A Didactic Experience in Designing Smart Systems for mHealth Services

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Abstract. The aim of this paper is to present a didactic experience in designing mobile health systems during a Bachelor Degree class in Industrial Design. The scope is to prove the role of Design in the innovation process and how its approach and methodologies connect research, innovation and technology. As case studies, two projects are presented. In the first one, the students have developed a training suite for figure skating; the second one is related to the development of a system that detects and counts instruments and sterile dressings in the operating suites.

Keywords: Design · Wearable technologies · Mobile technologies · Students' projects

1 Introduction

The aim of this paper is to present the work done during the one-semester class of the second year of the Bachelor Degree in Industrial Design at Politecnico di Milano. The course aimed to design products and systems addressed to sport activities. Moreover, the course focused on the relationship among human healthcare and wellbeing; sports' practice represents a driving force to prevent diseases and to maintain a good health status. One of the goals of Politecnico di Milano and of the class itself is to promote the integration of skills and collaboration different fields, such as social and medical disciplines, to design and develop innovative products, materials, technologies, methodologies and services thanks to a human-centered approach.

The course was coordinated by the prof. Giuseppe Andreoni with the collaboration of the prof. Marinella Ferrara, and the support of TeDH research group (*Technology and Design for Healthcare*). TeDH is a knowledge center specialized in the production and application of research and design (User Centered Design, Participatory Design, Co-design methodology, User research, Ethnographic observation) for product, interior and services development in the health care field. TeDH is an interdisciplinary team including designers, architects and engineers working in permanent connection with people coming from different research field and diverse specializations, such as doctors and nurses belonging to local medical institutions. TeDH's projects range from the design of biomedical wearable devices for remote monitoring of biological signals to the development of health care service scenarios supported by mobile communication technologies.

P. Perego et al. (Eds.): MobiHealth 2016, LNICST 192, pp. 187–194, 2017.
DOI: 10.1007/978-3-319-58877-3_25

Nowadays Design has a crucial role in the development of technologies and in how the users interact with them. Such interaction could determine the product market success or its failure. In fact, as the International Council of Societies of Industrial Design has stated, *"Design is the central factor of innovative humanization of technologies and the crucial factor of cultural and economic exchange"* [1]. For these reasons, design students have to deal with technologies to solve users' needs. They have to develop products and systems that make technology usable from everyone. Designers involve final users in the product's development since its beginning, to answer properly to their needs. Designers have to understand and to define how products really works and how they are made. They have to develop formal languages and expression, and shapes that reduce the "inside complexity" (Law of conservation of complexity - Larry Poser) [2].

Moreover, healthcare products often show their technological features instead of showing their usability characteristics. Products have to become simpler and understandable without losing their technological features. Human well-being is not only represented by the absence of disease but on the state of satisfaction on the surrounding environment and products. Interacting with objects, we can talk about physiological, psychological, ideological and social pleasure [3, 4]. Healthcare products need a more specific design focus, with regard to their features, such as materials, colors, shapes, textures and visual communication. In this process, Design and Human Factors and their multi-disciplinary approaches are strategic to analyze, define and understand the users' needs and desires, and in which way these needs can be satisfied [5, 6].

2 Materials and Methods

The course dealt with the topic of Sports and Human healthcare and wellbeing. This topic was chosen because of TeDH research group background and its involvement in a Lab named E4Sport [7]. This Lab focuses its research in the measurement and assessment of the athletes' performance and to the design of their equipment. Moreover, in 2016 there were the Olympic and Para-Olympic Games in Rio de Janeiro, and ADI (*Associazione per il Disegno Industriale - Italian Association for the Industrial Design*) estabilished an award for sport and well-being.

Measuring human functions and physiological parameters is also related to healthcare and for this reason the course added also this focus among its objectives. Sports' practice represents a driving force to prevent diseases and to maintain a good health status.

Developing products and systems for healthcare and sports' practice involves different areas of interest: comfort and discomfort, personal and social dimension, emotions and feelings, amusement and training, sports' practice for impaired people. Students were asked to deep investigate these topics before developing a product.

During the course, several experts presented their research and projects, to show students their point of view; doctors, engineers, designers told their experiences.

The course will follow five main phases:

- Theory lessons;
- Supervised analysis and concept generation;
- System design and development;

- Ex-tempore (prototyping/physical computing);
- Presentation and reporting.

The Teachers' team was composed by expert in different disciplines: one expert in biomedical and communication technologies applied to medicine and rehabilitation; one expert in design and materials supporting product and social innovation; one expert in Design for healthcare, ergonomics and Interaction design; one expert in Computer Science and Control Systems; one expert in technologies (hardware and software), wearable devices and Human-Computer Interaction. The Teachers' team expertise are complementary and functional to the topic of the course and the synergy among research and didactic activities allows students to face real case studies and to develop systems and products that answer real needs [8]. This approach is also useful for researchers, that can explain and discuss their research and find different points of view, strengths and weaknesses.

Students were asked to organize into groups of 2 or 3 people and to define a product concept to develop during the course. First of all, they were asked to define a research topic and to characterize the users and their needs. Students were asked to conduct a market and a patent research, to identify what is already produced and patented. At the end of this analysis phase, they were ready to define the general requirements of their concept and to start designing it. Table 1 below shows the groups' features and their topics.

Table 1. Students' groups and corresponding projects

Students' groups	Projects' topic
Group 1 (1 M, 2 F)	Stress monitoring and respiration training tools
Group 2 (2 F)	Swim cap with MP3
Group 3 (2 M)	Wearable monitoring tools for hiking
Group 4 (2 M)	Headphones with heart rate monitoring
Group 5 (3 M)	Martial art chest protector
Group 6 (2 M)	Smart wristband for tennis
Group 7 (2 M, 1F)	Postural shirt
Group 8 (2 M)	Interactive carpet for kids
Group 9 (2 F)	Swim headphones
Group 10 (3 F)	Baby sling
Group 11 (3 F)	Smart helmet for horse-riding
Group 12 (1 M, 1 F)	Smart tools for scuba diving
Group 13 (2 M)	Smart belt for weight-lifting
Group 14 (2 M)	Nutrition tracking system
Group 15 (2 F)	Gloves for people afflicted with the Raynaud Syndrome
Group 16 (2 M)	Mountain bike chest protector
Group 17 (2 F)	Smart garments for ice skating
Group 18 (1 M, 2 F)	Ankle brace
Group 19 (2 M)	Smart swim cap for blind people
Group 20 (2 M)	Rewarding system for gym clients
Group 21 (1 M, 1 F)	Swim vest for kids
Group 22 (1 M, 1 F)	Roller derby protectors
Group 23 (2 M, 1 F)	Smart rescue buoy
Group 24 (1 M, 1 F)	Smart system for detecting surgery instruments
Group 25 (1 M, 1 F)	Smart gym gloves
Group 26 (3 M)	Motocross chest protector
Group 27 (2 M)	Running shoes for preventing ankle twists
Group 28 (1 M)	Swim-board

3 Results and Discussion

In this section, two case studies are presented to prove the good interdisciplinarity achieved and the didactic experience. The first case study is a training suite for Figure Skating. Two students developed this project, both of them with experience in ice skating and artistic gymnastic. The aim was to create a wearable tool that can be used by expert to measure their performance and to prevent injuries or fatigue during their training session. Moreover, this device could give feedback related to their gesture performing an exercise. Their research process started with a deep analysis of the sport activity, using interviews and online form, to understand the critical issues of figure skating and the users' needs. At the same time, they analyzed the Figure Skating from the biomechanics point of view.

After this research phase, they defined their project brief: they would design a wearable monitoring system that could detect the muscular activity during the training session and give real time to inform the user of the muscular stress and avoid injuries. Moreover, the device had to register the training session and send it to a smartphone or a tablet.

They started analyzing the existing technologies, to identify the ones useful for their scope, that answers to their requirements. For measuring the muscular activities, they found interesting dry electrodes for electromyography; for transmitting the data acquired to the control unit, they choose smart textiles. They designed the dimension corresponding to a flexible PCB control unit that can be worn. To give a real time feedback, they identified the Lumigram, an optical fiber that can be sewed. When illuminated, the optical fiber can display which muscle group is activated during the exercise (e.g., an axel jump). Figure 1 below shows the elements and fabrics chosen to answer that needs.

They designed a product named "Electropants", that can be worn during the Figure Skating practice. These "lit pants" and their lighting effects can be seen both by the athlete itself and the coach and the spectators, increasing the involvement during the performance and its magnificent. The students answered the users' needs developing this interactive training suite, investing and cultivating *"the imagination with regard to physical and psychological human needs, and link them to positive experiences such as stimulation, relatedness, and competence"* [9].

According to Sheldon, competence is one of the top-ten psychological human needs based on a review of theories about the content of motives. Others are autonomy, relatedness, influence, pleasure, security, physical thriving, self-actualizing, self-esteem, and money [10].

Moreover, the students developed the UI of an App, that can be used to track the training session. Figure 2 below shows their prototype.

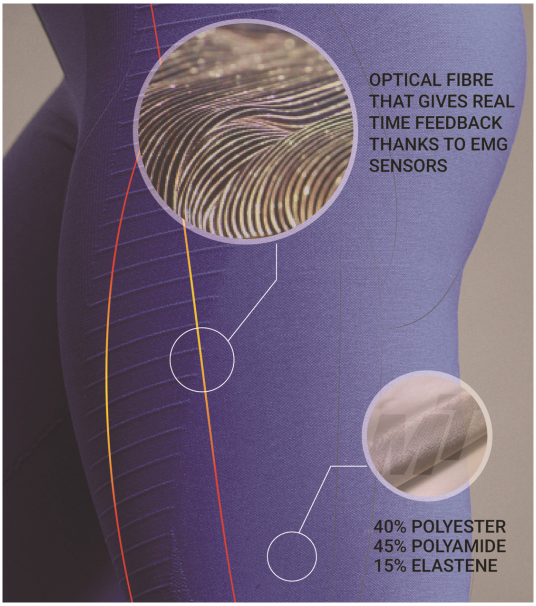

Fig. 1. Project requirements and related items.

Fig. 2. The concept prototype.

The second project is a system that detects and counts instruments and sterile dressings in the operating suites. Sometimes during or after a surgery, some items disappear or can be left inside the body and it represents a very high risk for both the patient and the medical team. To avoid that, these students developed a system that automatically count the items and in case of items' loss, can detect where it is thanks to a RFID sensor.

They started their research attending a surgery and interviewing the person devoted to the items count. This count is made more times during the surgery: before the beginning, during the surgery and at the end. Sometimes happens that an items could disappear. In that case, all the medical team has to look for the loss item; sometimes the patient must to undergo to other examinations, to detect the loss item. To avoid such problem, the students focused their project on the detection of the instruments, excluding needles and their similar due to their little dimensions.

At the end of this research phase, the students started searching for technologies that can be used to solve the loss of instruments and sterile dressings. They found that the RFID technology is already in use in several UK hospitals, to solve that problem.

Figure 3 shows the functioning of the identified technology.

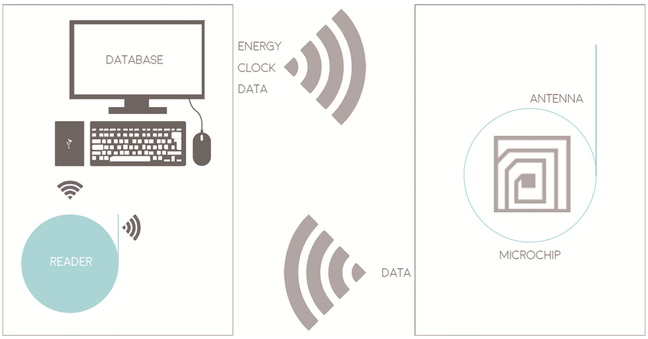

Fig. 3. The functioning of RFID technology.

They designed a desk for the person in charge of the instruments' count and a reader to be used just in case of loss items. Figures 4 and 5 below shows some sketches of the designed system.

Designing the smart desk, students took into account of the direct and indirect users' needs in the operating room. In fact, they choose a material that can be easily clean and sterilize, such as the Polyamide; the desk is white and the whole surface is polished. Moreover, it is suitable for a standing person because the work surface area is 91 cm high.

The reader must be used when a discrepancy in the count occurs and it is stored in a drawer at the back of the desk. It can be used with one hand. On the device top there is a button that must be clicked to turn it on. Once the system has been activated, the user has to scan the interested area, to detect the loss item.

The students also analyzed the visual and chromatic aspects of their project. In fact, they choose colors that are influenced by the context and by the healthcare: they choose a color range that is close to the "hospital green" (HEX # 2ab1bb). Moreover, the project logo is circular and divided into different parts, to recall their cyclical process. The project is named "No-Retech", is the meld of "No Retention" and "Technology".

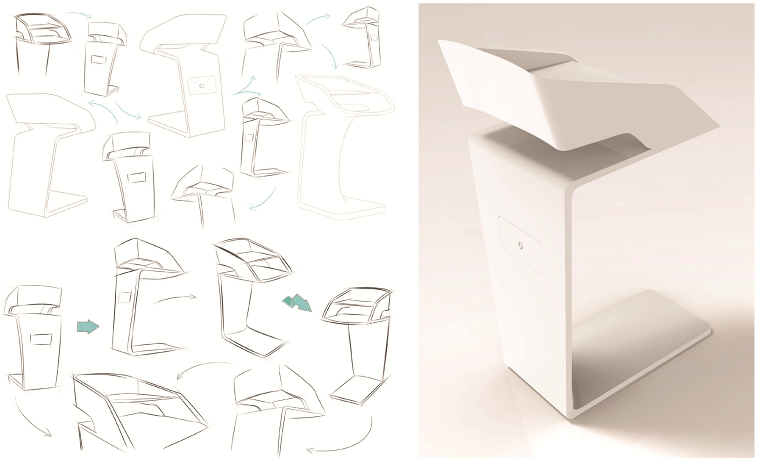

Fig. 4. The smart desk for the items' count

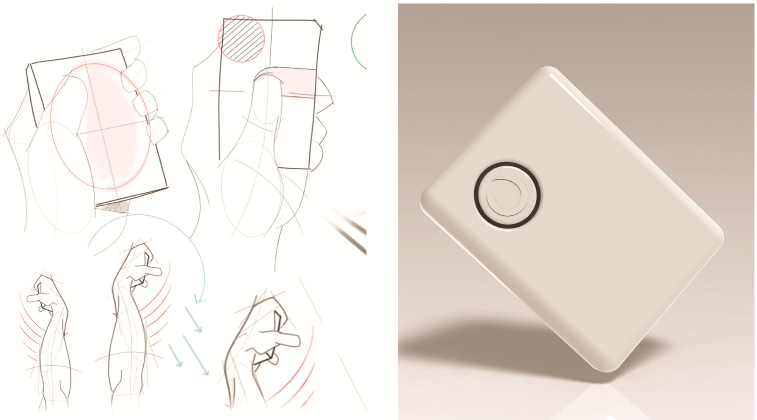

Fig. 5. The smart reader.

4 Conclusion

The described teaching and designing activities proves that a design approach is desirable in a field that involves sports' practice, wellbeing and healthcare. In such field, products are often complex and hard to use. Design research and its tools are useful to understand people and their needs in their everyday life context (such as workplace, home, gym and so on). Designers are able to understand the physical and psychological human needs, and to link them into positive experiences for their projects. A human centered design approach can be considered as suitable, in developing innovative products or systems.

Moreover, a multidisciplinary team represents an enrichment in the entire development process. The class proves its capability to research and examine in depth a topic and to define requirements and solution that take into account of the users' needs.

Acknowledgments. The Authors would like to thank all the students that took part to the "Disegno Industriale 2" Class, for their hard work. In particular, we would like to thank Eliana Martone, Daniela del Mar Gómez Guizo, Lorenzo Luchetti and Silvia Mascaretti, that allow us to present their projects.

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