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# INTERDISCIPLINARITY AND GLOBAL COLLABORATION IN BIOMEDICAL ENGINEERING AND INFORMATICS TEACHING

## INTERDISCIPLINA Y COLABORACIÓN GLOBAL EN LA ENSENIANZA DE LA INGENIERÍA BIOMÉDICA Y LA INFORMÁTICA

## INTERDISCIPLINARIDADE E COLABORAÇÃO GLOBAL NO ENSINO DE ENGENHARIA BIOMÉDICA E COMPUTADORES

**Bianca Vienni**[1]
**Franco Simmi**[2, 3]

**ABSTRACT**

This paper takes the Núcleo of Ingeniería Biomédica (NIB) from the Universidad de la República (Uruguay) as an example of how interdisciplinarity and global collaboration can be achieved in Higher Education teaching activities with a focus on Biomedical Engineering and Medical Informatics. We have recorded and analyzed using a qualitative strategy its practices in different teaching formats to interpret the best pedagogical strategies in the combination of interdisciplinarity and distant collaboration when using new technologies of communication.

[1] Doctora y Magíster por la Universidad de Granada (España) y Antropóloga por la Universidad de la República (Uruguay). Profesora Adjunta de la Unidad Académica del Espacio Interdisciplinario, Universidad de la República, Uruguay. Correo electrónico: biancavienni@gmail.com.

[2] Doctor en Ingeniería. Profesor Titular, Responsable del Núcleo de Ingeniería Biomédica, Facultad de Ingeniería y Hospital de Clínicas, Universidad de la República, Uruguay. Correo electrónico: simini@fic.edu.uy.

[3] Endereço de contato com os autores (por correio): Av. José Enrique Rodó 1843, 1220, Montevideo, Uruguay.

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**KEYWORDS:** Biomedical Engineering; Interdisciplinarity; University; Uruguay.

**RESUMO**
O artigo leva o Núcleo de Engenharia Biomédica (NIB) da Universidade da República (Uruguai) como um exemplo de como é possível conseguir interdisciplinaridade e colaboração global nas atividades de ensino do Ensino Superior com foco em Engenharia Biomédica e Informática médica. Do registro qualitativo e análise de suas práticas nos diferentes formatos de ensino; foi possível interpretar as melhores estratégias pedagógicas na combinação de interdisciplinaridade e colaboração à distância ao usar as novas tecnologias de comunicação.

**PALAVRAS-CHAVE:** Engenharia Biomédica; Interdisciplinaridade; Universidade; Uruguai.

**RESUMEN**
El artículo toma al Núcleo de Ingeniería Biomédica (NIB) de la Universidad de la República (Uruguay) como un ejemplo de cómo se puede lograr la interdisciplinariedad y la colaboración global en las actividades docentes de Educación Superior con un enfoque en la Ingeniería Biomédica y la Informática Médica. A partir del registro y análisis cualitativos de sus prácticas en los diferentes formatos de enseñanza; se ha logrado interpretar las mejores estrategias pedagógicas en la combinación de interdisciplinariedad y colaboración a distancia al utilizar las nuevas tecnologías de la comunicación.

**PALABRAS CLAVE:** Ingeniería Biomédica; Interdisciplinariedad; Universidad; Uruguay.

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## Introduction

Modern Technologies for Information and Communication (ICTs) multiply easy access to all sorts of information and experiences in all countries. This well-known characteristic of our century brings about increasing research possibilities. Moreover, with ICTs the disciplinary barriers are more prone to be overcome by scholars and ordinary people alike. What used to be a well-defined corpus of knowledge and established references now opens to different perspectives and points of view. This broadening of tools, both conceptual and practical, matches the increasingly complex problems derived from contemporary society. The inherent complexity of research problems has promoted and demanded the concurrence of diverse disciplinary approaches, at first as juxtaposition of knowledge (referred to as multidisciplinarity), and over time taking advantage of dialogue and integration between different fields (referred as interdisciplinarity).

Interdisciplinarity is applied as a concept particularly creative and socially relevant for the scientific development that integrates the social sciences, accurate and natural. Although in the last fifty years, a robust body of scientific literature has been built, it does not represent the same working time spent on the analysis of interdisciplinary approaches (FRODEMAN, 2014a). This fact is verified at the Universidad de la República (UdelaR, Uruguay), a public institution that includes the development of interdisciplinarity explicitly in its university policies (AROCENA, 2008). Understanding how interdisciplinary knowledge is produced is one key aspect to creating better conditions for its development and its transformation into a relevant research approach.

In this sense, the Biomedical Engineering Department (NIB, Núcleo de Ingeniería Biomédica) is an interdisciplinary group of the Faculties of Medicine

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and Engineering of UdelaR, devoted to the development of Biomedical Engineering (BME) as a contribution to the solution of medical challenges. Founded thirty years ago on the border between a physiopathological and clinical approach and the development of prototypes to support research, teaching and outreach (SIMINI ET AL., 2003). The study areas of NIB have allowed to go beyond the rationale of each discipline and by doing so obtained new apparatus, new methods and an sometimes original understanding of physiological and pathological facts. As an epilogue of the effort of understanding, development and solution of medical instrumentation problems, NIB tends towards the promotion of biomedical equipment up to the stage of technology transfer (SIMINI, 1994, 2015). The NIB has an interdisciplinary approach for the training of professionals in Biomedical Engineering, capable of facing the challenges of medical and biological instrumentation. Its contribution in teaching in the area of medical education (physician and medical technology or nursing degrees) contributes to strengthening the fertile dialogue between medicine and engineering.

This paper takes NIB as an example of how interdisciplinarity and global collaboration can be achieved in Higher Education teaching activities with a focus on Biomedical Engineering and Medical Informatics. We have recorded and analyzed itss practices in different teaching formats to interpret the best pedagogical strategies in the combination of interdisciplinarity and distant collaboration when using new technologies of communication and virtual spaces for collaboration.

The main objective of this article is to provide a diagnosis of the process of scientific knowledge production and its practice that allows visualizing its current features in the area of Biomedical Engineering. Evaluating these

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scientific and teaching practices contributes to the definition of institutional policies and the deepening of knowledge about this type of approach. Systematizing the similarities and the learning strategies within the university context may favor the conduction of research on social problems and scientific democratization through a better use of new technologies, including informatics. Rethinking disciplines and their integration, as a cultural approach, enriches the understanding of interdisciplinarity while suggesting how aspects of community and academic life influence perceptions and behaviors related to academic work (LATTUCA, 2001).

The first section outlines the theoretical framework and the conceptual approach of the paper. The next section details the context where NIB develops its work. We then present the background of the teaching activities of this group, along with specific actions carried out to address the interdisciplinary problem of Biomedical Engineering in Uruguay and how the new technologies helped or hindered that approach. Finally, we conclude with points of discussion and potential prospects for the future.

**Interdisciplinarity from its origins**

A growing emphasis is made in the literature, at both national (SIMINI & VIENNI, 2017; VIENNI ET AL., 2014; VIENNI, 2016a and b) and international level (LYALL ET AL., 2010; FRODEMAN, 2014b; among others), in interdisciplinary and transdisciplinary research (BAMMER, 2005; POHL AND HIRSCH HADORN, 2007; among others) to address problems that are considered complex and require new approaches and relationships. In this context, a new type of knowledge and its production (FRODEMAN, 2014b) are produced that have its origins in the interconnection between various disciplines and create new views and conceptualizations.

Interdisciplinarity can generally be defined as a synthesis of ideas, data or information, methods, tools, concepts, or theories of two or more disciplines seeking to answer a question, to solve a problem or to produce new knowledge, or to solve problems whose solutions are beyond the scope of a single discipline or research area (NATIONAL ACADEMY OF SCIENCES, 2005). This production of knowledge affects not only the knowledge produced, but also how it is produced, the context in which it is inserted, the way it is organized and the mechanisms that control the quality of what is produced (GIBBONS ET AL., 1994).

Among the most recent developments, we are particularly interested in what Barry and Born (2013) propose: they visit this concept and conclude that there is no direct link between interdisciplinary research and innovation. That is, not all innovation involves interdisciplinary research, and vice versa. The authors think there is a reconfiguration within the boundaries of both the social and the natural sciences as evidenced by the variety of interdisciplinary fields, institutions and specificity of their trajectories.

In this context, building knowledge is giving meaning to academic practices and involves a shared communication process, which can lead to the formation of a specific academic culture (BECHER, 1989). Scientific knowledge is understood as a social construction influenced by cultural, political, and economic circumstances, among others (GIBBONS ET AL., 1994; ZIMAN, 2003).
In the development of an interdisciplinary process, multiple tensions inherent in the academic system emerge. Focusing on the production of knowledge through academic science (ZIMAN, 2003) and the role that researchers play

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particularly in this context, it is essential that these processes of change and transformation are incorporated into the scientific ethos (MERTON, 1977), as they involve the construction of new paradigms in the organization and production of knowledge. These changes do not occur uniformly and linearly, nor do they develop equally in the various disciplines. This aspect has been studied extensively by the approach of STS (ALBORNOZ ET AL., 1996; GONZÁLEZ GARCÍA ET AL., 1996; IRANZO ET AL., 2005; LÓPEZ CEREZO & SÁNCHEZ RON, 2001; among others) which refers to the dynamics through which these three elements (science, technology and society) are related, alongside to how science itself works as both the most important structural element of our society and as a major constituent of our culture (ZIMAN, 2003). What we know about the world is closely tied to our sense of what we can do about it, as well as to the legitimacy we give to the actors, instruments and lines of action (JASANOFF, 2004). Science and technology are essential for the expression and exercise of power, given that they operate, ultimately, as political agents.

In line with the authors evaluated here, we incorporate an interdisciplinary approach to the understanding that enhances a strengthening and democratization of scientific knowledge production processes in society (ROMM, 1998). For these reasons, we have considered the development of an area of study called "Studies on inter- and transdisciplinarity" (ESIT, for its acronym in Spanish) (VIENNI, 2016a and b) to explore research practices and processes, as well as researchers´ perception and their relationships within the interdisciplinary and transdisciplinary groups. The approach that guides the proposal is itself interdisciplinary and is generated from existing results in the literature mainly in the field of STS and Development Studies (AROCENA &

SUTZ, 2003). It is understood that, generally speaking, the STS field studies is not comparable to the transformation of the forms of knowledge production.

The relevance of this research lies in its theoretical contribution to interdisciplinary work, from a comprehensive analysis of practices and the inner complexity of scientific knowledge (FRODEMAN, 2014a and b). The hypothesis proposed is that interdisciplinary work can help the process of science democratization while the interaction of different disciplinary perspectives contributes to the relationship of science and society from more pluralistic and collaborative academic practices (VIENNI, 2016a). The same can be said from interdisciplinary teaching formats as the ones detailed in this article.

In turn, ESIT as a field of academic specialization can contribute substantively to the promotion of interdisciplinary research. It seeks to motivate and support the researchers who strive to understand other disciplines while still cultivating their own, and from it to bring to interdisciplinary studies efforts to solve theoretical or practical problems. Through research on the theory and practice of interdisciplinary and transdisciplinary approaches of knowledge, we seek to explore the interdisciplinary nature of certain methodological approaches and how to shape and improve those research fields and disciplines.

Some of the questions we are interested in regarding interdisciplinary teaching are: How should we generate processes of interdisciplinary and transdisciplinary teaching appropriate to the Uruguayan context? What features should these processes and programs have? What traditions are identified in interdisciplinary teaching in undergraduate and graduate at our University? What are the scope and limits posed by various fields of training in their interdisciplinary approaches? How should we stimulate learning processes in

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inter- and transdisciplinary training appropriate to each context? What features should these processes and programs have in terms of ICTs?

## Information, Communication Technology and Interdisciplinarity

Inclusive teaching includes a very complex set of knowledge spanning from psychological to motricity studies, medicine and information technology. Traditionally tackled by voluntary loving care with little scientific background, the availability of ICTs has given the starting point of interaction between educators, health professionals and technology specialists. Interdisciplinarity is the key to successful applications for education of persons with autism or other syndromes (PASSERINO & COSTI SANTAROSA, 2008).

The ease with which ICTs access information favors the availability of diverse sources of knowledge and experiences, sometimes in nearby fields, sometimes in distant fields. This is not yet interdisciplinarity, but an open door to dialogue and integration. Our research groups are led naturally to address colleagues of different backgrounds, giving thus the first steps towards a meaningful interaction and exchange.

Among all disciplines, education stands out as a special field of knowledge, which special benefits because it is seldom limited to a topic, always including psychology, social and cognitive sciences and the specific knowledge to be taught. In addition, since Education builds upon a two way channel between members of the dyad, the bidirectional flow of ideas, plans and experiences naturally involves interdisciplinary contents. This is why interdisciplinarity has fostered special education tools so much (BEZ, 2014). The SCALA project, e.g., is a comprehensive set of technologies, both medico/psychological and computer/software, which addresses the social

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inclusion problems of children with Austism Spectre Disorder (ASD) using alternative communication tools, all of which can be described as "Interdisciplinarity landed on the mobile/internet realm". Not only content-wise, but also from the methods point of view, the development of SCALA uses a typical modern approach, reaffirming the close linkage of education, communication technology and interdisciplinarity (BEZ, 2014; PASSERINO ET AL., 2011).

But a profusion of data and references, easily obtained and unfiltered, can be deleterious to proper understanding of problems. Moreover, a superficial understanding of problems may come from this, preventing deep insight and research continuity. The data overdose situation is a great danger of profusion of ICTs in our Century. If not properly guided, students today produce plethoric written items full of disorganized material. The real knowledge contained in such texts is low, as a consequence of the lack of priorities assigned to single pieces of information, links and partial conclusions. The flash lights of circumstantial information gathering and contact have a limited life span, because they lack the meditation and deep integration -typical of true research- which is always present when interdisciplinarity is well understood.

A typical case of Interdisciplinarity is Biomedical Engineering, a recent field of study and technological research derived from the direct and close contact of clinicians and engineers. One of an increasing number of applied and basic sciences, BME also follows the global tendency to link many actors in several countries, regions, organizations and companies.

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**Biomedical Engineering Teaching in the 21st Century**

There is a growing number of BME undergraduate teaching offers throughout the world, proportional to the increasing medical care state and private expenditure and part of most research efforts to further medical knowledge. Within this framework, our NIB is an interdisciplinary group with a research and teaching experience of more than thirty years (SIMINI & VIENNI, 2017). Its seeks the immersion of engineers in a clinical environment and the joint work of teachers from different academic specialties to favor a gradual osmosis of knowledge and problems that include language (even jargon), values and work objectives. This allows to applyin methods and theories coming from one discipline to another without intermediation. The biomedical engineer can then sit in a round of clinicians without difficulty and will know when to intervene, providing from his perspective, clues for interdisciplinary integration. In a similar way, physicians who take part in a project with biomedical engineers learn to intervene at the right time from their own perspective, specifying medical requirements and learning something of the engineering method.

The NIB was originated from the needs of technological and theoretical support of medical research and in particular in three academic groups active in the second half of the 20th century: Dr. Roberto Caldeyro Barcia's group, the Center for Nuclear Medicine of Dr. Eduardo Touya and the Institute Biological Research Clemente Estable; all three in Uruguay. The technological and theoretical needs detected by researchers who, individually or in groups, led naturally to an interdisciplinary approach to solve those scientific problems. By broadening the discussion to several approaches, they were giving the fundamental steps to develop interdisciplinarity. In those groups one could find

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physicians who specialized in engineering by vocation and engineers who dedicated their energies to understanding physiological problems or conditions by means of a calm immersion in a research without external pressures nor demands.

There was a historical moment that allowed to consolidate the idea of NIB and it was the year 1984, when engineering students , in search of thesis topics, asked for help in what would become the research area of NIB. The original contributions of the group of Roberto Caldeyro Barcia received broad international recognition, based on the work of one of the first interdisciplinary groups of the Country (CALDEYRO BARCIA & POSEYRO, 1960).

As part of the Universidad de la República, NIB has developed the three university missions: research, teaching and extension, which in turn giveits characteristics to the group and to the interdisciplinary work. These three missions share interfaces that help to conceive interdisciplinary work in integrality of teaching (AROCENA, 2010; TOMASINO & RODRÍGUEZ, 2010). The university missions, in addition, contribute in their complementarity to the construction of the dialogue and research and development processes of biomedical solutions. Core activities include: (1) teaching courses and seminars, (2) research and development based on theses (3) consultancies to other departments of theFaculty of Medicine, (4) strong relationships with institutions, publications and exchanges and (5) technology transfer to industry. In all these activities, NIB has been using ICTs as a fundamental tool to develop the interdisciplinary interface needed. Despite these efforts, the new technologies have proven to be inadequate to solve all problems related to the multi- and interdisciplinary approaches.

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Teaching a subject such as engineering within biomedical research and its interdisciplinary nature has consequences in the design of training strategies. The modality adopted by NIB can be seen from the following examples (SIMINI & VIENNI, 2017):

a) The student of biomedical engineering has to be able to have a meaningful dialogue and to understand clinicians and physiology researchers: the culture, the habits of communication and reasoning of an engineer differ from those of physicians, whose training follows different intellectual processes and therefore develops different mental reflexes. NIB has devised a practical work by which biomedical engineering students have to teach physicians some elements of signal analysis. Students are forced to reach to their own theoretical training to adapt it to the lexicon and models of their medical students. Evaluation is done by questioning the physician, not the BME students, verifying whether the medically minded student could assimilate the concepts at the end of an interdisciplinary interaction. Prior to this exercise, the physician did not handle concepts such as bandwidth, frequency decomposition and the definition of "signal filters", all elements that induced him to walk along an disciplinary path with the help of the engineering students. This exercise won second prize in an entrepreneurial engineering teaching competition (SIMINI ET AL., 2013) and was tested for the first time in 2013. The four instances since that time show that physicians experience it with interest.

b) The appropriate language and problem solving capacity of biomedical engineers is paramount for their work in hospitals. NIB has defined an Internship in Biomedical Engineering. BME consists of a six-month internship during which the student -remotely led by BME instructors- works 44 hours a week in a hospital. Exposure to the problems of management of biomedical

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equipment, equipment break downs, information needs coming from clinical staff are all triggers of exchange and interdisciplinary training. A dialogue is thus started while solutions to the problems are sought in contact with NIB. The benefit of BME is two-fold because, on the one hand, with a minimum of prior preparation in biomedical engineering, studenthelp to detect management and BME equipment use problems, while giving the possibility to learn the lexicon and specificities of medical care in hospital facilities (SIMINI, LEÓN MOLONEY & DE GIOBBE, 2015).

c) The capacity for interdisciplinary dialogue is built through the formulation and joint implementation of projects or thesis of students of different disciplines. The "interdisciplinary project of computer software registries " (PIRIM, for its acronym in Spanish) is a joint activity of NIB and the University School of Medical Technology. Each project involves three students of the Medical Records Degree (RRMM) and three informatics students, all in their final academic year. The six students work together, exchanging information, until they define a project scope, its characteristics, its mode of use and verification. Topics are clearly interdisciplinary because they are defined by students of different backgrounds working together: engineering and medical records. Examples were medical visits optimal time assignments, an electronic medical record (EMR) system, a controlled terminology system or monitoring of adherence to medication. Engineering students are supervised by interdisciplinary tutors of both disciplines, in addition to what they learn from their contact with students of RRMM. Symmetrically, RRMM students receive training in computer systems specification, as they are guided by computer science students, simulating client-supplier scenarios in Medical Informatics (SIMINI ET AL., 2001). This is another example of how personal interaction and face - to - face teaching and learning processes cannot be replaced by new technologies. In order to keep the interdisciplinary teaching as a fundamental and substantive process for teachers and students, time and personal interactions must be an asset. Unsually, students are given thesis topics., but with PIRIM, students have to think together in an interdisciplinary work that receives the approval of teachers after one month of work. The computer prototype produced after six months is being tested by RRMM students who certify if it complies with what was originally specified.

d) Masters degree theses under the direction of two (or more) tutors, the main one coming from a different discipline as that of the student. NIB offers interdisciplinarity in a variety of ways and the degree of interdisciplinary is given by the diversity of formations of teachers and students involved. The proportion of non-engineers, and therefore active in the construction of interdisciplinary, ranged from 35% to 50%.

e) Shared courses are the norm with NIB. The courses offered by the NIB have evolved from an initial seminar inaugurated in 1992, during which applications, problems, solutions and projects were shown, alternating points of view, engineering and medical. It was seen that the weekly presentation by different invited speakers of different backgrounds gave students a broad understanding of what was available in BME. By 2015, NIB offers 10 courses and theinternship in hospitals. Single lessons or topics in these courses are presented by two instructors or professors. The first part may be the anatomical and physiological descrition of an organ or system (nephrology e.g.) and the second part would be the design of an equipment to measure, monitor, substitute that function (dialysis equipment design, e.g.). Both teachers are present during the two hour lesson, listening to their counterpart and eventually adding comments of pieces

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of information not fully mastered because of a different nature. The student receives in a single lesson both points of view, and is able to elaborate his or her own interdisciplinary knowledge. NIB courses are taken by Electrical Engineering, Informatics, Medicine or other student, including continuing education, undergraduate and graduate.

**Interdisciplinarity in BME teaching with ICTs**

ICTs evolve with great speed: what used to be a new educational tool may quickly become obsolete and is abandoned. In 2010, universities such as our own made the option to transfer much of the teacher/student interaction to a central ICTs tool based on the Modular Object-Oriented Dynamic Learning Environment (MOODLE), locally implemented as the "Entorno Virtual de Aprendizaje" (EVA, for its acronym in Spanish) (RODES, personal communication). Using EVA allowed teachers of different backgrounds to simultaneously access academic interchange with students, thus enhancing interdisciplinarity. Growing steadily from 2008 until now, a decade later, 84.000 users, 2.000 active courses and 68% (69.000 student) have a MOODLE user in 2012. ICTs have been a great interchange booster, but, as it will be shown at the end of this section, EVA may eventually be replaced by other virtual environments.

Research in BME equipment was described as a true interdisciplinary task (SIMINI & VIENNI, 2017) involving diverse personnel, in constant interaction, which is greatly possible thanks to ICTs. Student research introduction , as a complement to classroom teaching, is also based upon ICTs. The use of "clouds" -both local and remote- to allow sharing of documents raw data and all sorts of material, reaffirms the importance of ICTs in BME research. This is only one of

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several ICTs tools such as specialized software, reference managers, spreadsheets, laboratory equipment and instrumentation, among others.

For classroom teaching, BME is based on the personal experience and commitment in interdiscipline, present, for instance, in the following routine. As was described earlier, engineering students are expected to teach Signal Analysis concepts to Medical students., and this is possible only if both Medical and Engineering students are convinced of the value of interdisciplinary interchange. If ICTs are present in demonstrations, then they are easier to understand, better recorded and evaluated. Incidentally, evaluation of skills acquired is performed with multiple options quizzes to which Medical students are submitted to, showing the success of Engineering students teaching signal analysis to them.

## University Outreach based upon BME Interdisciplinarity

The task of extension, also known as University Outreach,is intrinsic to university work . Society demands clarifications, cooperation and proposals outside the teaching or training of citizens. It is about mutual participation and learning starring equally the counterpart and the group academic. Here are two examples of extensions recently carried out:

(1) The construction and furnishing of hospitals in Uruguay was traditionally performed by successive and independent stages. First the planned hospital is build and then equipment and sometimes full networks (such as pneumatic messaging systems) are purchased and installed. For the first time, in 2013, there was a decision (originally suggested by NIB) to work in an interdisciplinary way towards the selection of equipment and all networks for the hospital before the actual building started. This task was defined as both a contract and

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an outreach program, defined by the State Health Services (ASSE) and NIB for a new building of the Pasteur Hospital in Montevideo. The job consisted in the definition of equipment by biomedical engineers along with physicians involved in the emergency section and operating room staff. The joint development of specifications, connections, proof of concept and evaluation of solutions lead to a result that included an improved dialogue capacity and reduced misunderstandings. This outreach activity is being organized as a teaching module in clinical engineering, with guidelines for the selection of hospital equipment and facilities.

(2) The second example of university extension is related to the need of technical advice on biomedical equipment and the management of its maintenance, very often entrusted to third parties identified with suppliers. As previously mentioned,NIB has created an instance of practical training, the Internship in Biomedical Engineering(IIB) (SIMINI ET AL., 2015). It is not possible to separate BME teaching from its practice once the student has a minimum level of knowledge. This experience has multiple effects: (a) on electrical and labor safety in the use of biomedical equipment, (b) in the early detection of defects in data or electrical networks, (c) in the formation of the clinical staff, (d) in the availability of equipment in shortening times, (e) in the detection of instrumental needs derived from clinical practice and (f) in the use of equipment that comes to an end of his safe life, among others. Practical instances of such BME can be considered as university outreach for their impact on hospital staff, users and patients.

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**Conclusions**

Complexity occurs in an increasing number of activities which play an important role in the production of knowledge. In the case analyzed, these activities include interdisciplinary networks, loans, shared interests, learning communities of faculties (medicine, engineering, nursing, others) and participation in interdisciplinary fields, for example in informal clusters. The emergence of new fields also demonstrates the development of increasing complexity of knowledge (BRUUN ET AL., 2005). The growth of the last years responds to a availability of technological solutions to which researchers access to solve problems of increasing diversity. The clinician resorts to the interdisciplinary and the engineer proposes new solutions as a consequence of the existence of an integral practice and background of accepted answers. The prototype can be tested with test elements and goes to clinical application once safety and legal clearances are satisfied.

But what happens when these technologies are introduced in the teaching – learning environment? As posed before, BME has proved to be a fertile territory for introducing new technology to develop teaching formats. Although this is true, our analysis of NIB practices has confirmed that interdisciplinarity still needs a great amount of personal interaction and face – to – face work to achieve its full potential. Our study also shows that students can misuse ICTs to favor quick and irrelevant connections to the contents of a research area. In this case, the permanent contact and active relationship with patients and clinicians is the basis for a better development of prototypes in contexts where these interactions are rare and may derive into unwanted health problems.

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