INNOVATION IN HEALTH CARE: STRATEGY AND IMPACT ON THE NEXUS EDUCATION RESEARCH

Stijn VERWULGEN[1], **Chris BAELUS**[1], **Alfons CORNELIS**[1] and **Vanessa VAN KERCKHOVEN**[2]
[1]Master in Product Development, Artesis College, Belgium
[2]Vaccine & Infectious Disease Institute (Vaxinfectio), University of Antwerp, Belgium

ABSTRACT
Transition from a professionally oriented educational program of the master in product development to an academic context (the Bologna process) has induced the need to scientifically underpin the outcomes of design processes, as conducted in the educational program. Moreover, the master in product development has opted for science and technology as substantial drivers for value creation. To translate results of scientific research into new products that have value from an economic as well as user perspective, a research and educational line was organized covering topics on 'innovation in health care'. Our partners in industry, intermediate organisations of both industry and caretakers, other research groups and our own students supported this new track. In this paper, we illustrate how diverse projects are initiated in master theses, organised around different partnerships, and describe the merits for the master in product development as well as other academic partners involved.

Keywords: Valorisation, innovation in health care, product development

1 THE MASTER IN PRODUCT DEVELOPMENT AT ANTWERP

At the Antwerp school of product development, students learn to master the process of new product development, identify critical aspects concerning usage, technology and the market of a new product or product-service. They learn to resolve problems and cope with constrains to develop a validated product concept. Thereby human, economic and technological factors are equally important as drivers to create value through new product development. Methodology is essential for planning and to take account of all aspects in the process of new product development, including mapping of user requirements and expectations, market assessment, identification of the underlying value chain, verification of mechanical and technological aspects, constraints imposed by manufacturing and industrial standards. The Design Students are trained on analytical as well as synthetic skills, respectively to identify and pinpoint problems and to come up with creative yet feasible solutions. Problem solving skills are tangled and fully cultured. Students are challenged with a broad range of problems, ranging from real world problems that should be resolved through a practical approach, to problems that can be formulated in closed form, i.e. where determining variables and a known relation between them can be found and in which the solution is obtained by applying the identified underlying analytical model. The basis for the latter modelling skill is build up in scientific courses including applied economics, applied physics, mathematics, physiology, and sociology. The analytical and synthetic competences related to the realm of theoretically as well as practically oriented problem solving skills are assessed through design assignments that gradually increase in complexity, see for example [1]. Increasing complexity is achieved by gradually diminishing accompanying requirements and preconditions, as students proceed in their learning trajectory.
The endpoint in the line of design assignments is the master thesis in product development. It is an entirely open assessment: the initial preconditions, that characterize the topic of the master thesis, are different for each student. Each student identifies some potential topics for his or her master project, by specifying the field and drivers for the innovation. For each student, the proposed topics are ranked by teaching staff considering the potential to perform integrated product development, i.e. realize innovation on a technological, economical and human level, as well as on the internal and external resources available to resolve critical aspects and satisfactorily realize the project.

In his or her master thesis the student works on the selected, most challenging topic. Starting from the identified problem or opportunity, he or she analyses the broad the environment in which the future product or product-service will operate, to map all stakeholders, supporting technology and the underlying value chain and market conditions. Subsequently, requirements and specifications are deduced and a responding product architecture is defined, to end up with a product concept in which critical aspects are verified.

Evidently, CAD techniques are used as an efficient verification tool, applying theoretical models with minimal effort. Above all, other skills that make a good product developer, e.g. communication through sketching, presentation and writing, are also persistent in the educational program.

An extended program of 5 years has been implemented. Based on its intensive, length and scientific depth, product development is considered a fully academic degree, even long before the Bologna agreements and independently of the entailed reformations described in section 2. However, the underlying academic program is organised at a University College. Teaching staff is a mixture of academically and industrially orientated profiles: first generation product developers, civil and industrial engineers, a medical doctor, a psychologist, a mathematician and some graphic designers.

2 TRANSITION

The Bologna agreements have indeed induced a transition from a master education in Product Development organised at a University College that has by definition a professional orientation, to a University education, where the educational program is research driven [2]. The agreements have entailed the doctoral degree in product development, together with financial support for research in product development.

Within the national Dutch speaking region (Flanders), product development is the only program in the eponymous field of study. Although its educational program is de facto academic, which is also recognized by the latest governmental audit [3], there was no characterization of academic research in product development, neither could be built upon earlier tradition. Therefore, initial doctoral research was set up in collaboration with the industrial design divisions of the technical universities of Delft and Eindhoven. Also, contacts with research groups at national Universities where intensified and extended. The strategy is to conduct design projects in a pedagogical setting in collaboration with an external academic partner to initiate further and new collaboration. An increasing amount of topics for master theses is posted by industrial partners and research groups, mainly at national Universities. The latter projects are based on results of state of the art scientific research as a driver for innovation. They explore the potential of academic knowledge for value creation in the form of new products.

Examples of such collaborations are found in section 3 and 4.

3 RESEARCH DOMAINS

In the pre-Bologna area, underpinning research at the master in product development was oriented towards industry and mainly focussed on the development of tools and techniques to enable teachers, students and industrial partners to assess the state of the art technological and user related aspects in the process of new product development. Such translational research was mainly funded by intermediate organisations. It is still highly relevant for the mission of product development since it serves as a hub to connect industrial and pedagogical activities. Within the current research activities, two research domains are identified.

The first domain focuses on the methodology of product development [4] and is organized around the sub-domains 1) sustainability, 2) the process and organization of new product development and 3) human centred design. The global mission is to build a theoretical framework for a praxis of product development in which scientific as well as creative activities are systematically intertwined to support the research-education nexus. In this research domain, the activity of product development is merely used as a research instrument for it gives the opportunity to introduce variables in the design process and evaluate their effect. Insights obtained from the study of the methodology of product development are translated to tools and techniques that can be used by industry and in a pedagogical setting. Hence on top of the basis industrial and pedagogical activities, an extra activity "research" is added and a triad industry-research-education is formed, such that academic knowledge in product development is disseminated between industrial partners, researchers & teaching staff and students.

The second research domain aims at strengthening the research-industry nexus by translation of scientific knowledge to possible applications and vice versa, identifying interesting applications and defining what supplementary results are needed for an entire development. This research line is driven by the fact that results of academic research create economic opportunities and the proposition that such should fuel innovation and creates economic growth. By means of product development, results of scientific research might find their way to the market more easily. Often, product concepts reveal which supplementary research is required, so product development can be used for strategic research planning, see for example 4.2 below. In this research domain, the activity of product development is essential. The master in product development has opted to concentrate its mission in bridging the gap between science and market. For the health care domain, there is an in-house tradition, so one can build upon earlier experiences.

Master theses are a major resource to deploy product development in a research environment. Health care is indeed an appropriate setting to challenge master students in integrated product development. The need to take a user centred approach in health care innovation is omnipresent. Taking account of a variety of stakeholders, such as patients, caretakers, and medical experts instead of only focussing on functionality as a design driver, is a major source for innovation.

To support master theses in the health care domain, a collaboration entitled “i4health” (www.i4health.be) was set-up in 2010 between the units Product Development, Applied Engineering and Health Care at the Artesis University College, the interfaculty Centre of Health Care Technology (CZT) at the Antwerp University and the University hospital of Antwerp (UZA) [5]. This alliance bundles expertise on track and trace systems, electronics, programming, cardiovascular knowledge and facilitates access to medical specialists, care takers and patients, and facilitates clinical trials.

4 CASES AND STRATEGY

The choice to conduct new product development in the health care domain is relevant for several reasons. In this section we identify some of those reasons and how they related to the mission of stakeholders involved: society, industry, universities and the master in product development. Each reason is illustrated by a responding example of a recent master thesis in product development.

4.1 Societal relevance

Innovation in the health care domain is crucial to deal with the challenges of demographic evolutions, increasing life style diseases and diseases related to elderly. Focussed innovations can relive pressure on social security systems. New product-service systems based on advanced technologies can provide solutions with high societal relevance.

For example, “Stay home” is a product service system to allow dementia patients to reside at their own home for an elongated time period, thereby relieving the work of the home-carer, improve security and reduce stress for near family. An initial schedule of daily routine is defined by patient, caretakers and near family and refined through a series of observations and measurements. Once the daily routine is calibrated, it is constantly compared with the actual activities of the patient. Appropriate feedback is provided if necessary, to correct deviations that could have serious, unpleasant or undesired consequences, e.g. leaving the water tap open, keeping clothes in the oven. To measure activity, sensors are integrated in a wrist-watch. The medium to communicate feedback to the patient is dedicated; feedback is provided by means of spoken messages, displayed on a photo frame. Hereby instructions are given by a person that the patient trusts, e.g. the caretaker or a close family member.

The project was conducted by E. Heuvelmans in the academics 2010-2011 in collaboration with the local hospital network of Antwerp (ZNA). Medical experts at the dementia unit of the hospital were enthusiastic towards the idea to monitor and manage the behaviour of dementia patients through such virtual feedback. However, although the concept of activity monitoring was considered technologically feasible, see for example [6], actual testing required further investments that were not viable since the developed concept was situated merely in the front end and on a pedagogical level. However, the validation of the idea could initiate further research in that direction.

4.2 Valorisation of academic research

Universities and University Colleges in Belgium (Flanders) aim at increased targets for valorisation of scientific results. Product development can form a bridge between fundamental research and business by translating scientific insights and results of research into actual innovations and vice versa. The mapping of desired developments or identification of market opportunities, can drive research that is directly orientated towards practical applications as well as of theoretical nature. As illustrated in 4.1,

established technology could be a driver for innovation in health care, which often requires additional user related research. Conversely, the development of desired products often requires additional technological development or insights to be obtained through further research.
For example, "Septicare" is a portable medical device, to be used by physicians in a hospital setting for diagnosis of presumed sepsis. Sepsis is a potentially deadly medical condition that is characterized by a whole-body inflammatory state which is caused by the presence of pathogenic microorganisms (mostly bacteria) in the blood. Mortality associated with severe sepsis is very high (20 to 50 %), which means about 146 000 lives/year in the EU and an associated EUR 7.6 billion/year health care costs [7]. Faster identification of infecting microorganisms and treatment options is a first-ranking priority in the infectious disease area, in order to prevent inappropriate treatment and especially overuse of broad-spectrum antibiotics [8].
Whereas the current standard diagnosis (blood cultures) is very time-consuming and takes several days of lab testing to identify the bacteria as well as the resistance pattern, a one hour bedside diagnostic test could provide a major step forward. Within the framework of the EU-funded project, Intopsens (http://www.ee.kth.se/intopsens) a point-of-care test is being developed for the identification of bacteria and their resistance profiles in sepsis. In that context, a concept was developed that allows rapid identification of bacteria causing sepsis in the blood circuit and immediately map the corresponding patterns of resistance to pinpoint the most effective antibiotics. The product concept is a state-of-the art point-of-care device which integrates several technological challenges, including photonics, fluidics, biochemistry, electronics, but also ergonomics, ecology, economics, technology, and human factor. In addition to the supporting technology, also contextual requirements for transportability and immediate use at the place where the patients is localized, were analysed, from the perspective of both patient and physician, to end up with a product concept that can be used in extra muros critical conditions. The project was conducted by the master student Tobias Bossuyt in the academic 2008-2009 under the supervision of Prof dr. H. Goossens, Head of the Clinical Pathology Lab at the UZA and Head of the Laboratory of Medical Microbiology at the University of Antwerp.
Next to the Intopsens project, which is still ongoing, point-of-care diagnostics and lab-on-chip technology have become a new major research line within the Laboratory of Medical Microbiology. Currently, 5 EU-funded projects (Intopsens, TheraEdge, RAPP-ID, Chips 4 Life, ROUTINE) are ongoing that are developing point-of-care diagnostics for not only sepsis, but also lower respiratory tract infections, and tuberculosis. The product concept 'Septicare' has thereby initiated the development of lab on chip portable clinical devices at the Vaccine & Infectious Disease Institute (Vaxinfectio).

4.3 Available knowledge

There is a dense network of academic partners, university hospitals, care providers and health related industry, locally mapped out and covering a wide area of scientific, practical and operational knowledge.
For example, the Mindspeller® is a product concept based on brain activity causing small electric potentials that can be recorded non-invasively, with electrodes placed on the subject's scalp. These electroencephalographic (EEG) signals can be evoked in response to internal and external stimuli or events. From the EEG recordings, activity patterns of interest can be extracted by signal processing techniques [9]. The Mindspeller® product concept is developed for communication for patients suffering from severe brain injuries, following the observations of Mak and Wolpaw [10]. It is shaped as a *diadem* or *barette* that records EEG signals evoked in response to visual stimuli shown on a computer display. The device is fully adaptable to the users' head and designed to acquire two EEG signals of particular interest. Depending on the subject, the strongest signal is acquired and transmitted wirelessly to a computing device. Specially developed software decodes the EEG recordings to infer the commands the user wishes to be executed.
An interface in which 4 different targets can be selected was developed, to have an architecture that works well for both signals. When presented in 4 times 4 grids, 16 different targets can be selected in 2 steps. This configuration allows for T9 text completion, through which information might be drastically speeded up. To minimize discomfort due to periodically flickering stimuli or onset targets , green symbols with blue highlight where used, to yield a better information transfer rate compared to gray-white based target presentations [11].

The project was an I-ware assignment [12], conducted by the students N. Faes, M. Vandemergel, F. Van Hove, & D. Willems, in the academic 2009-2010 in collaboration with Prof dr. M. Van Hulle (laboratory of neurophysiology) and IMEC. It was guided by an interdisciplinary team of teaching staff at product development, to detect possible user problems (eg mounting in correct positions) and fixation in usage.
The Mindspeller® received a red dot award 2010 in the category design concepts for interaction and communication. The adaptability to different signals was particularly appreciated. Communication forms and stimuli form for revalidation with the Mindspeller® architecture, where explored by F. Van Hove in a master thesis in the academic 2010-2011. The project was particularly useful to reveal critical aspects such as electrode pressure, adaptability to the individual skull dimensions and robustness versus ease of use, in a clinical setting. It has initiated further research on the development of better electrodes, classification of skull geometry and anthropometrical features to design for reduced electrode pressure and optimal use.

4.4 Interdisciplinary collaboration

Cross disciplinary collaborations are vital for product development and as such challenging innovation that unite different disciplines and competences are an optimal learning environment for students.
For example, it is non-trivial to develop a device to administer vaccines more easily and with a higher efficiency.
A concept for nasal administration was developed first, by B. Bouten in the academics 2008-2009. It was however not considered feasible for the particular vulnerable meninges close by.
To date, the vast majority of vaccines are administered into the deltoid region (intramuscularly) or subcutaneously using needle and syringe. Intradermal (ID) injection, i.e. vaccination into the dermis (one of the two layers of the skin), by the Mantoux technique requires special training for medical staff and may not reliably target skin, but is nonetheless used as the route of choice for a very limited number of vaccines, such as Bacille Calmette Guérin for tuberculosis (http://www.cdc.gov/tb/publications/ltbi/diagnosis.htm). The past years renewed interest has been shown in ID vaccination due to its advantages, including dose-sparing, improved immunity, improved safety and simpler logistics of delivery. In the last decades it has also been investigated as an alternative delivery route for influenza, measles and Hepatitis B vaccines [13]. Despite this renewed interest, its use in medicine is limited by the lack of simple, available and reliable methods of ID delivery [14].
In the academics 2009-2010, a concept for an ID device was developed by W. Coemans in a collaboration of Product Development and Vaxinfectio.
In the academics 2011-2012, a prototype device is being developed which can be used to administer vaccines by the ID route (intradermal vaccination – VAX-ID). The project benefits from a close collaboration between Product Development and two faculties from the University of Antwerp, Faculty of Medicine (Vaxinfectio and Nursing & Midwifery) and Faculty of Applied Economics (Marketing), who will join forces and combine their technological, medical and economic backgrounds and expertise to develop and clinically and economically evaluate and validate the prototype device. The project is funded by the Belgian Industrial Research & Development conglomerate (BiR&D) in the framework of the Interdisciplinary Master of Science Thesis Programme. The developed prototype has valorisation potential as it could be patented and could give rise to industrial collaborations.

5 CONCLUSIONS

Health care is a challenging setting to conduct master theses in product development, considering technological, human and economic factors and the possibility to innovate on the tree domains together. Thereby, one has to identify requirements for all type of users, e.g. patient, caretaker and specialists. Academic partners, research groups and industrial partners in the health care setting, are open and eager to partner with product development, which makes all knowledge required from different stakeholders available to the master of product development. This is a precondition to realize innovation. Projects of product development in health care guard the balance between academic and professional orientation of the master in product development and ensure appropriate real world experience for students and teaching staff that goes beyond the pure concept development. To complement new product concepts in the health care domain with valorisation activities, prototyping and manufacturing for clinical testing as well as testing facilities are needed. As such projects increase and the latter are available, prototyping and manufacturing techniques are most urgent for the mission to transform scientific knowledge to direct value for economy and society. Whether or not such means such be outsourced, is subject to further analysis.

Collaboration conducted in subsequent master projects, first to explore potential for valorisation by generating concepts, secondly to pinpoint critical aspects and issues that should be resolved, are most likely to initiate further research and generate economic value. Cross disciplinary collaboration requires additional investments of team members involved. Whether those investments are be legitimated from an economic point of view is a complex picture and strongly depends on the valorisation stage of the product concepts that are developed in such configuration. However, activities in the process of new product development, deployed to translate state of the art scientific knowledge, also give rise to either supplementary research in the specific area or the development of tools and techniques that can be used by product developers. Master theses are a major resource to deploy product development in a research environment and a proven way to achieve such results, if guided by a multidisciplinary team, united to achieve a mutual "design driven" goal.

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