An Insight into Knowledge Flow in Biomedical Engineering Science

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Abstract: Technology has always played an important role in medical science by contributing to health care development. The use of technological instruments helps diagnostics of normal and pathologic states; and thus leads to a better understanding of human physiology. Once a diagnosis is established, a suitable treatment or surgical intervention can be considered, according to the available clinical capacities. In the last four decades, research in biomedical engineering science has led to the manufacturing of cutting edge medical instruments. For example, the introduction of endoscopes into surgical practice is considered one of the biggest success stories in the history of medicine. However in order to develop appropriate medical instruments or procedures, one key issue for successful biomedical research is the ability to understand in an efficient way the requirements of the medical practitioners. Furthermore, the two main actors namely biomedical universities and the biomedical industry involved in the development of new technologies need to collaborate and cooperate to a greater extent. This paper discusses the role and the process of knowledge flow between the various stakeholders involved in the design of medical instruments. The aim is the delineation of a general framework facilitating the understanding of the technical and medical requirements in order to develop new tools and methods.

Keywords: Knowledge flow, biomedical engineering, knowledge sharing and transfer process

1. Introduction

During the last decade the transfer to in-depth knowledge has surfaced (Corso et al., 2006). Previous studies indicate that there is a link between knowledge management and innovation processes (Arntzen 2006; Brännback, Renko, and Carsrud, 2003; Cormican and O'Sullivan, 2000). The emerging concept of the triple Helix described as the three way institutional spheres (public, private and academic) work together is considered as being the best approach to form an innovation system based on knowledge flow and interactive consultations (Leydesdorff and Meyer, 2000). Recent studies stress the point that a university in the triple helix; University-Hospital-Industry, represents the indispensable partner, which is able to grasp the concepts of a better innovation process through knowledge generation (van Baalen et al., 2005, Laestadius, 2004, Leydesdorff and Meyer, 2000). Furthermore, the value of research carried out by universities and research centres for industrial innovation and performance is well acknowledged (Grossman et al., 2001). However, it is commonly agreed that knowledge transfer from universities to industry is not optimal and that opportunities are overlooked due to the lack of a close and efficient collaboration (Brännback et al., 2003, Pérez and Sánchez, 2003). In addition, researchers at universities who work in an isolated context are often not aware of the needs and challenges of potential target users groups. Thus, some important research efforts can lead either to no concrete outcomes or to results that cannot be exploited or commercialised (Sandelin, 2003).

This statement is even more valid in the biomedical engineering field, where there is a stringent need to ensure a close cooperation between the University, Hospital and Industry, while developing specific tools and procedures to be used by clinicians. The cooperation and collaboration between the three stakeholders involves an effective knowledge transfer and sharing process mastering. Biomedical engineering (BME) is defined as the application of engineering disciplines and technology to the medical field. It combines engineering expertise with the medical expertise of the physician to help improve patient health care by designing suitable medical devices. As a relatively new discipline, much of the work in biomedical engineering consists of research and development. Therefore, it is crucial that heath institutions, research institutes and manufacturers work efficiently together. One way to ensure success in these types of cross-disciplinary activities is to examine the way scientific knowledge flows between engineers, researchers and physicians while they are involved in an effort to develop or improve diagnostic devices.

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The paper focuses on the facilitators and limiters of the knowledge flow between industries, universities, and hospitals within a biomedical engineering context. The study intends to explore the nature and the role of knowledge transfer between the various stakeholders. It examines the socio-technical factors that play a role in knowledge management leading to technology innovation in the biomedical engineering field (Bechina, 2002).The research questions are:

- What are the requirements for enhancing collaboration and networking between Industries, universities and hospitals?
- What roles do the use of information communication tools and organisational change have in the transfer and sharing of knowledge for innovative activities in biomedical engineering field?

The next section introduces the concepts of knowledge and knowledge transfer. The part three describes the context of study and outlines why and how the knowledge transfer is taking place within the biomedical engineering field. And finally a model of knowledge transfer and sharing is discussed.

2. Knowledge and knowledge management concepts

One standard definition of knowledge exists. One of the most referenced definitions in the literature of knowledge is provided by Davenport and Prusak (1998): “Knowledge is a fluid mix of framed experience, values, contextual information, expert insight and grounded intuition that provides an environment and framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of the knower. In organisations, it often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices, and norms.” (Davenport and Prusak, 1998a). Knowledge is defined as information in context with in background the idea to apply that knowledge (Brooking, 1999). It is also seen as a shared collection of principles, facts, skills, and rules (Pemberton and Stonehouse, 1999). In this respect, knowledge is what gives a “meaning”, thus the lack of significance leads to disorganised information (Bhatt, 2000). In addition, knowledge is seen as very subjective, because it depends on the believes, values, intuition and the emotions of the individual (Sunassee and Sewry, 2002). Furthermore, it is necessary to recognise the different type of knowledge in order to expose its potential contribution to the performance of the organisation and to determine the appropriate channels to transfer it (Pemberton and Stonehouse, 2000). The wide-based knowledge definitions highlight the presence of several forms of knowledge; tacit, explicit, implicit and systemic knowledge at the individual, group and organisational levels (Davenport and Prusak, 1998b, Dixon, 2002, Polanyi, 1958, Nonaka and Takeuchi, 1995, Inkpen, 1996).

Explicit knowledge has a tangible dimension that can be easily captured, codified and communicated. Explicit knowledge is referred to “know-what”. It can be shared through discussions or by writing it down and stored into repositories, documents, notes, etc. Instance of explicit knowledge might include a network directory, an instruction manual, or a report of research findings. In contrast, tacit knowledge is linked to personal perspectives, intuition, emotions, believes, know-how, experiences and values. It is intangible and not easy to articulate and tends to be shared between people through personal interactions. Tacit knowledge is both social and contextual, therefore storing and communicating it, is a complex task (Davenport and Prusak, 1998a, Sharif,2005). The distinction between tacit and explicit knowledge is important since their management is quite distinctive and requires different channels or means to transfer or to share it. Additionally, the distinction determines who owns the knowledge. Tacit knowledge being hard to codify, remains the property of the knowledge worker, while explicit knowledge remains in the organisation (Alm, 2005). However, quite often use of tacit or explicit knowledge is entangled, and it is often hard to have a clear separation between them. The following figure provides example of tacit and explicit knowledge in the field of biomedical engineering.

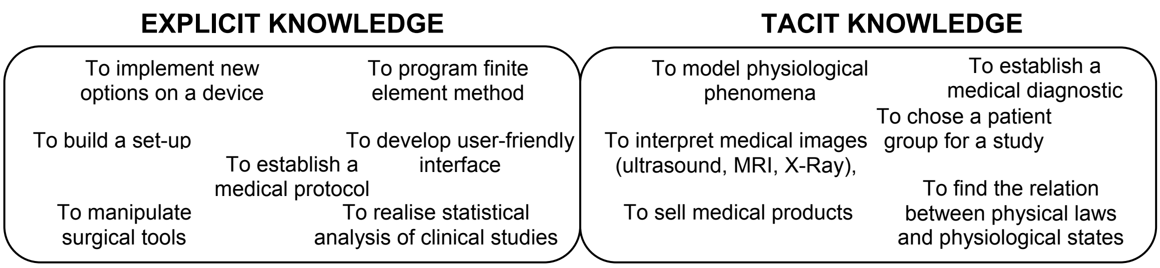

Figure 1: examples of tacit and explicit knowledge in the context of the biomedical field

For instance, accurate interpretation of medical image such as MRI (Magnetic Resonance Imaging) requires tacit knowledge of the physician. This type of knowledge comes from his/her experience of interpreting and will depend of contextual setting. Physicians can establish a diagnosis by following a medical protocol that is described usually as a set of rules. The Figure 2 outlines an example of tacit or explicit knowledge needed for the delineation of a physiological model.

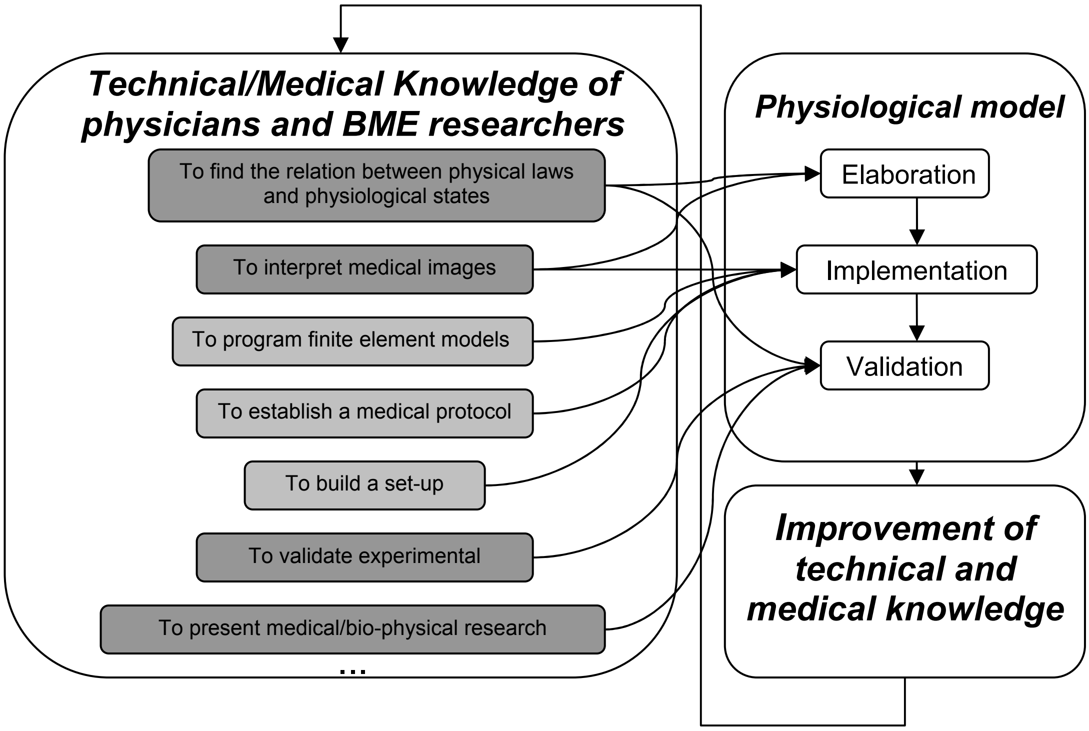

Figure 2: Example of knowledge requirements for a physiological model development process; tacit and explicit knowledge are differentiated by dark and light grey backgrounds respectively.

The management of tacit or explicit knowledge has been defined differently in the literature; this is due to the diversities of the undertaken initiatives. They all enlighten central ideas around the concept of knowledge management, but there are some apparent diversity in the definitions. The following conveys a few chosen definitions in the field: "Knowledge management caters to the critical issues of organisational adaptation, survival and competence in face of increasingly discontinuous environmental change. Essentially, it embodies organisational processes that seek to synergistic combination of data and information processing capacity of information technologies, and the creative and innovative capacity of human beings" (Malhotra, 2001). Knowledge management (KM) is as well seen as an effort to increase useful knowledge within the organisation by encouraging communication, offering opportunities to learn, and promoting the sharing and transfer of appropriate knowledge artefacts (McIrnerney, 2002). Most of organisations are attempting to use knowledge management in order to improve business performances or to foster innovation process. Amongst the KM processes, the one that is considered as the most important to understand is related to the transfer of knowledge from one set of individuals to another. Alavi and Leidner(2001) emphasise the significance of knowledge transfer by discussing the need for an organisation to be successful in its ability to generate new knowledge and to transfer it. In the biomedical engineering context, it has been discussed that understanding the mechanisms and the channels for transferring knowledge is an important dimension for fostering innovation in this field that is high-tech (Brennenraedts et al., 2006). It relies on a close cooperation and collaboration of the triple helix University-Hospital-Industry for a successful innovative technology. The next section discusses the need for sharing and transferring knowledge in a biomedical engineering area.

3. Knowledge transfer and sharing model in Biomedical Engineering

3.1 Context of study

In the context of fast technological change and emerging technology, organisations need to be highly innovative. Especially in biomedical area, where development of models based on new technologies has the potential to play an important role in improving the health care system. However specific constraints can be encountered like for example: how to make sure end-users will effectively use the systems in their daily routines? In fact, the last research studies showed that there is rather a latent or open hostility from some clinicians or administrative staffs to exploit fully the functionality of information systems or high-tech tools (McDermott and O'Dell, 2001). Furthermore, there is sometimes too little interest from the technical researchers in clinical applications or even little concern of academic researchers for marketing issues. Those can lead to strong challenges and prevent an effective exploitation of scientific knowledge in medical practices. It is recognised by medical communities, that although, several "breakthroughs" in scientific and technological knowledge have been validated through clinical trials, still many are not adopted by medical practitioners (Hilton et al, 2002).

In addition, it is as well acknowledged that innovation is led by research institutions and there is still too little interaction between the various stakeholder groups (e.g. different medical professionals, industrial scientists, academic scientists, managers, etc.) while developing new models or tools. The picture 3 illustrates the interaction between the mains actors.

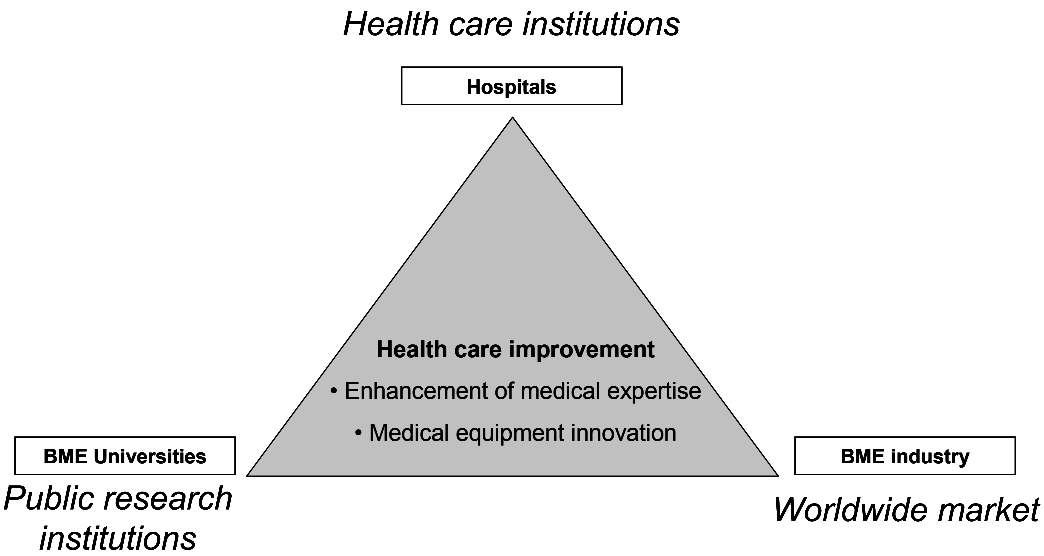

Figure3: Three clusters involved in Biomedical engineering effort

Obviously, the main characteristic of a biomedical project is the multidiscipline context and the need to foster integration of knowledge with various dimensions. The main challenge relies on understanding why knowledge integration and transfer processes are crucial between the different biomedical partners. As stated above, medical science has always been using technological tools to get understanding of the human body physiology in order to diagnose normal and pathologic state. Once, a diagnostic method is established the appropriate treatment and, or intervention can be considered according to currently available clinical capacities. The purpose of biomedical engineering science is to provide clinicians with appropriate equipments embedding new technologies (and models). A suitable set of medical tools will allow clinicians to enhance their clinical knowledge and know how, leading to a better treatment of patients. Then, one key issue for a successful biomedical research is the ability of technical partners to understand properly the requirements specified by medical practitioners leading to the technical specification of tools. Both biomedical universities and biomedical industries should be able to collaborate and cooperate closely with the medical specialists. Furthermore, most of the industrial partners developing such high-tech tools are medium enterprises, and do have research activities constrained by resources, time or lack of suitable competences. Therefore it is important to understand the mechanisms and channels of knowledge sharing and transfer between the triple helix University-Hospital-Industry. In order to illustrate how the knowledge transfer and sharing is taking place in this specific context, a scenario is outlined below.

3.2 Knowledge transfer process

A better understanding of the state and evolution of the human body physiology allows on one hand, the clinical researchers to improve health care quality and on the other hand, the technical researchers to develop more appropriate medical tools. The conception and development of physiological models is necessary in order to figure out laws driving diverse complex biological processes, which can be based on physics, biology and chemistry. Therefore, clinicians are able to estimate or predict some parameters, which cannot be seen or measured otherwise. In addition, the defined model needs to be refined and validated by both fundamental researcher and clinicians. This common and shared model is, at a later stage, embedded in medical tools. Therefore, only a multi-disciplinary expertise approach resulting from collaboration of the triple helix University-Hospital-Industry is suitable to achieve efficient results. Fundamental research is alimented by specific knowledge related to physical phenomena indispensable to build sophisticated physiological models. The universities play an important role in advancing fundamental research since they have conjugated resources such as top expertise of researchers that have conducted computational and experimental studies. Computational methods like finite elements are nowadays used in order to solve numerically theoretical laws based on differential equations (van Loon et al., 2006). Phantoms and/or in-vitro experiments can also be used in order to validate theoretical results (Geven, 2004). Therefore, those fundamental findings used together with clinical knowledge can be employed to delineate new physiological models. This scenario of knowledge sharing and generation is depicted in the following picture 4.

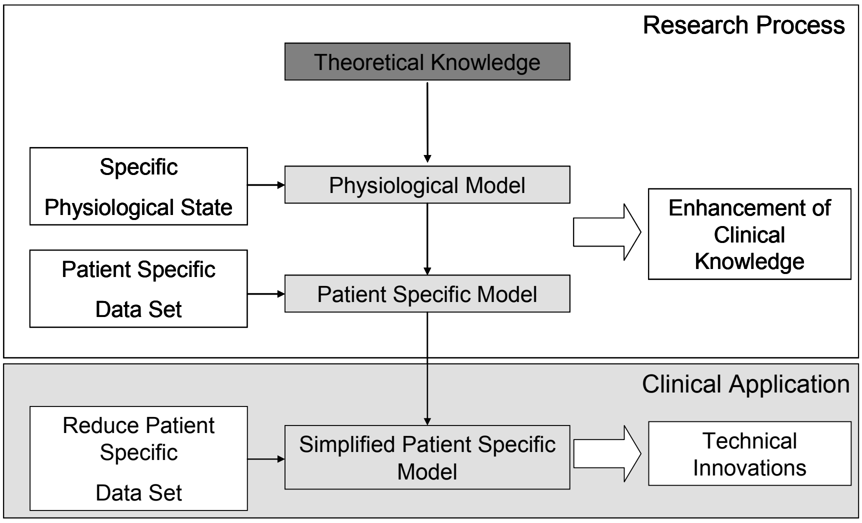

Figure4: Scenario of knowledge sharing and process in biomedical field

During the design and development of such models, technical researchers need to define the relevant input parameters in accordance with the requirements specified by the clinicians. In addition, some parameters resulting from the use of the designed device should be as well determined. Once the model is created, the specific physiological input state can be considered given the expected output parameters. Different given inputs can be used in order to estimate some biological phenomena under a controlled environment. The clinical expertise and knowledge of the physicians is then crucial for a proper interpretation of the given data.

The next step is to perform an in-vivo study by adapting the design model to a patient specific case (S. de Putter et al., 2006). Thus, research studies are further conducted and are based on the use of a high number of clinical data. Obviously, such studies lead to a better understanding of biological phenomena and in consequence contribute to advanced medical knowledge serving to the specification of further requirements to be shared with the technical teams. Moreover, other requirements such as ethical issues (compliance) and medical legislations have also to be considered and discussed by all the partners. This interactive design process requires better methods and tools to facilitate the communication. The interaction is as well characterised by the need to provide a viable business model for the industry related to the development in a larger scale of the new medical tools. Of course those business considerations are as well integrated in the set of requirements leading to the technical specification of the medical tools. A sharing knowledge model should be clearly outlined for the three partners. Some benefits are outlined as follows:

- Quality improvement in development of appropriate medical tools due to feedback from the users (clinicians)
- Development of medical tools that suits better the need of user groups

- Universities will benefit by testing their concepts and by applying their fundamental research
- Industry will benefit from expertise from top specialist researchers and can expect to improve their own expertise and extend their portfolio with new competences acquired while designing collaboratively new medical tools

3.3 Factors facilitating or inhibiting the knowledge transfer

Knowledge transfer and sharing process can take several forms but are categorised into three components. The challenge is to determine the right synergy by integrating people, processes and technology. The focus on one component or another one, depends of the strategy adopted by the managers and will be determined by the level of involvement of all the stakeholders. A successful knowledge sharing and transfer effort requires a right balance of these three components (Collison and Parcell, 2001, Hall and Andriani, 1998).

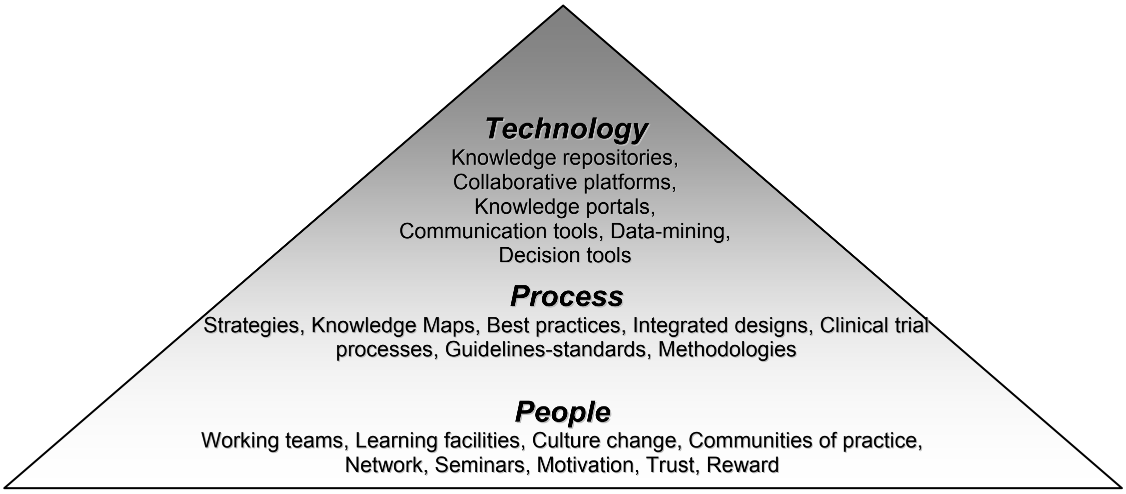

Figure5: Knowledge sharing and transfer model

At the bottom level of the pyramid, the people-based layer is the most important and should be the pillars for the knowledge sharing process in a biomedical engineering project. In order to overcome the difference of the three communities, it is crucial to define a framework where technical and medical knowledge can flow without meeting resistance from people. The top level of the pyramid indicates that although technology can be very useful to transfer or share explicit knowledge, the implementation and use of technology should be the last knowledge management focus.

People: Knowledge management is first and foremost an effort to manage, develop and disseminate knowledge and the full potential of people at an individual, team-based and organisation-wide level. Providing the right culture environment is the most challenging effort but achievable by enhancing learning facilities, providing a trustful working atmosphere, where collaboration and sharing are encouraged. Others aspects that need to be considered include: motivating and rewarding people that create, share and use knowledge, encouraging communities of practice and promoting network creations.

Processes: Processes play an important role by providing support for any KM implementation. Organisations might need to restructure their internal processes or even the organisation structure itself in order to support KM processes such as knowledge sharing or transfer. Managers must identify knowledge that exists in various forms in the organisation. One way to achieve the goal would be, for example, creating a knowledge map by initially finding out where knowledge resides, point it and then provide instruction on how to get there.

Technology: Providing a knowledge portal, linking people by e-mail, building knowledge repositories contribute efficiently to sharing knowledge. However using technology alone will not ensure successful knowledge management as organisational factors such as adequate training needs to be taken into account as well.

Focusing mainly on using technology to support knowledge sharing or transfer as, building knowledge repositories might actually slow down the process of sharing. This is mainly due to the fact that many clinicians are reluctant to use on a daily basis information communication tools. Therefore in this specific context, it is important to prioritise human side by encouraging training of biomedical engineers and clinicians under co-responsibility of educational teams composed of both medical and technical specialists. Such early stage collaborations should foster better communication by exposing involved stakeholders to different cultures. Focus on others processes such as for example, best practices dissemination, needs also to be considered (Bechina , Michon, and Nakata, 2005). Focusing mainly on using technology to support the knowledge sharing or transfer such for example building knowledge repositories might actually slow down the process. Since many clinicians are not comfortable using information communication tools. Therefore in this specific context, it is important to put great efforts on people by for example encouraging training of biomedical engineers and clinicians under co-responsibility of educational teams composed of both medical and technical specialists. Such early stage collaborations should foster a better communication by exposing involved stakeholders to different culture. Focus on the processes for example encouraging best practices dissemination, needs to be considered as well (Bechina et al., 2005). Following the suggested knowledge transfer and sharing model is not enough to control the flow of knowledge. It is crucial that managers consider the inhibiting factors including for example:

- The inability to recognise and articulate intuitive competencies such as tacit knowledge
- Diverse areas of expertise
- Internal conflicts and interests difference
- Lack of incentives and rewards for sharing tacit knowledge or using ICT for sharing explicit knowledge
- Problems with sharing beliefs, assumptions, and cultural norms
- Motivational issues
- Rigid and or highly hierarchical organisations
- Lack of leadership and a Knowledge sharing evangelist
- Organisational culture fostering the innate feeling "Knowledge is power"

4. Conclusion

The paper discussed the need to establish a strategy for knowledge transfer in biomedical area. Some factors facilitating or inhibiting the transfer of knowledge have been outlined. Of course there is a need for a methodology. The following roadmap suggests the steps to undertake for an effective knowledge transfer process. Firstly, it is important to identify the key knowledge workers within the organisations, and launch a campaign of communication stressing the importance of sharing Knowledge. Some incentives or rewards need to be established in order to motivate all the knowledge workers involved in the process of developing new tools or technology. The third phase should be dedicated to the design of specific sharing mechanisms facilitating the knowledge transfer. One indispensable issue is related to setting up some metrics to measure the impacts of knowledge transfer process on the innovation process. It is clear, that the choice of metric relies heavily on the type of initiatives implemented for transferring knowledge. The focus might be either organisational change or the use of appropriate information communication tools. This study is at an earlier phase, and we intend at a later stage to collect qualitative and quantitative data from different stakeholders in order to understand the current knowledge transfer that is in place and to provide a set of recommendations in order to improve the flow of knowledge in the triple helix university-hospital-industry.

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