Interdisciplinary Collaboration Within Medicine-Based Informatics and Engineering for Societal Impact

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Abstract This chapter elaborates on the challenges and opportunities that interdisciplinary collaborations have for Medicine, Informatics and Engineering. It argues that interdisciplinarity is a means to better approach current societal challenges and therefore to achieve meaningful impact on current problems, as the ones presented in this book. We seek to open a fruitful pathway to reflect on the urgent demand to bridge knowledges, perspectives and insights, that help to overcome crisis such as the current Covid-19 pandemic. In so doing, we identify challenges coming from a national and international perspective and we analyze them in the light of a Uruguayan interdisciplinary program: the Núcleo de Ingeniería Biomédica of the Universidad de la República (Uruguay). This program has been working for almost 40 years in the interface between Medicine and Engineering, training scientists and researchers in how to foster meaningful solutions to health problems. Lessons learnt and successful narratives are presented as means to promote interdisciplinary collaborations between these and other fields of knowledge. We also build on general and also specific research strands that have historically pursued collaborations among different disciplines to approach complex problems. Several examples have also been provided in this book so as to include two powerful ideas to leverage BME and MI as means to achieve socially robust solutions for health and well-being. As chapters in this book show, the development of biomedical devices, software and systems must stem from clinical wish lists and desiderata. Technology follows, in these cases, medical specifications applying an interdisciplinary approach.

Keywords Interdisciplinary research · STEM disciplines · Biomedical engineering · Uruguay · University programme · Societal impact

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F. Simini and P. Bertemes-Filho (eds.), *Medicine-Based Informatics and Engineering*, Lecture Notes in Bioengineering,
https://doi.org/10.1007/978-3-030-87845-0_11

1 Introduction

Science and technology have interacted in an ever increasing depth since the beginning of speculative thought, which is approximately the time when civilizations have started their written history, i.e. when documents in writing were produced.

Ancient Greek culture was the place and time where the pleasure of thinking and the satisfaction of intellectual speculation were developed and socially valued. Philosophy was made possible by long hours with no material nor practical burden on the shoulders of free citizens. Within an ideal framework of social interactions, geometrical theorems and other speculative forms of science were considered to be of great importance, challenging and reaching the aesthetic characters of beauty. The practical aspects of life—left to be taken care of by slaves—dealt with the evolution of technology, be it food preparation, house building, crop growing or materials management. Very little contact—if any—was developed to enhance technology using results of thinking, speculation and theorem demonstration. Different people and different communities dealt with each activity of the dyad science and technology.

Therefore, the origins of Science and Technology are different and clearly separated, the former being originated by intellectual curiosity and the latter by practical barriers to be overcome. The increasing sophistication and complexity of our culture is having the effect of bringing Science and Technology to a close synergy, together with society in three vertexes bidirectional dialogues. By doing so, the original dyad was challenged to include the societal perspective in this equation. Science, Technology and Society studies (STS) have become a means to understand and to problematize the relationship among these (Hackett et al. 2008; Jasanoff 2005).

Technology tackles complex problems today to produce simple usable goods and services. Its complexity implies an interdisciplinary approach to better approach multidimensional problems that foster improved quality of living conditions. The complexities of practical problems call for new knowledge which is the result of research devoted to augment the scope and specificity of technology (Bammer 2008; von Bertalanffy 1968).

In an ever increasing fashion, Science, Technology and Society interact closely as a system according to the observations and theory put forward since 1940 by von Bertalanffy (1968). With the difference that almost a century ago, von Bertalanffy and contemporaries longed to "improve communication among specialists" (von Bertalanffy 1968) while full scale interdisciplinarity (ID) is necessary in the present century.

This chapter elaborates on the challenges and opportunities that interdisciplinary collaborations have for Medicine, Informatics and Engineering. It argues that interdisciplinarity is a means to better approach current societal challenges and therefore to achieve meaningful impact on current problems, as the ones presented in this book. We seek to open a fruitful pathway to reflect on the urgent demand to bridge knowledges, perspectives and insights, that help to overcome crisis such as the current Covid-19 pandemic. In so doing, we identify challenges coming from a national and international perspective and we analyze them in the light of a Uruguayan interdisciplinary program: the NIB (Núcleo de Ingeniería Biomédica of the Universidad de la República, Uruguay). This program has been working for almost 40 years in the interface between Medicine and Engineering, training scientists and researchers in how to foster meaningful solutions to health problems. Lessons learnt and successful narratives are presented as means to promote interdisciplinary collaborations between these and other fields of knowledge.

The chapter is organized as follows: first, we look at the definition of interdisciplinarity and present the challenges that Science, Technology, Engineering and Mathematics (STEM) currently face as separate disciplines. We argue for more collaboration between them and Arts, Humanities and Social Sciences (AHSS). More specifically, we analyze the implications of the challenges of integration in collaborative research. We then detail the historical conditions that helped integrate Medicine into STEM. Next, we provide the example of the interdisciplinary program NIB, as a successful example of such encounters. We conclude with some insights on how these interdisciplinary collaborations provide a fertile territory for societal impact outcomes within STEM and Medicine (STEMM).

2 Interdisciplinarity and STEMM Disciplines

The progress of interdisciplinary collaboration is fundamentally entwined with the process of social research and the societal context of doing science (MacMynowski 2007). Within this framework, our perspective on ID corresponds to a twenty-first century vision of the problem of how different disciplines interact and collaborate towards approaching current societal challenges (following Bammer 2008). In this section, we present the main challenges of what we understand as interdisciplinary collaboration(s) between STEMM (Science, Technology, Engineering, Mathematics and Medicine) and AHSS disciplines (Arts, Humanities and Social Sciences).

Interdisciplinarity is a widely used term, particularly as part of present efforts to transform the relations between research, economy and society. Most generally, ID is understood as:

> a mode of research (…) that integrates data, tools, (…) perspectives, concepts, and/or theories from two or more disciplines to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline (National Academy of Sciences 2005: 4).

Beyond this specific understanding of the term, other definitions are possible and coexist within the academic literature (Vienni Baptista et al. 2019). When facing the challenge of defining ID, these concepts still represent contested discourses that reveal an interwoven set of different understandings of the term (e.g. Barry and

Born 2013; Klein 2017; Lury 2018; Lyall 2019). Differences are meaningful when thinking the implications for the roles assigned to different disciplines in collaborative work (Vienni Baptista et al. forthcoming).

A main feature of all definitions include the important role that integration has in interdisciplinary research. Integration is a process to combine and synthesize different concepts, methods and/or theories from two or several fields of knowledge in different stages of the research process. It is considered "the core methodology" (Pohl 2008: 421) of collaborative research.

ID implies activities ranging from individual to large-scale team-based initiatives integrating insights from other disciplines, such as the one we present in this chapter. The purpose of interdisciplinary collaborations varies depending on the research aims and specific questions it addresses; both determining the scope that the synthesizing process may achieve. For instance, Mäki (2016) contrasts managerial top-down interdisciplinarity with practitioner bottom-up interdisciplinarity. In what follows, we focus on the second type of interdisciplinary initiatives.

Integration, as the basis to build a collaborative endeavor, needs to be guided using different methods and tools (Pohl et al 2021). One challenge of successfully fostering integration is finding adequate forms of collaboration between researchers and practitioners (Pohl and Wülser 2019). Violeta Bulc (in this volume) argues that these bridges are necessary and require specific skills from researchers and societal actors to build a common ground for collaboration. The "Society 5.0" concept includes ID as a distinctive and identifiable aspect of modern and future human life organization.

The promotion of ID has come to be central to the governance of research (Barry and Born 2013). Despite the long history ID has in different fields of research, integration is still weak between some disciplines. Many factors that hinder ID are associated to what Snow (1964) defined as the "two cultures" as it constitutes a significant influence in attempts to bridge AHSS and STEM.

Efforts to connect disciplines are present in different countries as part of science policy efforts. Currently, the Irish Council of Research (2018), to give one example, characterizes its legacy as "STEAM" research: this is research combining knowledge from Science, Technology, Engineering, Art and Mathematics. In a recent study at the European level, Medicine was also included in this equation, defining STEMM as Science, Technology, Engineering, Mathematics and Medicine (Vienni Baptista et al. 2019, 2020a). It can be argued that none of these terms are new but need to be incorporated more widely into policy to have a real effect on practice (Irish Research Council of Research 2018). In this regard, ID that focuses on challenge-based research accompanies current trends from funders and policy makers world-wide (Kania et al. 2019; Bammer et al. 2020).

STEAM approaches are crucial to understand the social and environmental interactions and their implications and impacts on solutions to grand challenges (De la Garza and Travis 2018). Emerging fields of knowledge and bridges between them build interactions on boundary-crossing exercises and experiments (Klein 2005). These cross-fertilizations are becoming more relevant than ever (de la Garza and Travis 2018), especially in fields as the ones this book focuses on. A multitude of science policy actors, such as research funders, policy makers, journal editors, think tanks and research lobby organizations, all seem to agree that the future of science is to be found outside of firm disciplinary boundaries (Stamm 2019: 376) and well into interdisciplinary research.

In this sense, Arts, Humanities and Social Sciences are also faced with the need to position themselves as part of the current realm of knowledge; including their own definitions of ID. Not only by taking roles that might have an instrumental function, but also by facing conditions that affect their success or failure as disciplines in the scientific environment. We argue that instrumentalization of AHSS disciplines has pervasive consequences on potential interdisciplinary research (Vienni Baptista et al. 2020a) as the evidence from a recent Horizon2020 project confirmed. The project "Shaping interdisciplinary research practices in Europe" (SHAPE-ID)[1] has done an extensive literature scanning exercise on a large set of academic and policy literature on inter- and transdisciplinary research (Vienni Baptista et al. 2019). Authors proved that the Social Sciences and STEM interactions are more diverse than in the case of AH-STEM. While AH connects strongly with Social Sciences, Engineering, and Computer Science; Social Sciences connect strongly with Arts and Humanities, Environmental Science, Business Management and Accounting, Medicine, Computer Science, Engineering, Economics Econometrics and Finance, Psychology, Earth and Planetary Sciences (Vienni Baptista et al. 2019).

This shows that the AHSS-STEMM gap remains a significant challenge in practice and policy (Stamm 2019). MacMynowski (2007: 3) considers that.

> evaluations of interdisciplinary research in journals targeted at biophysical scientists include virtually no citations from the social science literature on disciplinarity and interdisciplinarity; even of one of the most widely cited books on the history, theory, and practice of interdisciplinarity is absent (i.e., Klein 2005). Likewise, in the social science literature, there are virtually no citations from the biophysical literature. The two discussions are running in parallel with stunningly little crossover.

The academic and policy literatures show successful examples of AHSS integration in interdisciplinary research should look like, but there are few factual ideas about how this integration can actually be achieved (Fletcher and Lyall 2020). Examples from practice as the one developed by NIB and described in this book by Martha Ortiz, Marta Bez and Violeta Bulc provide meaningful suggestions that can be replicated in diverse academic contexts associated with social initiatives. For its part, a recent movement within the British Academy proposed the acronym SHAPE for Social Sciences, Humanities and the Arts as a joint movement for the people and the economy (British Academy 2016). SHAPE is:

[1] Some of the outcomes detailed in this section are framed in the project "Shaping interdisciplinary practices in Europe (SHAPE_ID)", which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 822705. More details on the project: shapeid.eu.

> a new collective name for those subjects that help us understand ourselves, others and the human world around us. They provide us with the methods and forms of expression we need to build better, deeper, more colourful and more valuable lives for all (British Academy 2016: 1).

While policy reports frequently advocate for the contribution AHSS disciplines can make to solving societal challenges, the academic literature suggests that there is often a perception that humanities researchers have little to offer and their contributions are difficult to understand and integrate (Callard and Fitzgerald 2015). There are indications that few in the sciences are aware of what humanities researchers can contribute, and that few in the humanities are aware of it either (Robinson et al. 2016). Following Snow, Robinson et al. (2016) argue that the lack of interdisciplinary interaction involving scientists and humanists is less about hostility and more about mutual ignorance.

One of the main challenges that AHSS currently face is related to how disciplines are grouped under the labels used to refer collectively to the Arts, Humanities and Social Sciences—'AHSS' and 'SSH'—. These labels obscure important differences between disciplines that bear on the different ways they position themselves in relation to doing interdisciplinary research and to interactions with other disciplines like the STEMM (Vienni Baptista et al. 2019).

Interdisciplinary collaborations also have long traditions in Latin America (Simini and Vienni Baptista 2017) but differences between countries pose difficulties to researchers in finding a community of practice and participating in associations and networks. Moreover, scientific papers are published in different journals, partly due to the lack of specialist publications, and researchers often face substantial obstacles trying to publish their results. Gaps in the literature, widely dispersed findings and scattered literature are key challenges in interdisciplinary research, as also proved in the European context (Vienni Baptista et al. 2020a).

These challenges cause that ID is not yet mainstream and is questioned by institutions, policy makers and researchers alike (Vienni Baptista et al. 2020a). It is rendered invisible in many academic spheres and its outcomes are not always taken into consideration by research institutions, policy makers and funders (Fletcher and Lyall 2020). This implies that systematizing the features that ID has in different contexts is an intricate task: scientific papers, reports and internal documents from funding agencies and research organizations, randomly and selectively promote the advantages of interdisciplinary research.

Above all these levels of complexity imposed to the concept, ID reveal differences that have to be taken into consideration when AHSS disciplines are to be integrated. Callard and Fitzgerald (2015), for example, consider that there are real opportunities for collaboration between the social sciences and the neurosciences. These opportunities are often occluded by the narrow discursive range of contemporary understandings of interdisciplinarity. We argue that many problems related to interdisciplinary research and its conceptualization relate to the current state of research and its obstacles (Vienni Baptista et al. 2020b). There are specific challenges that ID needs to face in order to transform factors into positive conditions for research. Interdisciplinary research imposes a new level of complexity to research practices, one that is it still not yet fully understood by researchers and funders at large (Vienni Baptista et al. 2020b).

Committing to interdisciplinary research pose different risks and benefits for researchers in terms of the balance of transaction costs and collaborative benefits (Feng and Kirkley 2020). The motivation for researchers to participate in interdisciplinary research highly depend on the evaluation of such perceived risks and rewards. Increasing attention is directed toward better understanding the factors driving collaborations among researchers (Boix Mansilla et al. 2016). Nevertheless, further research is also needed to explore the conditions affecting the success of research collaborations in interdisciplinary research (Feng and Kirkley 2020) and specifically concerning how STEMM disciplines can facilitate integration processes (Vienni Baptista 2009, 2020a), as shown in the next section.

3 Opportunities for Medicine Within STEMM

After centuries all branches of knowledge which included Astronomy, Mathematics, Engineering and fine Arts, experienced deep interrelations during the period known as the Renaissance (Snow 1964). The paradigmatic case of Leonardo can be mentioned as an engineer solving mathematical problems, studying Anatomy and producing remarkable paintings. But in modern times, special careers and specialists arose which separated the different disciplines to meet the requirements of the new phenomenon of industrialization. Medicine was left to the medical corporation, engineering to engineering schools and professional bodies, while science took a different path adopting the speculative attitude, taking distance from production, the fine arts and human experience. For two centuries specialization took Science, Technology, Engineering and Mathematics apart, arriving at the beginning of the XXI century as substantially separate bodies of knowledge. The first reaction may have been the theory of systems by von Bertalanffy (1968: 29) who at the beginning of the second chapter of his most cited book reveals:

> Modern science is characterized by its ever-increasing specialization, necessitated by the enormous amount of data, the complexity of techniques and of theoretical structures within every field. Thus science is split into innumerable disciplines continually generating new subdisciplines.

As a reaction to this specialization and the growing complexity of problems to be solved along with the sophistication of the products expected by an increasingly demanding market, the concept of ID arose (Vienni Baptista et al. 2020b). One could say that the Renaissance approach is again present in researchers who follow ID, but in a less “amateurish” way, if the expression is allowed. A Renaissance person could have notions of what became known as different fields of knowledge, such as Anatomy, Geography, Engineering, Mathematics, History and Humanities. The relatively incipient nature of these areas was such that the synthesis could be made by a single person during a lifetime. A similar interaction of diverse knowledges happens in ID, not within an individual but as collective work of several cooperating specialists. By introducing ID, contemporary organization of research is reinstalling the broad scope of methods, models, and information which characterized the Renaissance. Additionally, the production of goods and services is increasingly associated with academic research. The cooperation between Science and Engineering, sometimes also including Mathematics, is a specific characteristic of twenty-first century industry (Sábato 1979).

Biomedical Engineering has been developing during more than a century to provide Medicine with instrumentation of growing complexity and specificity as technology and theoretical tools became available (Bronzino 2006). To the initial cooperation of Engineering and Medicine, Informatics—which is a specialized branch of Engineering—is also added in the design of technologies to be used in Medicine. Medical Informatics starts to produce clinical software shortly after computers were used for the first time in ballistic, scientific or commercial applications. Informatics was first seen in hospitals as payroll and administrative systems, later also in electronic clinical records systems. The mutual interaction of Informatics and Medicine has allowed over the decades to develop a separate field of study and a profession devoted to clinical records and patient management. Albeit initially the Informatics approach to Medicine has been limited to a mere translation of commercial processing concepts from "products" and "transactions" to "patients" and "physician/patient relationship", over the years interdisciplinary cooperation modified Medicine. Physicians now use more statistics, expect clinical records to be available over the internet and make some use of diagnostic aids (Simini et al. 2019).

In a reciprocal way, once clinicians grasped the telematic potential, they are inducing Medical Informatics to be conceived from a medical perspective and help to abandon the simple paradigms of early industrial or commercial systems. Personal assistants to help "solve" patients in less time and with higher chances of success are designed based on typical medical intellectual itineraries rather than product stocks or sales logic. One typical example is PRAXIS (Simini et al. 2019), a software designed to acquire medical office data and to turn them into a powerful "suggestion machine" for each future patient, based on the accumulating experience of the MD user. Additional evidence of Medical Informatics being reformulated to adopt a medical starting point is found in the recently patented concept of "prescription Apps" (Simini et al. 2019) by which a personalized App is installed in the patient´s mobile phone to perform follow up tasks. Thanks to the telematic capacity of recent Medical Informatics, the follow-up becomes active, personalized and omnipresent in everyday life, at very low costs. Pregnancies can benefit from close monitoring (Simini et al. 2019), cardiac failure can be managed for long periods of time optimizing quality of life (Simini et al. 2019) as opposed to frequent drop-outs with sometimes ominous consequences and persons with diabetes can be helped on a regular basis with reminders or active inquiries triggering useful tips over the years.

The societal impact of Medicine with Medical Informatics tools is relevant because it has the potential to foster optimal adherence to treatments and compliance to preventive Medicine practices. Medical Informatics acquires an indirect relevant role in people's health by allowing a better medical care at very low costs and therefore available to increasing cohorts of citizens. The societal impact of MBEI may be evaluated looking at medical and epidemiological statistics, where the extent of disease or quality of life can be estimated. For example, during the current COVID-19 pandemic, a Bluetooth based App can help trace contacts after an infected case is detected, thus cutting to some degree the contagious spread of the disease.

In a mutually stimulating fashion, clinical work and engineering tasks adopt each other´s mindset to accomplish biomedical engineering and informatics projects of ever increasing complexity. This is the result of putting in practice the interdisciplinary approach to complex problems (Vienni Baptista and Simini 2018). As a consequence, medical perspective changes when exposed to engineering methodology, nomenclature and reasoning. After a Medical Informatics course during the last year of medical training, students admit their perspective and expectations change with respect to Electronic Medical Records or to diagnostic assistance. From a semi "magic" concept of cybernetic mysterious tools, they acquire the general concepts of data processing, data matching, artificial intelligence and algorithms. All of which stimulate their clinical use of new MBEI tools (Vienni Baptista and Simini 2018).

Conversely, consider the following example: last year Engineering students who declare a preference for biomedical applications are asked to be present during neuro-pediatric rehabilitation visits. Study of the biomechanical, cognitive and communication difficulties of every child, and conversation with clinicians after patient and family have left, allows the engineering students to suggest tools, Apps or instruments to overcome the disability they have seen. The clinical perspective has thus modulated the engineering capacity to suggest either existing or new technological solutions, case by case. Not to mention the empathy stimulated in the engineering student as motivation for further work and study.

The Núcleo de Ingeniería Biomédica (Universidad de la República, Uruguay) described in the next section is but one of hundreds of academic groups in Latin America devoted to the identification, specification, design and testing of new devices, models and software tools to be used in clinical practice. Medicine comes into the interdisciplinary space both giving and receiving ideas for creativity, innovation and further societal impact.

If technological elements are clearly influencing Medicine, the opposite can also be found in examples of biological models turned into technology to be used in all areas of Engineering. For instance, consider the well-known "Schmitt Trigger" which is an electronic circuit opening in a ON/OFF fashion as a consequence of some input signal compared to a given threshold (Schmitt 1938). The circuit evolved from neurophysiology research performed by Otto Schmitt, on the firing of giant squid neurons taken as an animal model of human neurological transmission. This case can be taken as an example of a Biological or Medical contribution to Electronic Engineering, since the Schmitt Trigger has been used extensively as a building block in the design of circuits of all sorts and for decades.

The interaction within once-separated knowledge branches such as Science, Engineering, Technology must include Medicine as a major partner, not only as a beneficiary of new techniques but also as an original source of problems and requirements to stimulate theoretical and applied research. Societal impact of such encounters are also larger as the interaction with patients allow for solutions that are problem-based. This has proved to be a fertile space in Latin America and specially in Uruguay, as detailed in the example we present in the next section.

4 The Núcleo de Ingeniería Biomédica: A Fertile Landscape for Interdisciplinary Encounters

Biomedical Engineering (BME) has proved to be a fertile territory for introducing new technology to develop research and teaching formats that adequately involve interdisciplinary collaborations. Although this is true, ID still needs a great amount of personal interaction and face—to—face work to achieve its full potential. In this case, the permanent contact and active relationship with patients and clinicians are the basis for a better development of prototypes in contexts where these interactions are rare and may derive into unwanted health problems, as the experience of Núcleo de Ingeniería Biomédica shows (Biomedical Engineering Node) (NIB for its acronym in Spanish) (Simini and Vienni Baptista 2017; Vienni Baptista and Simini 2018).

NIB is an interdisciplinary group of the Faculties of Medicine and Engineering of the Universidad de la República in Uruguay. Founded in 1985, it has focused on the development of BME as a contribution to the solution of medical challenges. The group is placed at the boundaries between physiopathological and clinical approaches through the development of engineering prototypes to support research, teaching and outreach (Simini and Vienni Baptista 2017; Vienni Baptista and Simini 2018). The study areas of NIB have allowed to go beyond the rationale of each discipline, fostering the solution of medical problems by means of technology transfer (Simini et al. 2019).

The NIB has an interdisciplinary approach to train professionals in Biomedical Engineering, capable of facing the challenges of medical and biological instrumentation. This approach is translated into research projects and students thesis. NIB is an example of how interdisciplinary collaboration can be achieved in Higher Education research and teaching activities with a focus on Biomedical Engineering and Medical Informatics. By evaluating these scientific research and teaching practices we aim at contributing to the definition of institutional policies that better support them. Systematizing the similarities and the learning strategies within the university context may favor the conduction of research on societal problems and scientific democratization through a better use of new technologies, including Informatics.

NIB seeks the immersion of engineers in a clinical environment and the joint work of scientists of different academic backgrounds to favor a gradual osmosis of knowledge and even language (jargon), values and work objectives. For these reasons, students and researchers at NIB are embedded in a meaningful dialogue 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.

A Biomedical Engineering or Medical Informatics project usually starts from a problem in clinical practice, management or some adverse result. All are interdisciplinary by definition. The general description of the desired instrument, software or setting is seldom given by clinicians alone as there is a need to refine or confirm the goal during engineering sessions. BME and MI are intrinsically a two sided activity where medical concepts are enhanced with all available theoretical and practical assets. The following is a review of only three case studies taken from the extensive experience of NIB in the last decade, from 2010 to 2020 (other examples are described in Simini and Vienni Baptista 2017).

A. The problem: Chronic patients are lost to follow up. Cardiac failure patients are asked to periodically come to medical visits where clinical evaluation allows to adjust medication, nutritional counseling based on clinical records, measurements and lab results.

SIMIC (Spanish acronym for Cardiac Failure Management System) is the result of an interdisciplinary discussion where the goal of securing patients and keeping in contact with them was revisited. No personal calls are possible, no human memory is enough to manage hundreds of patients and to keep them informed and willing to come to consultation. A new concept arose (Patented), that of a “prescription App”. SIMIC would be a set of recommendations, questions and alerts which the physician agrees with the patient to install in his/her mobile. During normal life SIMIC acts as a constant, and yet discreet, reminder and data logger, analyzing data to emit alerts based on algorithms taken from best practices. Additionally, ominous combinations of variables and timing trigger alerts dispatched to the health care team.

B. The problem: Parkinson patients need more rehabilitation hours. Guided gait is limited by staff availability.

PARKIBIP (Spanish acronym for PARKInson disease rehabilitation by BIP sound feedback stimulation during gait) is the result of an interdisciplinary discussion where the goal is to have patients walk with no professional assistance and yet be stimulated by sound and continuous guidance. PARKIBIP is an active wearable device which detects all movements of both limbs, analyses gait and emits sounds (bip) or words to encourage the patient, at the right time, to lengthen the step or to reduce gait frequency.

C. The problem: Pregnant women seldom comply with recommendations. Treatment opportunities are lost due to delayed consultation. Active Medical Follow up is not possible due to cost and staff availability.

SEPEPE (Spanish acronym for Personalized Perinatal Follow-up) is the result of an interdisciplinary discussion where the goal of detecting signs during normal life at home suggested an App. The spirit of the existing Perinatal Information System (SIP) is enhanced using ubiquitous communication and information technology (TIC): the perinatal passport in the hands of the pregnant woman was only used during medical visits at the antenatal clinic, while SEPEPE is programmed to be used recording data and answering questions at all times, under the initiative of the App. Two levels of alerts are available, one for the woman and the other for the health care team, only when a very serious situation is found to be compatible with data collected or missing data.

As part of the Universidad de la República, NIB has developed the three university missions: research, teaching and extension, which in turn gave its characteristics to the group and to the interdisciplinary work. These three missions share interfaces that help to conceive interdisciplinary work as part of “integral activities” (Arocena 2010; Tomasino and Rodríguez 2010). The University missions, in addition, contribute in their complementarity to the construction of dialogue, research and development processes of biomedical solutions. Core activities include: (1) teaching courses and seminars, (2) research and development based on thesis (3) consultancies to other departments of the Faculty 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.

5 Conclusions

Complexity occurs in an increasing number of activities which play an important role in the production of knowledge. These activities include interdisciplinary networks, loans, shared interests, learning communities of faculties (Medicine, Engineering, Nursing, among others) and participation in different fields. The growth of BME and Medical Informatics in the last years responds to the availability of technological solutions to which researchers access to solve problems of increasing diversity. The clinician resorts to ID and the engineer proposes new solutions as a consequence of the existence of an integral practice. Prototypes can be tested with phantoms and simulators before going to clinical application once safety and legal clearances are satisfied (Simini and Vienni Baptista 2017; Vienni Baptista and Simini 2018).

This concluding chapter elaborates on general and also specific research strands that have historically pursued collaborations among different disciplines to approach complex problems. Several examples have also been provided in this book so as to include two powerful ideas to leverage BME and MI as means to achieve socially robust solutions for health and well-being. The limitations of technology should no longer be considered as the starting point of design, because technology is so generous and abundant. Nevertheless, following technological capabilities alone can lead to irrelevant so-called medical applications. On the contrary, chapters in this book show that the development of biomedical devices, software and systems must stem from clinical wish lists and desiderata. Technology follows, in these cases, medical specifications applying an interdisciplinary approach.

BME and MI should merge into a single body of knowledge to better follow the demanding clinical challenges of modern Medicine. Interdisciplinary methods and theories developed in the last few decades provide promising means to achieve this (Bammer et al. 2020). Having mastered problems to be solved for survival, to repair physiological impairmentand to reduce pain, BME and MI are now asked to start from bedside and develop sophisticated tools to deliver better quality of life for increasing cohorts of ageing populations.

Within this framework, the book includes chapters of diverse authors addressing a range of fields wide enough to give the reader an overview of what to expect in the coming decades in BME and MI concerning new medical software systems, pervasive medicine, intelligent follow-up and implanted devices. This will also have a great impact on electronic clinical records and data analysis. The point of view of the book follows the academic experience of authors from different countries around the world, including Latin American entrepreneurs and scholars.

BME and MI have proved to constitute a fertile territory for introducing new technology to develop research and teaching formats that adequately involve interdisciplinary collaborations. Although this is true, our analysis of NIB practices has confirmed that ID still needs a great amount of personal interaction to achieve its full potential and overcome the challenges inherent to collaborative practices. An active relationship with clinicians is the basis for a better development of prototypes and societal impact (Simini and Vienni Baptista 2017; Vienni Baptista and Simini 2018).

Interdisciplinarity constitutes an important and rewarding practice in current times. If we acknowledge the fact that collaborative research has a substantive role in addressing and framing the complex socio-technical problems the world is facing today, we need new and sustained pathways to develop interdisciplinary research between AHSS and STEMM disciplines. To achieve this, change is needed urgently in research institutions, funding mechanisms, societal participation and policy measures.

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