Experts in Medical Computing: Designing a continuous education program with clinical relevance and industrial applicability

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***Abstract*—In this work-in-progress, we present the design and implementation of a novel higher education medical computing continuous program that addresses on-demand, relevant clinical and health-care industry needs. A consortium of computing science and engineering academics and researchers, entrepreneurship and industry representatives, and clinicians is jointly designing an ecosystem that channels relevant needs from medical, clinical, and industrial environments into requirements for medical computing academic training. The design of this interdisciplinary program adheres to participatory design principles. Here, we outline the motivation and demands of such program, the design of the program, the principles and practices planned and implemented, and we report on first implementation steps. Since the graduate programs of computing and engineering mostly provide broader education, the graduates from these programs lack relevant clinical perspectives, necessary to work in- and advance the domain of medical computing. Likewise, the graduates from clinical and medical programs are often missing up-to-date computing skills, essential to comprehend and manage the fast-developing industry of medical computing technology. By implementing the processes of funnelling industrial and clinical aspects, we ensure that the graduates are equipped with relevant knowledge, and become a part of germane networks. We also report on challenges, experience, and lessons learned.**

***Index Terms*—medical computing, educational program design**

I. Introduction

In this paper, we present the design and implementation of a novel higher education medical computing continuous program that addresses relevant clinical and industrial needs. While markets related to medical technologies, medical education, AI in health care and associated industries grow rapidly and are expected to reach a sum of 280 billion dollars in 2021, there is a recognized lack of qualified workforce in the domain, both in industry and clinical institutions.

One of the leading challenges that medical computing curricula need to address is the ever-changing societal expectation of the health care stakeholders and fast pace of the health-care development. Similarly, as with the expectations on medical education [1], the role of physicians, technological innovations, health-care environments, industry and associated markets – all jointly affect the requirements that influence the medical computing as a discipline.

Medical computing, however, can only be successfully developed, improved, and deployed when competent workforce is available [2]. However, workforce knowledgeable in both medical and computing fields is currently underrepresented since medical professionals and computing experts have been primarily trained only for their respective fields. Consequently, with the proliferation of modern computing methods, current medical personnel needs to become more acquainted with and trained to incorporate new computer tools. Similarly, computing graduates and professionals need to become aware of principles and challenges of working in medical settings.

In 1979 and 1980, Wasseman [3] and Shortliffe [4], respectively, discussed the status and importance of medical computing as an emerging discipline in the boundaries between medicine and applications of computers. At the same time, new graduate programs started to appear. Duncan et al. [5] presented the first curriculum for health computing education. Since 2010, our research group has been fostering a collaboration with the local university hospital [6] and industry, directly or indirectly involved in medical computing. We ground our motivation from our discussions with numerous hospital personnel and computing professionals, who inspired and informed our efforts.

Here, we are presenting a way to design a medical computing educational program such that these challenges are addressed. We report on requirements, mechanisms, and processes we adopted. Our approach to developing the program adheres to the participatory design perspectives [7], which is common in the technological development. We applied similar principles in the design of a higher-education program that is

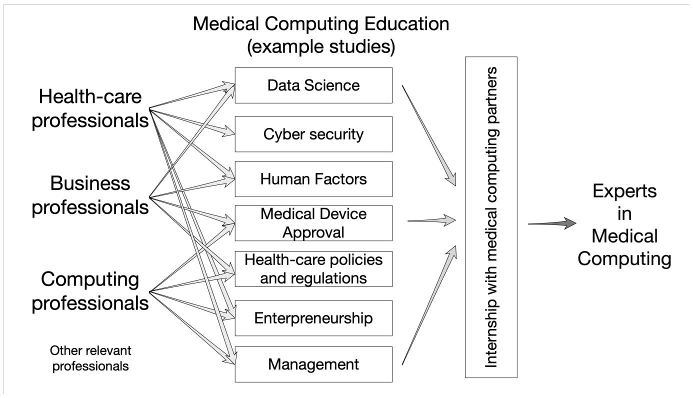

Fig. 1. Adaptation. Example paths through the program curricula with respect to the profile of the participant. Each of the background profiles may lead to various unique paths through the studies.

suitable for continuous education of computing professional and medical personnel. The program is positioned as a non-degree expansion of a university curriculum, and aims to offer domain-targeted education and industrial experience and collaboration. The graduates from the program shall directly address the needs of health care and industry for the specialized workforce.

II. Experts in Medical Computing: a continuous education program

The domain of applications of computers in health care has been referred to in many ways, including health information technologies, health computing, medical informatics, bioinformatics, biostatistics, medical computing, and many others. In our work, we refer to the domain as *medical computing.*

Professionals in medical computing have been present in the healthcare workforce under diverse roles. In the medical field, these roles ranged from hospital technicians, technicians at operation rooms, devices ”masters” (nurses and technicians trained in operation of a particular medical device), information system managers, up to hospital physicists.

In the computing field, the roles comprised computing practitioners, programmers, technicians, consultants, and entrepreneurs with various levels of medical background, such as medical doctors and nurses who changed their profession, or medical and computing students who shifted their line of studies to the other field. All these shifts present an uncharted territory of medical computing since their knowledge of both fields has been obtained as a unplanned combination of their prior education, experience, and practice. Such diversity presents both opportunities and challenges for the interdisciplinary program, which aims provide the education relevant for medical computing.

A. Motivations

The motivation for improving medical computing workforce are numerous. In Europe alone, over 675 000 workers are employed by 27 000 Medical Technologies companies, which are predominantly small or medium sized enterprises. The industry is characterized by fast-paced innovation and produced 12 000 patent applications to the European Patent in year 2016 - more than any other field of industry in Europe and still increasing[1].

However, preoccupation to innovate and to produce cost-effective health benefits is nevertheless endangered due to medical fields strictly regulated nature and recognized inconsistency in the value of certifications such as CE and immaterial rights[8]. The innovation-driven health-care business faces both economical and ethical challenges, advocating for interdisciplinary sense of medical, technical and business trends for all stakeholders. By providing a hybrid education, adopted from fields of computational sciences, medicine and business, we intend to provide just that.

One of the core motivations is also a recognized lack of computing knowledge in the health-care professionals. For example, concerns related to health-care professionals' computational background and implementation of patient safety have recently surfaced. More concretely, cyber-security related crime in health care has become an increasing concern [9]. At the same time, however, cyber security awareness is generally very low in health care workers [10], and there have been reports of hacking into health-care records [11].

Another motivation for developing a continuous education program is the fact that professionals involved in work-life do not have time and resources to enroll into a full-time degree programs. To lower these obstacles and provide more formal learning at the same time, we aim to design the education as time- and space-independent. Here we present our approach to developing medical computing as a non-degree, continuation education program.

B. Profiling the experts of medical computing

The common denominator of medical computing applicants is their enthusiasm for and lack of the opposite field [11]. Computing professionals are usually equipped with skills to create products and services that are missing in the health-care sector, however, they lack the knowledge of health care-specific policies, requirements, and regulations. Such knowledge is essential to ensure patient's safety since related requirements are often more regulated than in other computing-related fields (i.e., game industry). Another lack is related to the missing knowledge of the human factors and product use in the health-care environments, which is essential in communication with prospective customers from the health-care environments (i.e., doctors, nurses, patients). Since computing professionals often lack a practical experience from a particular health-care environment (i.e., an operating room), they do not understand the context, in which their product is used, and, thus, often do not comprehend fully the customers' needs.

Similarly, health-care and medical professionals have a thorough understanding of health-care environments (comprising drugs, instruments, devices, ORs, protocols, patients, and personnel) from the perspective of a hospital insider. Indeed,

[1]The European Med. Techn. industry in figures 2018: https://www.medtecheurope.org/resource-library/the-european-medical-technology-industry-in-figures-2018/

Domain	Primary target competencies	Example course units
Computing	Artificial Intelligence and Data Science, Human-Computer Interaction, Photonics and Imaging, Bioinformatics, IoT and IT architectures	R-programming, User Centered Design, Spectral Imaging, Big Data, Machine Learning
Health care	Health-care service system, ethics, legislation, privacy protection	Medical Device Approval
Business	Business economics, management of business operations and technology, marketing	Management in digital health

TABLE I

CURRENT DOMAINS COVERED BY EXPERTS IN MEDICAL COMPUTING AND EXAMPLE COURSES. COMPUTING DOMAINS AND UNITS ARE ADAPTED FOR THE HEALTH-CARE PROFESSIONALS, AND VICE-VERSA, HEALTH-CARE DOMAINS ARE ADAPTED FOR PROFESSIONALS WITH COMPUTING BACKGROUND.

they understand the best practices and limitations present in their daily practice, and often have a clear view on what and how should be improved. However, they are lacking the skills to implement their needs (e.g., design, hardware or software development, data analysis, testing, security). While they can work with industrial partners (i.e., sales, project leads, or programmers), they miss the development-specific background and the language that would allow them to communicate efficiently the specific requirements. For example, they are often unaware of design principles, iterative cycles of development, and human factors. Consequently, they are uninformed how their ideas will materialized and when they can expect the product of their ideas.

C. Program design and stakeholders

Duration of the program is one academic year, and participants receive a completion diploma. The design of the program adheres, for many of the parts, to the participatory design principles. This, in practice, means that the various stakeholders are actively included in the design and implementation of the program from the very onset. Doing so ensures that the traditional *IT-medicare divide* [2] is further minimized.

Two Finnish higher education institutions jointly implement the program: a multidisciplinary, one of the largest universities in Finland, and a university of applied sciences. In addition, the local university hospital is a strongly committed development partner. In particular, the participants involved in the design include the academic experts and administrators, medical professionals including physicians and health-care administration, and health-care industry representatives. At the early stages, the students are not active participants in the design process.

To warrant industrial and clinical relevance of the medical computing continuation program, we adopted the following principles, practices and processes: 1) Close cooperation with med-tech industry and clinics - We call this *the funnelling process*. We created a steering group with industrial partners involved and have interviewed them to elicit the set of skills and knowledge they believe each new worker should poses. To address clinical relevance, we created a clinical advisory group consisting of representatives from major clinics, and also interviewed them to elicit expectations and needs the clinical practitioners have from a medical computing workforce.

2) Because of the inherent interdisciplinarity of medical computing, the participants may come from various background and often have extensive work experience. Therefore, the path through the continuous education needs to be adaptive, see Figure 1. To that end, we aim to create a variety of courses and seminars that help participants gain skills towards the attempted trainee placement in the participating companies and, ultimately, a career in medical computing.

3) Guidelines for transitioning the traditional materials to time- and space-independent mode of delivery. The traditional modes of education delivery do not allow for flexibility. For example, industry professionals wishing to gain new knowledge in medicine may be unable to take a typical lecture-demo-exam course. We therefore analyze the offerings at the local university-level institutions and offer actionable transitioning guidelines towards creating online, time- and space-independent materials.

4) Include practical pre-employment training. The core principle of the program is that participants take part in the companies as trainees. This serves both as a pre-employment training, and a low-risk trial period.

D. Skills and Competencies

Hersh [2] claims that *"It is increasingly recognized that a well-trained [Health Information Technology] professional should have knowledge not only of information technology, but also of health-care, business and management, and other disciplines."* We designed the curriculum and content of the program to ensure that the graduates encounter information technology and computer science knowledge, health-care (hospital) settings exposure, and business and entrepreneur skills.

Table I shows an overview of the main domains covered by our version of the medical computing curricula. When generating the content of the program, we search support in the strengths of the local high-quality research and teaching. The current best practices and developed study courses at the involved institutions form the basis of the units offered to the program participants. The resources of the program are then targeted at improving the medical-computing relevance, and at adapting the form of delivery.

We recognize that there are other domains pertinent to medical computing, such as law, nursing, bioinformatics, technology in medical education, public health, medical simulation, information systems and others. We do not aim, nor are able to incorporate the competencies of all these related domains into one single, year-long continuing program. The limited local resources, time limitations, costs and other constrains needed to be taken into account in our implementation.

Characteristics	Typical computing program	Experts in Medical Computing
Industry influence	Typically limited	Informed by industry
Interdisciplinarity	Typically single discipline	Interdisciplinary
Clinical relevance	Domain specific	High in collaboration with the local hospital
Knowledge of computing	General knowledge, focused on theoretical fundamentals	Introductory and applied knowledge in the medical context
Mode of delivery	Present lectures, demos, projects, exam	Hybrid with focus on remote online learning
Mode of learning	Time and location-constrained	Time and location-independent
Graduation requirements	Thesis work and maturity exam	Internship and internship report
Career aims	Professional in the area	Extension of existing career

TABLE II
A COMPARISON OF THE CHARACTERISTICS OF TRADITIONAL COMPUTING PROGRAM AND EXPERTS IN MEDICAL COMPUTING.

E. Innovations related to student learning

The participants of the program recruit from various backgrounds and have varied possibilities to satisfy the demands associated with taking part in a traditional mode of delivery. For example, some of the participants may be hospital nurses, while others recruit from the unemployed. Therefore, we aim to provide time- and space independence of the studies.

By closing the gap between professionals from health care and applied sciences with relevant backgrounds, we establish better means for relevant knowledge communication and capable problem solving. This is expected to provide basis for start-ups and to result in accumulation of disruptive innovation processes, which have been identified as a key method to change culture and add value to health-care systems [12]. Table II illustrates a comparison of the traditional programs in computing and the Experts in Medical Computing program.

III. Discussion and Conclusions

At the moment, it is not clear what are the best ways to train qualified workforce for medical computing [2]. The domain of medical computing is also constantly evolving. We approach these challenges by adopting the participatory design stances. In our implementation, medical professionals, computing and business academics and practitioners, and industry representatives are invited to co-create and update the curriculum.

Health care is burdened by expansive budget, which seems to have no limits due to co-occurring increase of both demand and supply of care. Consequently, health benefits cost-effectiveness guides budgeting, which challenges prospective investments on establishing sustainable innovation ecosystems. This economic challenge is addressed here by designing the educational program in collaboration between more immediate beneficiaries: regional funders, higher education institutes and health-care and medical companies. As the authors of this program we strongly recommend all parties interested in establishing similar programs to support health-care involvement by seeking out other public and private forms of funding in terms of regional development and innovation.

A. Challenges and Lessons learned

Currently, the program runs through its early stages and we are able to reflect on initial challenges and lessons learned. One of the challenges is related to the implementation in clinical environment and the related interdisciplinary collaboration. University hospitals are accustomed to in-house training of health care disciplines such as doctors, nurses and technical staff. However, non-medical education (e.g. computing and human-factors) is unorthodox and many cultural factors intervene in the design of the education. Detailed addressing of this challenge is beyond the scope of this work, however, we put forward the patient safety, opportunities of interdisciplinarity, and the common goals to further lower the potential communication, organizational, and institutional barriers.

Second, involvement of patients is susceptible to not only data security policies, but to the limited amount of hospital staff resources, and unexpected threats such as contagious diseases, too. The 2020 COVID-pandemic has forced the development of remote forms of communication to hospitals and created demand and means for digital collaboration. We saw an increasingly approving culture for conventional telemethods such as peer to peer internet telephony between patients, health care professional and teams. New services have been developed to enable live-streaming from sensitive environments such as the surgical ORs, too (for example Live International Otolaryngoloy Network www.lion-web.org).

Third challenge lies in transformation of traditional lecture-homework-exam courses and adjusting the modes of delivery. This includes transitioning of the courses into lightweight, time and space independent modules, selecting the relevant courses from the general curriculum and re-focusing the courses to be better applicable in tasks of medical computing.

Further challenges include dealing with variety of applicants' background and readiness prior to enrolling into the program, activation and involvement of industrial and clinical partners, including eliciting needs, and internship placements negotiations, and communicating the benefits of participation.

Computers in health care continuously improve patient safety and quality of life. In order to better prepare qualified workforce for medical computing labor markets, we designed a novel higher education continuous program. Adhering to participatory design principles, we involve various stakeholders to include academic, clinical and industrial relevance.

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