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# Managing Open Innovation in Connected Health through a Living Lab

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**Abstract**—The digital footprint marks all parts of society and impacts our lifestyles. Beyond perceived changes in individual way of life, digital revolution also affects sociotechnical systems, collective structures or communities that delivers primary services for citizens. Healthcare is deeply impacted by such a digital mutation at many levels (patient expectations, caregivers practices and organization). We are probably witnessing the emergence of smart and personalized healthcare with a very large scope. To be included in this dynamics, many healthcare organizations now feature collaborative approaches and open innovation management to improve their performance in a sustainable perspective. But the complexity of systems is often a limit to their progress. This paper discuss the place and role that could be played by new utilities that are naturally based on open innovation approach: the living labs. In connected health where many stakeholders should interact, they are naturally expanding. Using an example, we show the gains in value chain that this new envision of open innovation could provide. In parallel, the paper argues for a development of open innovation engineering in such labs. It leads to the conclusion that a reference framework is helpful in such a perspective.

**Keywords**—open innovation; connected health; living lab; healthcare services; innovation engineering.

## I. INTRODUCTION

In today's fast-changing world, competitive organizations are those that quickly transform new ideas into new products, services and organizations. In fact, innovation is the cornerstone for a successful and sustainable society since it stimulates new needs of consumers while searching solutions that meets their expectations. Innovation practices promote creativity in many kind of organizations. It often leads to competitive advantages in terms of cost, brand image and value for companies. But innovation also open new perspectives to imagine new ways of life in modern societies into which citizen empowerment has become a political reality. So, it leads to the emergence of new problems which must be addressed at the right level, and finding this level is still an open question.

Intrinsically, an innovation process is difficult to understand and always depicted as very risky to execute. That is why, managers seek to better control their innovation process, making them more efficient on all the functions of the corresponding value chain: from the sourcing of ideas to the breakthrough in the markets. Beyond this challenge, the rising pressure of time

and limited capacity of investment have been at the root of an ongoing trend to shift from a closed model of innovation to more open innovation strategies. The difficulty to rationalize innovation management rises when many independent actors have to share common objectives, skills, resources, projects and savings. The efficiency of collaboration adds a new dimension to the challenge of innovation. If it is a greater challenge to tackle, open innovation is potentially an answer to the question of conciliation between company's vision of market needs and society yearnings. One difficulty in this perspective is to capture knowledge from potential future consumers/users and to streamline the information into well-designed projects.

Although they are widely studied in a multidisciplinary context, innovation and open innovation remain in their infancy in terms of engineering and a lot of research has still to be done to recognize this relatively new engineering paradigm beside more improved ones like design engineering or production engineering, inside the discipline of industrial engineering. We are searching for concepts, approaches, methods and tools for a rationalization of open innovation engineering. In this context, our research aims to imagine a methodological reference framework adapted to a collaborative space into which stakeholder representatives are working together whatever the process phase in progress, trying to reduce many sources of uncertainties. Our framework will try to fill this gap, provide indications on who and why people shall work, how to proceed and on what subject they will have to focus on. Intensive use of digitalization in product design as well as evidence-based involvement of people in IT services foster an integrated approach of both product and service design in R&D activities. As a matter of fact, new areas are investigated with this idea and the health sector is one of them.

Open innovation in connected health area is a high level challenge for our society and has been identified as so by the WHO at a global scale. Health is integral part of public policies, subject to strong regulations at the national level, operated by care facilities, but also more and more by self-managed persons. Indeed, connected health promotes use of IT to help patients manage their own diseases (chronic diseases). A new concept of expert patient is born from this observation. In fact, each initiative in this particular sector involves at least four categories of stakeholders (patients, technology suppliers, health practitioners and public policy institutions). So, the relevant

open innovation process is complex due to human factors and needs to be managed with the diversity of stakeholder requirements, among them, we could say the criticality of service quality for patients, the respect of caregivers skills and associated responsibilities, the adequacy of technology and risk management for providers and finally the cost control for public institutions.

Last, but not least, medical practices are changing and science delivers really new artefacts that will deeply modify our relationships to healthcare practices in the next decades. There is a move away from the medical curative model to a social interconnected health perspective into which prevention and self-management of patients will be paramount [4]. Let's give some illustrations about this. Following regulatory obligations, telemedicine services are an example of connected health expansion in France. Services are widespread at the regional level and stimulate eHealth policy development [2]. The "Hôpitaux 2012" plan and the Law on Hospitals, Patients, Health, and Territory (la loi HPST) are worth mentioning in this regard [10]. It is a reality that health care systems are under pressure as a consequence of the ageing population and fast demographic growth with chronic diseases increase, in a situation of decreasing financial budgets. Therefore, the connected health sector has been declared as a component of the national economic strategy in July of 2016. In the text that describes the strategy, open innovation is enhanced and the inclusion of living labs in the innovation process is recommended.

This paper is organized as follows: we first provide a literature review on recent developments and our positioning in relation to the existing works before we explain our research approach. Finally, we present our findings before concluding.

## II. LITERATURE REVIEW

### A. Research context and problematic

As we aforementioned, innovation has become a strategic issue for organizations as well as for the society of the future. It has even attracted the attention of researchers who focus on innovation engineering. Innovation is a complex paradigm that requires concepts, methods and tools in order to develop new products, processes or services. Upstream in the innovation process, to solve inventive problems during preliminary design, researchers and engineers use traditional methods such as: the C-K approach, the brainstorming theory and the trial and error approach. Their major drawbacks are known: a random process, a lack of systematization and a huge part let to talent of people. To overcome these drawbacks, we work on the emergence of more structured innovation management, based on an engineering framework with an emphasis put on systematization of the upstream phase of the innovation process, in the stages of formulation/problem resolution and the generation of innovative ideas [5]. Research works have been carried out by Penide [5] and Lopez Flores [6] to develop models in order to manage the innovation process. For reference [5], innovation is a process of problem resolution and knowledge transformation, e.g., the first activity aims to define or redefine a problem. The corresponding model proposed attempts to align operational, supporting, and management activities, which inspire us for constructing the

innovation life cycle thereafter. Nevertheless, reference [5] didn't take into account the collaborative aspect of open innovation as has been done in reference [6]. In fact, [6] proposed to define a conceptual framework for the development of a Computer Aided Innovation tool in open innovation mode supported by the Web 2.0 technologies. Finally, [6] used the notion of collective intelligence to improve the innovation process which has been considered as a linear one, and this doesn't match with the reality. Consequently, our research is in line with these previous works.

Let's precise that the corresponding approaches have in common to understand innovation as a process of information management and knowledge transformation. Optimally, we will mix the business process model of [5] to optimize the use of the Computer Aided Innovation tool of [6].

This concept has been growing since the term was coined by Chesbrough in 2003. This paradigm considers that organizations can expand their innovation capacities beyond their own boundaries. Indeed, it implies inbound and outbound knowledge flows across the organizational boundary. [7] describes this concept as a phenomenon of companies making greater use of external ideas and technologies in their own business, and letting unused internal ideas and technologies go outside for others to use in their business. Many organizations now feature collaborative practices in their activities, even in R&D activities, such as IBM and Procter & Gamble, who have shrunk their internal R&D departments and successfully tapped into external sources of innovation [8]. Hence, the concept of open innovation [17] has been introduced and defined as a paradigm that assumes that organizations can and should use external, and internal and external paths to market, as the organizations look to advance their technology.

Therefore, our innovation framework is adapted to a collaborative space between organizations working together. It promotes greater a social dimension with controlled information and knowledge exchanges. Consequently, we will focus on potential interactions among diverse actors of the innovation ecosystem.

However, the large number of definitions, with so much different points of view, that we could found in the scientific literature about innovation shows that it is a complex paradigm, and that, for engineering purposes, it must be studied as a set of inter-related concepts. As it is a dynamic in an organization supported principally by motivated people that drives innovation, business process are also useful to explain how to do and capture the different ways of making progress over time without being too much unstructured. Today, there are several forms of innovation that have been introduced as a form of specialization of the global concept. But there is a lack of a global view of this different views and the tentative of unification of them could be of added value to encapsulate knowledge about them, as well as to minimize the features that have to be analyzed when talking about a special application. That is why, we decided to develop a methodological reference framework which raises a problem of knowledge, life cycle analysis and information system as a support.

### B. Living lab: new innovation tool

In this very intense collaborative context of knowledge sharing, new entities have appeared to enhance the open innovation paradigm. In fact, new spaces of co-creativity have been recently created, like the Fab Labs [9] and the Living Labs [1]. The Living Lab concept originates from Prof William Mitchell, MediaLab and School of Architecture and City Planning, MIT, Boston. Living Labs represent a user-driven research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts. The first Living Labs created from the initial ideas were in the area of smart/future homes. In those settings real people (visitors) were observed in their usage of emerging technologies in the setting of a real home. In many of the implementations people stayed in these homes for several days or weeks [3]. A major contribution to the living lab concept came from research on lead users as an important origin of innovations causing a greater emphasis on involving users more actively and early in the new product, process and service development [4]. So, the living labs promote the open innovation approach [19]. The European Network of Living Labs (ENoLL) counts today almost 400 historically recognized Living Labs and more than 170 active members. They defined the living labs as user-centered, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings. They added that living labs operate as intermediaries among citizens, research organizations, companies, cities and regions for joint value co-creation, rapid prototyping or validation to scale up innovation and businesses.

Health is not an area insensitive to this new innovation tool since it is currently subject to important changes. E-health or connected health are new areas that have emerged, not only as a new specialty in medicine but also a new paradigm of health consideration for people [11]. As a consequence, several living labs work for the health care sector. For example, the Medical Field Lab (MFL) in Maastricht (Netherlands) and the Health Innovation Lab (HIL) in Copenhagen (Denmark). In France, the General Council for the Economy, Industry, Energy and Technologies (CGEJET) launched a working group in 2009, in consultation with the Ministry of Health. All stakeholders, public and private, were represented. About fifteen French

Living Labs have been identified in the Health and Autonomy sector at a national scale.

According to [28], a Living Lab is currently considered as a user-centered open innovation ecosystem integrating research and innovation within a Public-Private-People partnership through an iterative Experiential Design process [20]. It means that within a Living Lab, the focus on the user covers the entire innovation process as shown in Fig. 1, where all the stakeholders are collectively engaged in creating and validating innovative solutions in a kind of “knowledge refinery”. First, they begin by an analysis of user’s needs in which there is a proposal for several investigation tracks and representation to collect and organize knowledge on the ecosystem and to classify identified needs. The second stage is the implementation of several sketches to allow stakeholders to focus on early solutions and select suitable ones for implementation in early prototypes. Then, they proceed to a primary implementation of the fully functional prototype and user tests to address the deficiencies left by the previous stage of co-conception in order to meet the user’s needs. Finally, we find the deployment stage for a law scale on pilot sites to refine deployment procedures for later, resolve gaps and implement back-up strategies in case of a solution failure, including financial and legal safeguards for all the stakeholders. When working on technology, the living labs can be positioned between Technology Readiness Levels (TRL) 3 and 7, since they include the conception, validation, prototyping and pilot production phases. Thus, we will integrate in our research approach the presence of these new environments of co-creation and testing with users.

In fact, considering health services, these new spaces reinforce inter-relationship between actors and makes the patient a central actor who participates in the development of new services. We believe that this very particular organization is a good vector for boosting the culture of user centered innovation [16] in healthcare.

Indeed, as introduced before, if medicine will become predictive (use of big data for particular diseases), participative (long term patient pathways), preventive (anticipation of problems), personalized (adapted to individual profile) and patient driven (mediation for design of care plan with practitioners) [11], innovation in health will be a large breakthrough for society of the future. Clearly, each of these characteristics will contribute to a new need of managing innovation in health.

### C. Applying UCD and Agile Methods in the Living Lab context

User involvement can take a variety of forms. From the One hand, some instances position the user as the main creator, in the case of lead users [26] or open source communities. Others see participants operating as co-creators in practices such as design thinking [27]. From the other hand, participatory or User-Centered Design (UCD) treats users as passive subjects whose insights are captured and introduced in the innovation process, such as usability, human interaction [21]. As we aforementioned that Living Labs are situated between those limits of user involvement, it seems quite logical to apply some UCD and Agile practices in a Living Lab context. In fact, working with

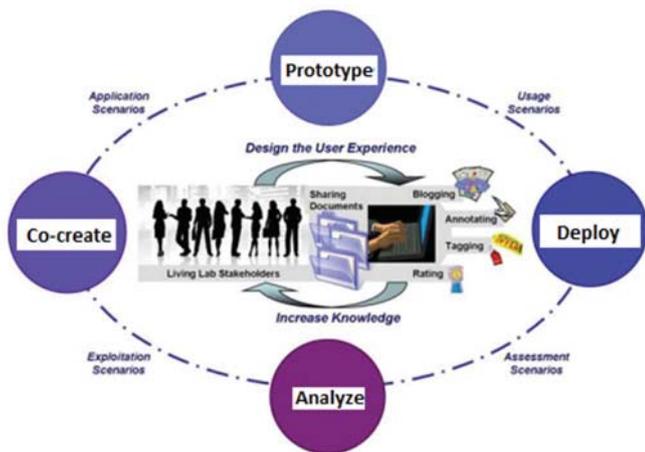


Fig. 1. The Living Lab Experiential Design (adapted from [20])

Agility improves collaboration and communication; it involves a local representative of the client (considered here as a user) to shorten the feedback loop between the development team and the end user [22]. We now identify some key concepts related to the UCD, which is an approach that aims to involve the users in a meaningful and appropriate way throughout a system's development [23]. Concerning prototyping, [24] recommends the use of User Interface prototypes to bring the known customer requests into the discussion as quickly as possible. [25] comments that sketches in addition to User Stories can be used as means of revealing errors, temporal information such task sequence, contextual information, etc. Concerning Users testing, as the name suggests, it involves the use of users testing for usability evaluation. Moreover, Users Stories should be integrated with scenario-based design and could be defined for the construction of prototypes [22].

UCD and Agile methods should be started in the early stages of the innovation process and applied all along. The Living Lab is a space that allows the implementation of these methods in a collaborative context from the stage of the idea to the stage of the result successfully put in the market. Indeed, this open innovation location has the faculty of simulation which strengthens the stakeholders' relationships to enhance the collaborative aspect.

### III. RESEARCH APPROACH

With the same idea, digitalization will probably be one of the key point inside any strategy wanting to tackle these new medicine challenges. That's why, we try to conduct in our research approach a case study in the Connected Health Lab (CHL) of Castres (site web : isis.univ-jfc.fr). In fact, the CHL is an open innovation platform where user experience in ICT for Health (e-Health) is assessed. By users, we mean both patients and caregivers. The CHL recreates the environment of a patient pathway for simulation purposes to highlight all factors of resistance to open innovation. In an experience, the objective is either to detect the actual specific needs in terms of digital solutions or to evaluate the value of a digital solution at the prototype status under simulated conditions, including the level of change in practices related to its use. Fig. 2 shows a general overview of the CHL which constitutes our field of study. The CHL is composed of five rooms that represent different locations of the patient pathway. Three rooms are associated to

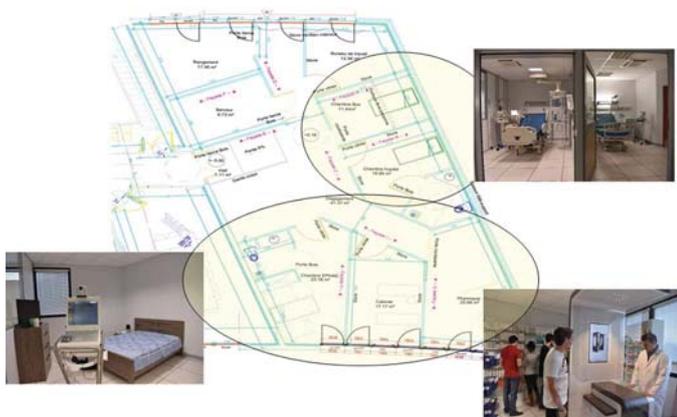


Fig. 2. General overview of the Connected Health Lab [11]

classical homecare: home bedroom, general practitioner office, and drugstore. The other two rooms play the role of the hospital environment (reanimation room, bedroom). The living lab helps to assess the technology readiness. It gives a real alternative to experiments that are generally performed *in vivo*, in public healthcare institutions, which could not be considered as test beds for many reasons as discussed by [11]. For our research methodology, this living lab plays the role of a "Broker" location. In fact, it is a common resource in the collaborative space which ensures a coordination function between the various stakeholders. In addition, as we mentioned in the Fig. 1, it is useful at all stages of the lifecycle, particularly in prototyping and development.

At an engineering reference point of view, our challenge is to create a methodological reference framework with for a better steering of the innovation process, particularly within the scope of open innovation. To do this, we will observe activities performed in the CHL to build and improve our conceptual propositions starting from the field. We choose to adopt a model-based approach [5] to design the reference framework. This framework will help us to define the data collection in order to position the Key Performance Indicators (KPI) that will build the dashboard to control the innovation process.

Knowing with accuracy the business level of the system, we will be able to explain the use of an Open Computer Aided Innovation tool at the software level, both levels being mapped to help stakeholders managing open innovation [12].

### IV. FINDINGS

A reference framework (Fig. 3) for open innovation engineering will characterize innovation with a model of key concepts, named meta model, and a life cycle (generic processes describing how to conduct and drive open innovation). A meta model defines the key concepts that can be used to describe a domain [13]. So, we start by defining these key concepts first for innovation and then for open innovation. Fig. 4 is an extract of our meta model that shows few core concepts. In fact, our meta model contains a total of 71 concepts. We just want to summarize the context into which a living lab could be included when open innovation is depicted.

Then we defined the life cycle, i.e. classical innovation activities, based on business process models structured in three levels (management, operational and support levels). This results in a high level innovation process map that is relatively generic (Fig. 5). The major phases are in agreement with the

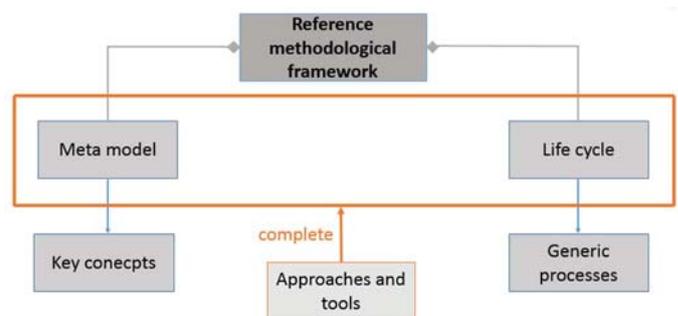


Fig. 3. The reference methodological framework

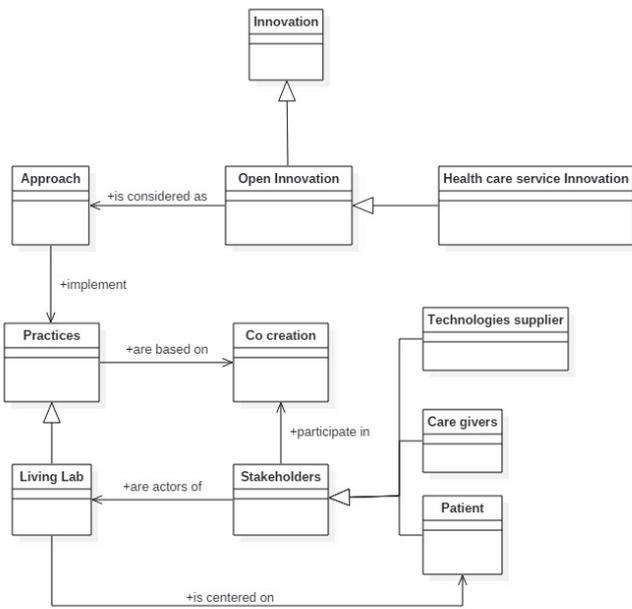


Fig. 4. Extract of the meta model

approach adopted in our living lab. In fact, in the first stage of framing, we analyze the type of innovation (innovation by need, by opportunity, by technological market pull...) in order to evaluate the motivation to innovate and to delimit an idea with a real added value. Thereafter, we try to acquire the knowledge needed to implement the idea selected. Then, in order to evaluate the technical feasibility, we need to prototype and experiment the solution. Finally, we validate the solution in a real environment through a pilot development.

As a matter of illustration, we introduce an example of a project in telemedicine [14] for the elders that we have performed on the living lab in 2016. Telemedicine technology is developing and there is yet a real offer of technologies on the market. The experience was mainly on the developing operational phase of the map (Fig. 5) and it conveyed the concepts presented in the Fig. 4. The goal was to make an evaluation of practice changes to assess the level of maturity in the innovation when General Practitioners and patients are using the telemedicine terminal to operate. This project aims to promote the use of telemedicine, in parallel to the conventional practice of General Practitioner visits. The CHL team first provides a knowledge base in the form of a business process

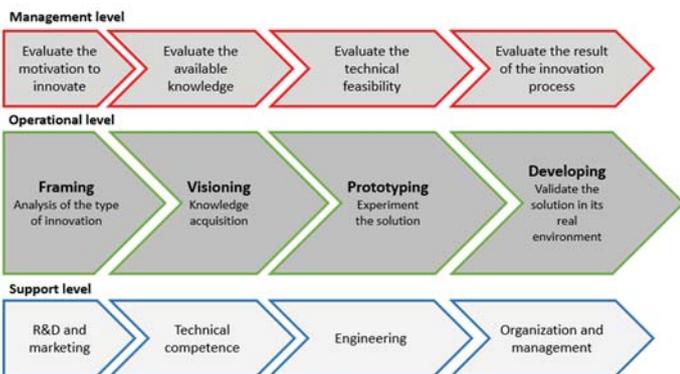


Fig. 5. The innovation process map

model at a more detailed level in order to have an explicit basis to think about practice assessment. The experience includes a characterization of changes in professional practices that has been associated with defined activities of the process model. By doing so, the context into which new practices born is more easily captured. Therefore, a comparison between the ex-ante and ex-post reality is possible. We show how changes has been characterized on Fig. 6 that describes the macro-process "prepare telemedicine consultation notice". The modelling language uses actigrams to represent inputs and outputs of activities. Activities are done by actors who are reference at the left side of a lane. From general point of view, the project identifies high level stakeholders linked by the associations summarized in Table I.

TABLE I. STAKEHOLDERS RELATIONSHIPS

| Stakeholders relationships | Focus on practice changes – examples                                     |
|----------------------------|--|
| GP-P                       | Remote diagnosis and prescription in TLM                                 |
| P- TPS                     | Patient literacy on TLM platform   |
| P- PI                      | Minimize transport activities for frailty people                         |
| GP-PI                      | Modification of economic model for TLM service payoff                    |
| GP-TPS                     | Risk assessment and quality improvement about medicine practice exercise |
| TPS-PI                     | Diffusion of technology for equal access to TLM services                 |

P = Patients, TLM = Telemedicine, TPS =TLM platform supplier, PI = Public Institution, GP = General Practitioner

Our observation on the experimental pilot was based on three axes of analysis: organization of the coordinated care path, performance of the coordinated care path and the steering of the coordinated care path. The first axis describes how to practice the telemedicine service and it is dictated by the generic process models that we have defined. On the second axis, that of performance, it seems important to us to consider the main expectations of patients in terms of value, namely the quality of care provided and the control of the risks associated with the care path. Finally, the performance of the coordinated care path is based on decision-making at a collective level and this immediately raises the question of the exchanges constructed by this collective. This structuring dimension of steering has been

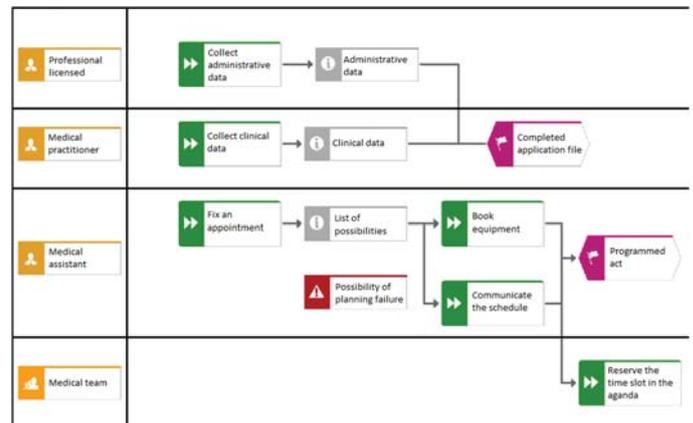


Fig. 6. The macro-process "prepare telemedicine consultation notice"

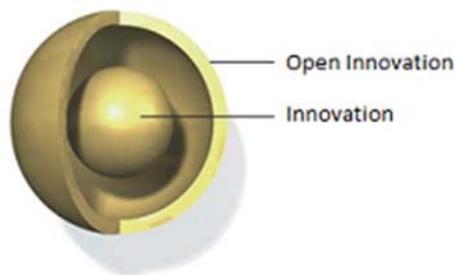


Fig. 7. The meta model structure

referred to as information sharing for coordination purposes. This repository of knowledge provided the basis for the collective reflection of the actors of this project. All the information gathered was a basis on which we were then able to study in order to construct proposals for indicators of changes in practices in the field of healthcare care services for the elderly.

## V. CONCLUSION

Much has been written since the advent of the living labs a decade ago. Several articles, such as [18], attest to the growing academic interest in living labs and its user driven innovation approach. This paper attempts to add a contribution in the scientific literature on the usefulness of living labs in the field of connected health in order to manage the open innovation. First, we provide a literature review on the open innovation concept. Then, we introduce the living labs as an open innovation tool, particularly in the health care field. Lacking an engineering global view to manage the open innovation process, we are studying the development of a methodological reference framework adopting a model based approach. By doing so, we try to describe a problem through models, concepts and languages. In fact, we are building a meta model with a structure of two concentric spheres (a spherical core and a first concentric layer) as shown in Fig. 7. The core part represents the meta model of innovation and the peripheral part represents the open innovation one. Our first instantiation of the meta model still needs to be refined. This is a first perspective for the following of the study. In parallel, it will be closely related to the life cycle that we are defining, using the concepts of the meta model. To do so, we rely on a case study in the Connected Health Lab in order to improve our conceptual propositions. This is a second perspective for us. In addition, this paper introduces a case study performed in the living lab to better organize the care path in Telemedicine practice for the elderly [15]. This experiment will be helpful to illustrate the added value of the reference framework as an engineering foundation.

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