others can cause problems requiring big changes to recover stability on associations among all elements involved in a specific domain. In education, and in the particular case of Science and Engineering (S&E) courses, technology is spreading its influence, promoting changes in the way teaching and learning methodologies are applied. This is particularly relevant in the practical work required in S&E courses, by the proliferation of remote laboratories. The adoption of these laboratory types is supported by the concept named Remote Experimentation (RE). RE is classified as a sub-domain of the traditional E-learning, since it extends the common features of Virtual Learning Environments (VLE) (supporting multimedia and management tools) providing resources, tools and methodologies that allow the conduction of real experiments through the internet. Basically, a traditional experiment becomes a remote experiment when it comprehends real Instruments and Modules (I&M) that, connected to the internet, allow both students and teachers to interact remotely with them, like they do in a traditional laboratory. Furthermore, they are usually supported by the VLEs and by communication tools (e.g. video-conference). The educational advantages that RE brings to education (Chetz et al., 2002) are proved by the proliferation of remote laboratories, some of them implemented in prestigious schools like the MIT with the i-Lab (MIT, 2010), and by the evidence of ongoing activity e.g.: architectural proposals like SOLA (Garcia-Zubia et al., 2009), ontologies for specifying laboratory types (Christian & Michael, 2010), projects (Gustavsson et al., 2007), conferences (REV, 2010), journals (iJOE, 2010) and journal special issues (IEEE TLT, 2010).

However, it is fundamental to stress the factors that influence its adoption in an educational context. In (Hine N. et al., 2007) authors adopted a conceptual map to describe relationships among some elements in RE, but they don't use any theory sustaining the presented relations. The attention on relations the environment has in influencing practices and even the creation and the adoption of some particularities in a remote experiment, may be analyzed through the lenses of Actor-Network Theory (ANT) constructs. Commonly applied to analyze general socio-technical relations, after an analysis of ANT principles it became clear that the ideas presented are suitable for mapping RE domain, since the model proposed could be of added value for decision making on how to create, maintain and disseminate remote laboratory infrastructures.

Next section provides an overview of ANT. Based on its concepts, section III contextualizes RE as an actor-network within the wider educational context, and section IV presents the actors and associations. Before the conclusions, section V provides some considerations on reshaping the actor-network, by the inclusion of a new actor named "FPGA-based boards" which may be seen as a new technological resource used to implement a remote laboratory infrastructure.

2 Actor-Network Theory

Mainly supported on Callon and Latour contributions (Law & Hassard, 1999), (Michel Callon, 1986), (Bruno Latour, 2007), ANT stresses the idea that human or non-human actors influence and are influenced by the specific context where they dwell. It is a semiotic method, since it maps relations that are simultaneously material (between things) and "semiotic" (between concepts). Elements usually belong to several contexts that shape their attitudes and/or characteristics during life-time. These elements are named actors, becoming actants when they take an active role in the whole context by influencing all other actors with believes and attitudes. As illustrated in figure 1, the heterogeneity of actors with established associations creates networks that may belong to more than one context. A network is easily changed due to several influences of external contexts with their own networks. If a network comprehends several actors connected through extensive paths with a set of aligned interests, those associations become facts. The stronger and more extensive associations are, the more solid facts become. In ANT, those associations are known as black boxes that represent situations with undoubted and solid dependences among actors usually difficult to change (e.g. the dependency between theoretical and practical components in S&E courses is strong and required, and there is no doubt about its relevance for learning outcomes). A network may integrate several facts that joined together lead to successful networks since there is an alignment of interests, motivations, and desires of each involved actor. Furthermore, a hierarchical approach can also be followed, since a specific actor may integrate several other actors interconnected, depending on the detail-level of the conducted analysis.

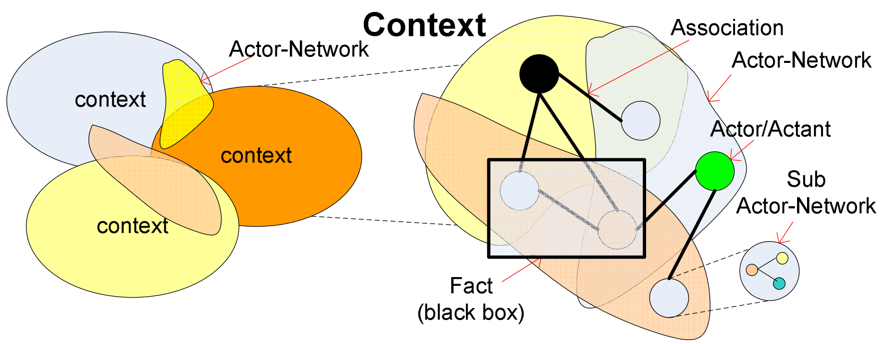

Figure 1: Conceptual model of Actor-Network Theory.

It is unusual that a specific network, comprehending many actors influenced by several contexts, may keep-on stable during long periods of time. Usually networks are dynamic structures facing frequent changes of interests and/or attitudes, as exemplified in RE by the relation between users and technology. This is a general example, but it is evident that there is a strong and unstable association between both, since recent trends show that remote laboratories are constantly changing their infrastructures based on technology evolutions essentially to i) get users' interest and motivation for its adoption in a specific course and, ii) to improve the quality of the provided experiments. This association reveals the challenge that an analysis on RE may pose, becoming difficult to analyze it as a stable network. Technology changes so rapidly that the development of a laboratorial infrastructure must provide specific tools and procedures to enable its easy reconfiguration (e.g. changing a specific instrument should not affect the network of associations among actors). Analyzing RE using ANT requires a classification of each involved actor. It is fundamental to understand different interests, motivations and values for enrolling an actor into a network, requiring an alignment of interests, even if they are only temporary. Therefore, a negotiation before mapping a specific actor into an actor-network is required, and the process that may be used is named Translation.

Translation, introduced by Callon (Michel Callon, 1986), is a transformation process that comprehends a strategy to integrate a new actor into an actor-network. In this process, an actor, usually referred as the macro-actor, becomes the focus of the translation process. The challenge of the macro-actor is to persuade actors to follow a direction aligned with its interests in order to transform the network. During the translation process, the new actor must pass through the so-called Obligatory Passage Point (OPP) which represents achievements defined by the macro-actor that an actor must accomplish before belonging to a specific network. The RE domain has a set of well succeeded translation processes. Gathering different technologies to achieve the specific goal of a remote experiment (conduction of real experiments), represents by its own a well succeeded translation process. A more specific example is the adoption of Webcams to provide visual feedback of the laboratory for students. Webcams weren't created for RE, but an alignment of interests mobilized them as an important resource to conduct remote experiments.

Independently of the context under analysis, the translation process is not trivial, because, as represented in figure 2, it comprehends four major stages that must be satisfied before a specific actor may belong to a network (Michel Callon, 1986):

- *Problematization*: the macro-actor defines the identities and the interests of other actors that are consistent with its own interests.
- *Interessement*: represents the process of convincing other actors that a macro-actor has specific relevance in the whole network.
- *Enrolment*: achieved when a specific actor accepts that the interests of the macro-actor are really fundamental for belonging to the network. This represents the successful outcome of the *problematization* and *interessement* processes and the inclusion of a new actor into the network.
- *Mobilization*: when actors are persuaded to accept the enrolled actor, since its interests were accepted by all actors already in the network. The aim is to maintain the commitment among actors within the network.

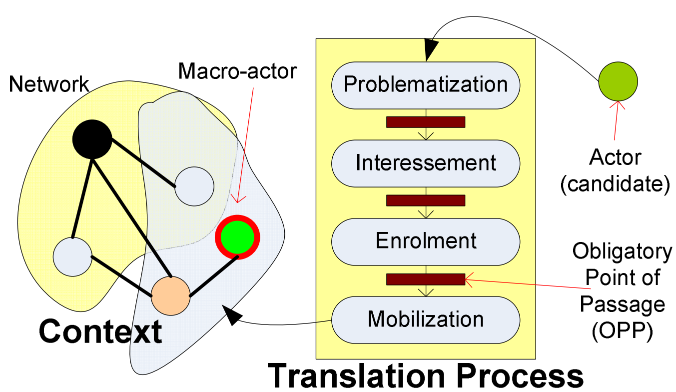

Figure 2: Translation process to join an actor into an actor-network.

In literature, ANT is considered to be an interesting methodology to analyze the inclusion of Information Systems into companies (Roque Licínio et al., 2004). As briefly exemplified in previous paragraphs, ANT may be applied in several contexts, namely in educational ones that may include RE as an actor-network.

3 Influencing Contexts

RE provides all mechanisms, supported on technology, for remotely conducting experimental work activities. Applying ANT to RE is a challenge that requires analyzing the involved contexts that may influence its actors. As illustrated in figure 3, RE may be represented as an actor-network mapped into the interception of two contexts (technical and educational) surrounded by the social context.

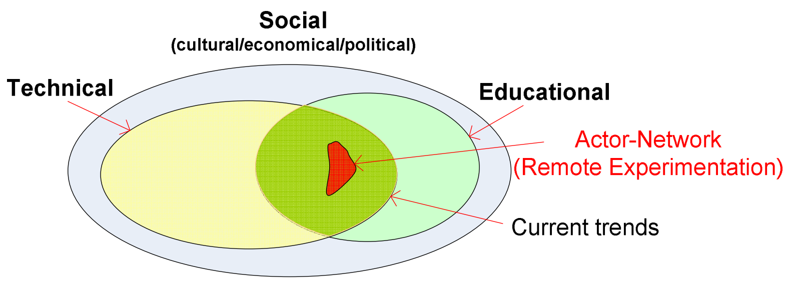

Figure 3: Situating RE as an actor-network.

Social context is wide and corresponds to the expectations of many involved actors divided into several networks associated to one or more contexts. At least three sub contexts have direct impact in the social context, namely: i) cultural: people in different countries have different ways of thinking, acting and ruling their lives with distinct values; ii) political: governmental decisions have priorities that align and influence people acting; and iii) economical: ruling the production, distribution, and consumption of goods and services are related with budget availability and influence cultural and political decisions. Hence, it is reasonable to say that every context must be analyzed taking into consideration a society integrating people with distinct interests, motivations, believes, past experiences, expectations, attitudes, etc.. Understanding how those social issues interact with others contexts, namely the technical and the educational, is therefore fundamental.

The socio-technical relation has being debated in the last years and currently is fundamental in several domains, since people's lives depend on technology. This is evident in health, work and leisure, and in almost all countries technology plays an active role also in economics. At the same time, technology is constantly changing, which impacts the whole behaviour of society, namely of each single person. This is clear with the social networking media provided over the Internet (e.g. blogs, wikis, facebook, etc.) which are changing the way people communicate. In fact, several examples can be presented that feed the association between these two contexts (social and technical), but the educational context can not be forgotten, since currently it is seen as the platform for social maintenance and evolution.

The whole society is ruled by what people learn and the learning outcomes tend to be defined according to society requirements. Socio-educational relation is strong and in recent years is being supported by technologies. The way teaching and learning methodologies are applied in education is changing from a mechanical era, where teachers lecturing, discussions and the conduction of practical work activities were made inside a classroom and/or laboratory, to a digital era, where new technologies are being applied to complement and, in same cases, replace the traditional teaching and learning methodologies. While the mechanical era corresponds to the socio-educational relation, the digital era corresponds to the intersection among the three analyzed contexts, i.e. the social-educational-technical relation. So, facing current trends on technology evolution and the interests that are getting from society, namely by younger people, it is reasonable to say that there is a shifting in the educational context from the traditional in-classroom learning to an emergent distance learning trend. This tendency shows that technology is impacting every teaching/learning methodology providing all tools and services for a distance learning supported by the Internet and its associated services/tools. In the particular case of S&E courses, it is important to make a distinction on two required components for the learning outcomes:

- theoretical - represents the transition of knowledge using the traditional pedagogical contents supported by documents, images and animations, describing specific theories.
- practical - represents the manipulation of variables and objects by doing laboratory work.

Both components are fundamental and have direct impact on the adopted technology that fulfils their requirements. As presented in table 1, the traditional (local) learning, that requires the physical presence of students to interact with teachers and/or laboratorial equipment, is being replaced (or complemented) by distance learning. This applies to i) VLEs, that provide pedagogical material (e.g. documents, podcasts, images, etc.) for satisfying the theoretical component, and to ii) Virtual, Hybrid and/or Remote laboratories for conducting laboratorial activities. Currently, technology already provides all the resources to complement and, in many situations, replace the traditional learning. Understanding the active role of each involved actor, and the impact that technological changes may have in the whole educational context can be made using actor-networks. In the particular case of the practical component, the presented laboratorial solutions were already analyzed in (Ricardo Costa et al., 2010) based on characteristics like availability, reliability, flexibility and others, placing remote laboratories as an interesting solution for conducting remotely real experiments. Therefore, in order to understand the involved actors and the associations among them, the next section analyses RE through ANT.

Table 1: Learning Components in S&E Courses.

		Components in S&E courses	
		Theoretical	**Practical**
Learning	**Traditional (local)**	Classes	Laboratories
	Distance	Virtual Learning Environments	Virtual, Hybrid and Remote laboratories

4 Identification of Actors and Associations

The first step to analyse RE in ANT is the identification of the context where it belongs. This was already made in the previous section, placing RE in the intersection of three main contexts: social, educational and technical. In this section, the involved actors and the associations among them are specified.

4.1 Actors

As defined by ANT, an actor may be a human or a non-human element that influence and are influenced while participating in a specific social context. Several actors may be identified, from human that directly interact with a laboratory infrastructure, to non-human that involve technologies to create a specific laboratory infrastructure, and concepts representing activities that must be assured by a remote experiment.

Regarding human actors, four were identified:

- **Students:** Conduct experiments remotely using a device connected to the internet. The access to control/monitor a remote laboratory, comprehending several instruments and the experiment(s), is made using a web interface. Real data is retrieved from the laboratory so students can analyze it as they do in a traditional laboratory.
- **Teachers:** Provide the theoretical and practical framework needed by students to conduct a remote experiment. They can take the role of assistants/tutors providing pedagogical support during a laboratorial activity, as they do in a traditional laboratory.
- **Developers:** Have the task of developing the entire laboratory infrastructure so students, teachers and technical staff may control/monitor the experiment(s) and, in some cases, the entire infrastructure (namely when it may be remotely reconfigurable). Developers may be teachers. However, it depends on the domain of the experiment, because providing a remote laboratory requires informatics and electrical skills teachers may not have.
- **Technicians (lab. administrators):** Must maintain and guarantee that an experiment is always ready to be used by students and teachers. They should also be concerned with the supporting tools required to provide remote experiments with security and reliability. They should be aware of issues like: i) ensuring that collaborative tools are available, ii) that the network infrastructure is always up and running, iii) guarantee the correct access scheduling to remote experiments, iv) the execution of setup procedures, etc..

To satisfy the requirements of human actors involved in the laboratory work, several non-human actors were also identified, namely:

- **Access devices:** Although several devices may be adopted for accessing a remote experiment and/or the remote infrastructure, PCs are the most common ones. Its processing capabilities, which enable the use of several useful services and tools for supporting remote laboratory work activities, place them as the most common choice. However, current trends show that smart phones and PDAs will also be used in the near future.
- **Networks:** Represent the communication channels used in every remote experiment. Without this actor it will be impossible to provide remote accesses to the laboratory infrastructure. Today there are several networks, but the most common one is the Ethernet that may be wired or wireless (Wi-Fi), since they provide high data rates and reliable connections.
- **GUIs:** Are the Graphical User Interfaces and correspond to panels comprehend graphical elements that allow control/monitor the remote laboratory. They are strongly related with technology, since they depend on development software tools, like LabVIEW, Java, HTML, etc. (Mergl C., 2006).
- **Infrastructure devices:** Represent the set of devices used in the laboratory infrastructure. In the electrical domain they usually comprehend several I&M (e.g. oscilloscopes, multimeters, and others), that allow controlling and monitoring experiment(s). Typically they are inter-connected by instrumentation buses controlled through a PC, acting as an instrumentation server, or independently, using integrated Ethernet interfaces that presently are common in

some instrumentation. In this last case, the instruments already have GUIs that enable their monitor/control.

- **Institutions:** Are schools, faculties or other institutions that provide all technical, human and physical resources to develop, maintain and accommodate the laboratory infrastructure.
- **Experiments:** Are the remotely accessible units under test.
- **Pedagogical contents:** Represent the theoretical support required by any laboratorial activity. They usually comprehend multimedia resources (simulations, animations, etc.) and/or simple documents.
- **Teamwork:** Represents the collaboration activity that must be guaranteed in any educational context, as defended by several educational theorists. It comprehends interactions between student-student and student-teacher that allow exchanging experiences and knowledge for improving the learning/teaching processes.

4.2 Associations

Every actor is associated with one or more actors in the actor-network. Those associations are constantly reshaping based on interests and needs of each involved actor, which may be strong or weak, and ideally should never break. Together represent complex structures that require detailed analysis to understand what are the needs and interests of each actor, and to predict future directions (or associations) among them that may expand or shrink the RE actor-network. This reshaping process may be seen as an alarm since it creates destabilization. However, in some situations it means innovation, which is difficult to predict since it is usually associated with previously unforeseen issues.

In spite of the involved complexity and the challenge of analysing the associations among actors, figure 4 provides a suggestion for a RE actor-network. Some actors were joined as sub actor-networks (technical and human) and some associations were established between those sub-networks and simple actors (e.g. pedagogical contents were associated with both sub actor-networks and with the experiment actor).

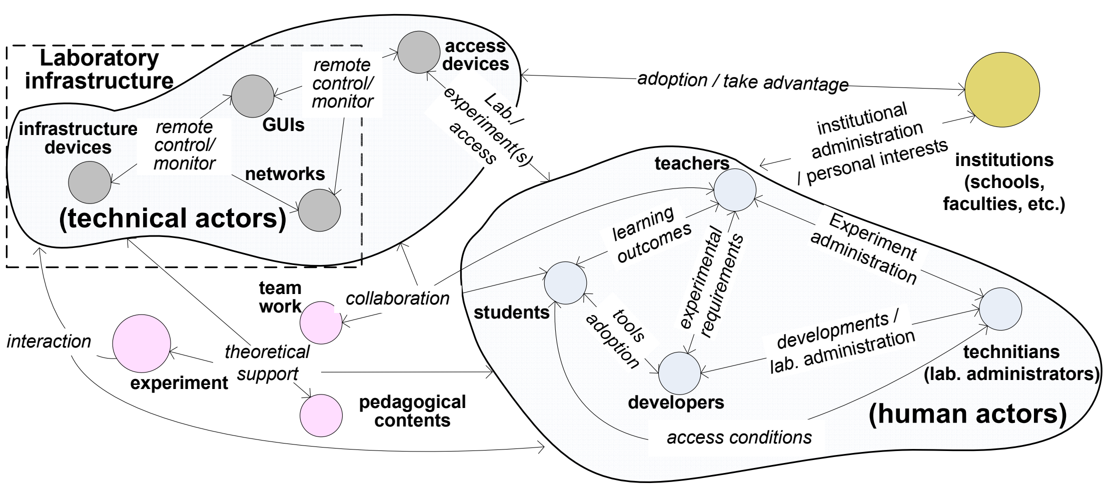

Figure 4: Remote Experimentation as an actor-network.

Each association and respective intermediaries will now be commented. Some involve more than two actors to simplify the analyses.

- **Students - teachers:** Teachers define the learning outcomes of a specific experiment shaping students' interests and motivation. At the same time, the definition of the learning outcomes are not limited to the subjects but also based on previous students' backgrounds. The dependence of this association can be more or less strong depending on the teacher's ability to capture students' interests on using a specific remote experiment.
- **Students - developers:** When a specific experiment is provided, the target are students. So, the developer must take into consideration those targets providing the best tools, so students feel comfortable interacting with the experiments. Adopting technological resources already known is an approach that captures students' interests. A developer may also innovate, although a previous analysis should be made for evaluating if new solutions are well accepted by students.
- **Teachers - developers:** The association is essentially made during the development phases of the laboratory infrastructure. Developers should align their interests based on teachers' requests, since the requirements for an experiment are to be defined by teachers. However, not all the requirements posed by teachers may be satisfied, because developing a remote laboratory is strongly mediated by technology, which may pose many constraints.
- **Teachers - technicians:** An experiment has requirements that depend on the learning outcomes previously defined by teachers. Connecting a specific instrument in the laboratory and manage scheduling accesses may be defined by technicians. In a specific experiment the teacher may want to connect a different instrument and/or restrict the access to the laboratory. If the remote laboratory does not allow controlling those aspects remotely through a GUI, the technician should do it in the laboratory infrastructure. However, if the laboratory provides these features, probably this association is not so relevant, since technicians' tasks are limited to setup procedures.
- **Technicians - developers:** Developers define how a laboratory infrastructure is administrated by implementing (or not) some features, e.g. some laboratories may be remotely reconfigurable which pose, as already referred, distinct administrative requirements. In this situation, developers must define the appropriated GUI for that purpose. Technicians will use developer definitions for administrating locally and/or remotely the laboratory infrastructure.
- **Students - technicians:** If the laboratorial infrastructure does not implement scheduling techniques, concurrent accesses to the same experiment will create problems, especially in experiments controlled/monitored in a real-time mode, i.e. remote actions retrieve real-time results. In this situation, and supposing that different students may want to access an experiment at the same time, the technician should control the accesses without teacher's guidance. For batch mode experiments, i.e. the remote actions go into a queue before retrieving results, some administrative support may also be required, but only if the number of accesses overloads the servers available in the laboratory infrastructure. Technicians must also guarantee that all other features of a remote laboratory are running correctly.
- **Institutions - human actors:** Human actors are strongly connected with the institution where they belong to. Political and economical decisions made by a specific institution affect the interests of those actors, while requirements posed by them will also influence some of the decisions made by an institution. Several examples may be pointed out, but the most evident is

the influence that institutions have towards teachers and vice-versa. Providing an experimental work activity using a remote experiment is strongly related with a teacher decision but should also be supported by the institution where he/she belongs to. Adopting a remote experiment is usually a cheaper solution and is an opportunity for collaborating with other institutions by sharing experiments.

- **Institutions - technical actors:** Technical actors satisfy institutional needs by providing all features to create a remote laboratory. Gathering the infrastructure devices available in the institution and connecting them to a network, allow the creation of a remote laboratory providing remote access through GUIs. In this association it is also important to emphasize the possibility of reusing deprecated equipment for developing a laboratorial infrastructure which may reduce institutional costs.
- **Access devices - human actors:** This association is strong in the meaning that without it, RE does not make sense, but simultaneously it is very unstable since devices' features are changing constantly. At the beginning, accessing a remote laboratory was made using PCs. However, technology evolution is promoting the adoption of other devices (e.g. PDAs, smart-phones) that may replace the common PC in experiments that not need many software tools to support their conduction. This is a tendency, since devices are improving their processing capabilities with good GUIs bringing several interface connections to the internet. Gathering all these aspects, with the mobility they offer, make them an interesting solution for accessing remote laboratories. The relation between each human actor and the access devices has different implications, always depending on the experiment and the adopted tools, namely the communication tools. Every human actor interacts differently with the remote laboratory. Students control/monitor the experiments gathering values for latter analysis, while teachers and technicians usually make some definitions in a specific experiment and in the remote infrastructure. Developers usually don't use a device to access the remote infrastructure since their task ends after the development phase. Besides the typical access to the remote laboratory, the adoption of a particular device should also concern users with visual and audio disabilities. In this situation, the adoption of a specific device must be well analysed since those users need large visual displays and specific software tools should be supported by the selected device.
- **Infrastructure devices - GUIs - networks:** To allow the remote control/monitor of a specific device two issues are required: i) they must be connected to the internet/intranet and ii) some GUI must be available. While specific modules and old instruments required technical developments for that purpose, more recently, instrumentation is facing big improvements, namely concerning the provided network interfaces. At the beginning instruments were attached to an instrumentation server using dedicated instrumentation buses (e.g. the General Purpose Interface Bus (GPIB)) requiring the development of specific GUIs. Currently, other options are available, namely the adoption of a standard solution named LAN eXtensions for Instrumentation (LXI). This solution is already integrated in many instruments, bringing Ethernet interfaces and GUIs that allow controlling/monitoring the remote laboratory through the internet, without technical developments. This way, the association "Infrastructure devices - GUIs – networks" is becoming simpler and may tend to become a fact in ANT meaning.
- **Access devices - GUIs - networks:** This association emphasizes the importance of the adopted device for accessing a remote laboratory. PCs are already common choices in RE, since they have high processing capabilities, which allow the inclusion of several and recent

network interfaces together with large and advanced GUI for conducting remote experiments. However, recent developments are placing new and powerful portable access devices in the market (e.g. PDAs and smart-phones with tactile displays and Wi-Fi network associations) that also satisfy RE requirements. Companies must also see advantages on RE, since it should be seen as a potential market that should be carefully analysed.

- **Experiment - technical/human actors:** The development of a specific experiment depends on technological resources and users' requirements. Currently, technology is facing many improvements allowing the development of remote experiments with almost the same features provided by traditional laboratories: control/monitor equipments, interaction among students and students-teachers using communication tools (e.g. e-mail, videoconference), etc.. Technology has a strong impact in the laboratorial infrastructure, but RE may dictate and contribute for some changes in technology, as exemplified by the new instruments that already bring Ethernet interfaces (e.g. LXI). Therefore, this association is fundamental to be constantly analysed so better experiments may be delivered using new and more recent instruments.
- **Pedagogical contents - experiment - technical/human actors:** Remote experiments require theoretical support made by the so-called pedagogical contents. Disseminating those contents may benefit from current technologies, namely by using VLEs, since these allow students to access multimedia resources through their devices. This way, the quality of the experimental work will improve, since students will have access to better contents (animations, simulation, images, etc.) and teachers will have their tasks simplified, since they can deliver and update more easily those contents, putting them available in the web.
- **Teamwork - students/teachers - technical actors:** This association emphasizes the importance of communication and collaboration among teachers and students during the conduction of an experiment using technological resources. The intention is to provide the same conditions available in a traditional laboratory when different students and teachers share ideas and opinions to solve a specific laboratorial activity. In the case of remote experiments, those same students and/or teachers are usually geographically dispersed, so adopting communication tools, synchronous (e.g. videoconference) or asynchronous (e.g. email) is a solution that guarantees the teamwork requirement.

5 A New Actor for the RE Network

All actors and associations were identified taking into consideration current RE circumstances, i.e. translation processes were not specified. However, a recent proposal identified Field Programmable Gate Arrays (FPGAs), namely FPGA-based boards, as a potential solution for replacing the usual PC, that implements the so-called instrumentation server, and, in many situations, some I&M used in a remote experiment. The idea proposed in (Ricardo Costa et al., 2010) is to embed a set of I&M inside an FPGA-based board for controlling/monitoring remote experiments. I&M will be developed using standard hardware description languages (e.g. Verilog or VHDL) and will follow the IEEE 1451.0 standard (IEEE 1451.0 Std., 2007), so they can be easily interfaced and shared. Then, a new actor, named FPGA+I&M, becomes a candidate for integrating the RE actor-network.

As previously said, in ANT each actor may be detailed into sub-networks. This is the case of the identified actor, named "infrastructure devices", that represents all devices adopted in a laboratory infrastructure (e.g. web and instrumentation servers, laboratorial instruments and modules, webcams, etc.). Since the candidate actor requires changing the “infrastructure devices”, it becomes important to analyse, based in the translation process, the impact that actor may pose to the actor-network. For that purpose, figure 5 details the infrastructure devices usually adopted in any laboratory infrastructure and stresses the proposed changes, i.e. the replacement of the instrumentation server plus the I&M by a simple FPGA-based board (the FPGA+I&M).

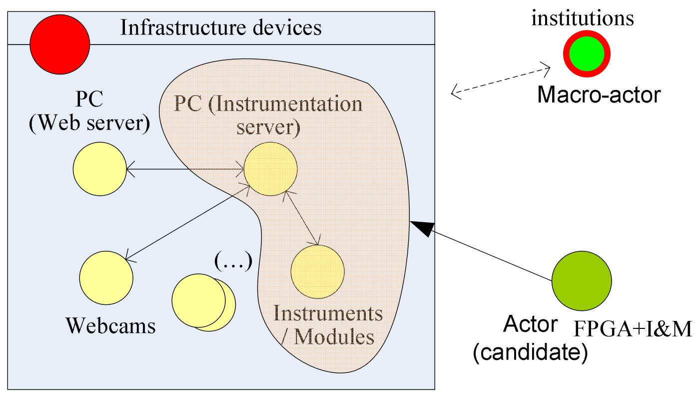

Figure 5: Example of a translation process in the RE actor-network.

As defined in the translation process, the first step is to identify the macro-actor. Although several opinions may be considered, from our point of view the macro-actor is the institution, since it is based in its main interests (that currently represents unsolved problems in RE) that the candidate actor may be integrated into the actor-network, namely; i) costs savings (using a simple FPGA-based board is normally cheaper than using PCs and several I&M) and ii) collaboration among institutions (sharing I&M will become easier since they are developed using standard hardware languages able of being embedded in any FPGA, which enables each institution to easily share its knowledge). These are issues that presently represent problems of the translation process, and no doubt they are extended to other actors like students *(problematization)*. This way students will also have interest on solving those problems (*interessement*) becoming enrolled in the process of applying FPGA+I&M into the RE network (*enrolment*). In other words, if the macro-actor problems are solved, human actors will also get advantages: i) students and teachers will have access to better experiments, since developing new laboratory infrastructures will become easier; ii) technicians will have their tasks reduced, since the use of FPGAs and I&M does not require any software maintenance (software layers are not required and concurrent accesses will be easily implemented); and iii) developers only need to integrate I&M already defined by others (I&M are easily shared). Therefore, all changes that this new actor may pose to the network may be viewed as advantages that will easily mobilize other actors to accept the change and maintain future commitments among them (*mobilization*).

6 Conclusion

More than ever, in current society education is viewed as an asset that guarantees social sustainability in values, attitudes, and knowledge. Technology is influencing people habits and attitudes and thus the educational context landscape. Many technological resources and tools are being applied to improve the traditional learning/teaching methods. In the particular case of S&E courses, where laboratory work is fundamental for learning outcomes, RE is spreading its influence, providing the ability to conduct real experiments through the internet. Flexibility to access real laboratories and collaboration among students and teachers are increasing. However, the involved elements, which comprehend the implementation of a remote laboratory infrastructure, require an analysis of the adoption context, actors and their associations. This paper provided a first analysis, situating education as a context dependent of social and technological contexts, that integrates RE as an actor-network. For that purposed, actors, and associations among them, were described and commented using ANT as socio-technical lenses. With this contextual mapping we then analyse the adoption of FPGA-based boards as the main device of a laboratory infrastructure as the inclusion of a new actor into the RE actor-network, based on a translation process.

References

Bruno Latour, 2007. Reassembling the Social: An Introduction to Actor-Network Theory. *Oxford University Press, USA*.

Chetz Colwell, Eileen Scanlon and Martyn Cooper, 2002. Using remote laboratories to extend access to science and engineering. *Computers & Education. An International Journal from Elsevier*, 38(1-3), 65-76.

Christian Maier and Michael Niederstätter, 2010. Lab2go – A Repository to Locate Online Laboratories. *International Journal of Online Engineering (http://www.i-joe.org/)*, 6(1). Available at: http://online-journals.org/index.php/i-joe/article/view/1117.

Garcia-Zubia, J. Orduna, P. Lopez-de-Ipina and D. Alves, G.R., 2009. Addressing Software Impact in the Design of Remote Laboratories. *IEEE Transactions on Industrial Electronics*, 56(12), 4757-4767.

Gustavsson, Zackrisson, Håkansson, Claesson and Lagö, 2007. The VISIR project – an Open Sources Software Initiative for Distributed Online Laboratories. *Conference on Remote Engineering and Virtual Instrumentation (REV'07)*, 6.

Hine N. et al., 2007. Institutional Factors Governing the Deployment of Remote Experiments: Lessons from the REXNET Project. *International Conference on Remote Engineering & Virtual Instrumentation (REV'07)*.

iJOE - International Journal of Online Engineering, 2010. *http://www.online-journals.org/*.

IEEE 1451.0 Std., 2007. Standard for a Smart Transducer Interface for Sensors and Actuators - Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats. *The Institute of Electrical and Electronics Engineers, Inc.*, 335.

IEEE Transactions on Learning Technologies - Call for Papers: Special Issue on The Many Faces of Remote Laboratories in Engineering Education, 2010. *http://www.computer.org/portal/web/tlt*.

Law J. and Hassard J., 1999. Actor network theory & after. *Blackwell Publishing/The Sociological Review, Oxford*.

Mergl C., 2006. Comparison of Remote Labs in Different Technologies. *International Journal of Online Engineering (iJOE)*, 2(4).

Michel Callon, 1986. Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. *J. Law, Power, action and belief: a new sociology of knowledge? London, Routledge*, 196-223.

Michel Callon, 1991. Techno-economic networks and irreversibility. *Routledge, Taylor & Francis Group*.

MIT iCampus: iLabs - Massachusetts Institute of Technology (MIT), 2010. *http://icampus.mit.edu/iLabs/*.

REV - Annual International Conference on Remote Engineering and Virtual Instrumentation, 2010. *http://www.rev-conference.org/*.

Ricardo Costa, Gustavo Alves and Mário Zenha-Rela, 2010. Reconfigurable weblabs based on the IEEE1451 Std. *1st IEEE Engineering Education 2010 – The Future of Global Learning in Engineering Education (EDUCON'2010), Madrid - Spain*, 8.

Roque, Licínio, Almeida, Ana, and Figueiredo, António Dias,, 2004. Context Engineering: An Is Development Research Agenda. *European Conference on Information Systems, ECIS 2004, Turku, Finland*, 14.