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How do we need to adapt Biomedical Engineering Education for the Health 4.0 challenges?

Proposal for novel HealthTechnology teaching focused on applied Innovation Generation

Abstract: Novel challenges and developments require adaptations on skill set, content, and associated education. A biomedical engineer will require a broad range of skills — which to a large extent are currently not taught — in the coming years to meet the development needs of future healthcare: intensive interdisciplinary team work, advanced communication skills, team management and coaching capabilities, advanced project management, learn how to learn, visionary and forward looking thinking, understanding of health economics, entrepreneurship and leadership. But above all empathy towards the clinical user and patients is needed as well as a basic understanding of the current and future clinical workflows that can globally vary. An innovation process for a healthcare related product or service will likely only create value through the consideration and implementation of several of these points. Even though techniques for the development of innovation and enhancing creativity in individuals are widely discussed, there are relatively few reports on the practice of mainstreaming creativity in an organizational setting. We report on the setup of our Graduate School "Technology Innovation in Therapy and Imaging (T^2I^2)" that has implemented a structured post graduate program and focuses on interdisciplinary and application-oriented innovation generation education. The educational process starts with the observation and identification of clinical needs and an in-depth understanding of the problem and subsequently covers all steps necessary to transfer prototypes into viable solutions and further into implementing valuable products.

Keywords: Biomedical engineering education, Innovation generation, clinical translation, Biodesign, Healthcare challenges, 21st Century Skills,

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1. Introduction

Modern Medicine is evolving fast. But the education lacks behind the new and needed developments. The following needs should be included in training innovation oriented biomedical engineers:

(1) Since technology is the driving force to improve diagnosis and therapy there is also a growing need for professionals that specialize in bridging the gap between traditional and a new technology driven medicine.
(2) This needs to be combined with effective tasks management within a customer focused and economic context.
(3) Innovation generation and subsequent professional translation from bench to bedside should be introduced at German universities. While basic research is of course needed, applied - and possibly - disruptive development focusing on improving treatment quality and patient experience, while reducing delivery costs significantly will become more and more important.

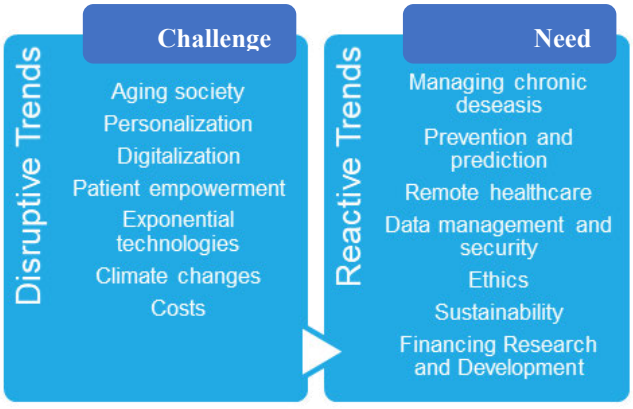
The current medical technology engineering courses are designed to impart knowledge from the natural sciences in the technical context. Innovation, creation and implementation, including some economic understanding and entrepreneurial training are rarely part of the curriculum, nor are interdisciplinary or application focused approaches within a clinical setting. Structured innovation generation, translational concepts understanding local and regional needs, as well as knowledge of manufacturing and management processes are likely as important as technological depth for successful product and service implementation.

The important cooperation between clinical users, engineers, economists, and politicians is becoming increasingly difficult due to the fragmented value chains but the core of an innovation process solving unmet clinical needs and creating valuable products and services.

2. Challenges and requirements for Future Medical Technologies

European healthcare technologies are in worldwide demand and a very successful export. To keep technological leadership future healthcare related trends need to be understood and considered as important input for the development of meaningful and affordable products.

Understanding future needs means dealing with current scientific topics, market developments and needs, as well as upcoming social changes. For this, we differentiate between disruptive trends and reactive trends. Disruption comes and can be beneficial in reshaping healthcare. Reactive trends are emerging as a result of the disruptive trends and can be acted upon [1].



1. Disruptive trends as future challenge resulting in reactive trends- as need for educational focus [1 - 4]

Aging society

In the next 20 years, 2040, the German population of ages of 65-79 and 80+ is expected to have an increase up to 24% and 79%, respectively. Up to 30% of the population would be retired from the working life [5]. Especially, the increase of 80+ agers requires more healthcare resources which can be supported by daily life's diagnostic tools and devices. Early detection of health problems will be the most relevant impact factor of successful treatment. This will affect the entire care sector. There is a need for smart diagnostic devices and tools which are connected to a whole care network with local care services, hospitals, medical offices and pharmacies.

Personalization

Personalized medicine, uses diagnostic testing for selecting appropriate and optimal therapies based on the context of a patient's genetic content or other molecular or cellular analysis. Personalized medicine may provide better diagnoses with earlier intervention and more efficient drug development and therapies. As personalized medicine is practiced more widely, a number of challenges arise. The current approaches to intellectual property rights, reimbursement policies, patient privacy and confidentiality as well as regulatory oversight will have to be redefined and restructured to accommodate the changes personalized medicine will bring to healthcare. [3, 6] Genetic data obtained from next-generation sequencing requires computer-intensive data processing and adequate tools will be required to accelerate the adoption of personalized medicine to further fields of medicine, which requires the interdisciplinary cooperation of experts from specific fields of research, such as medicine, clinical oncology, biology, and artificial intelligence.

Digitalization

The digital transformation stands for a global change of economy and society, caused by the consistent penetration of daily life with information and communication technologies. Compared to the classical contents of engineering studies, competencies in a cross-sectional area are added that can be described as digital technical content. In 2025, up to 175 ZB of digital data will be produced daily (Healthcare is one out of four main industries beside Production, Media and Entertainment and Financial Services). 90 percent of the world's total data has been generated over the past two years. [7] These big data and the explosion of digital data will lead to infrastructure and application changes. In addition to IT-related content, this area also includes more extensive aspects such as the understanding of new, digitally induced business models, data security and protection, and social implications (e.g. technology assessment), this offers opportunities for a remote health system, but places high demands on data management and security. [3, 7]

Patient empowerment

Focuses primarily on people who receive health care services - people with physical and mental health needs. Fast communication, better education and the involvement of the wider public (citizens) in local planning and priority setting are important to get health across all policies and move away from societies that actively market unhealthy lifestyles [8]. Networks and information systems help patients to make their decisions - making the healthcare sector more transparent from diagnosis to therapy. There is clearly a significant overlap with health needs and services:

- Better understanding their condition.
- Participating in making decisions about their care.
- Being supported to better self-manage their health and treatment.
- Feeling confident to ask questions and challenge professionals and organizations.

- Having the chance to join networks or groups of other patients in similar circumstances.

Exponential technologies

Exponential technologies describe new, mostly digital, technologies that are experiencing exponential growth. These include Sensors, 3D Printing, Virtual Reality, Drones, Artificial Intelligence, Blockchain etc... These developments are based on Moore's Law, which states, exponential growth based on the example of integrated circuits. This development is the basis for the digital revolution we are currently experiencing. Every industry and every business will be affected by the consequences of this digital revolution. Exponential technologies offer innovative companies great potential in terms of cost and time savings.

There is a need to impart an exponential mindset to all innovative and future-oriented executives and decision-makers in order to jointly define extraordinary goals. Exponential technologies could lead to a dramatic change in the way that healthcare is delivered. Currently almost all of the national healthcare systems treat sick patients rather than to prevent people from becoming patients.

Climate changes

More clearly than ever before, the United Nations Climate Council (UN) warned in its World Climate Report (2019) of the consequences of the greenhouse effect. The controversy over climate change will also affect the healthcare system in future. The effects of anthropogenic climate change are already taking root in nature and society. Existing climate projections prove a future strengthening of already recognizable climate impacts.

Primary level of affection: The Human.

Increasing temperatures can lead to a change in the spread and activity of pathogens, particularly diseases transmitted by ticks and mosquitoes. Food-borne and water-mediated infections can increase the incidence of diarrhea. Heat waves put an enormous strain on the organism of old and ill people as well as children. Also the increase of allergies, e. g. through new immigrant plant species is possible [9].

Secondary level of affection: The Healthcare sector.

The markets are closely linked to production, storage and delivery. Here, new low-emission and environmentally friendly approaches are sought. Based on this, adaptation strategies and measures can be developed and implemented. These increase the resilience of the environment and society to current and future climate impacts. Increasing damage and costs of climate change are reduced [9].

Costs

Germany affords one of the most expensive health systems in the world. Last year, for the first time, more than one billion euros were spent daily (376 billion in 2019) [10]. Ascending trend. However, there is a lot of inefficiency in healthcare, up to 20 percent of healthcare expenditure could be saved (OECD) without quality loss. Starting points for savings would include less unnecessary double examinations, avoidance of unnecessary operations and a more reserved use of antibiotics. Many treatments that are carried out in hospital today could also be carried out on an outpatient basis.

2.1 Face these needs towards postgraduate education

We have to react adequately to the challenges and to build an interdisciplinary exchange in education - to enable the creation of creative and innovative clinic engineers who are not only interdisciplinary but interprofessional.

Disruptive trends will come with political, economic and social changes. But they also provide great opportunities to serve the sectors with new innovative ideas and establish not only new tools and equipment, but also services and business models. The trends not only generate costs but also have a significant impact on cost savings - with better process design (e.g. through digitalization). This requires a basic understanding of processes, decisions and impacts and increased need for innovative solutions with global focus.

Healthcare 4.0 is heading for a reduction of inpatient treatments and increased outsourcing of specialized clinical services. With higher quality and efficiency and a vertical integration between providers who offering various services, from preventive models to acute- care and after- care solutions.

The Biomedical Engineering education as we know them today will need to change to cope with these issues or adapt to become driving forces of innovation. Engineering students and early stage researchers need collaborative and problem-solving skills to perform in teams of high diversity. With the aim of translational research - to create new therapies, medical procedures, or diagnostics to act on the disruptive trends and handle the reactive trends.

3. The Graduate Program T²I²

The T²I² intends to foster the coming generation of health engineers to efficiently develop medical technology and ensure that this technology is a marketable resource. A structured education program with an interdisciplinary approach in the disciplines of Medicine, Technology and Economics is provided. Currently 13 international Ph.D. students (from Egypt, Mexico, Nepal, India, Iran, Taiwan and Germany) are in that structured doctoral program for innovation generation, technology transfer and business

implementation of medical technologies. The participants have to successfully attend at least 300 hours of lecture or lecture equivalent study over a 36- to 48-month period. They work on topics and projects in the main area of medical imaging, minimally invasive therapy, image guided surgeries and catheter technologies. Soft skill development is a core challenge and objective. Close contact to clinical users, direct involvement of industry and application oriented research projects, an international exchange and regular further training are core components. The graduate school, while engineering oriented, is located and placed within the medical faculty of the Otto-von-Guericke-University in Magdeburg in order to create a close clinical relationship. The students are supervised jointly by a clinical and a technical professor. Additionally, a strong education focus is on the 21-century skills to approach complex challenges, teaching competencies like critical thinking, creativity, communication and collaboration. Furthermore, for individual and subject-specific education, an external stay of at least 6 weeks is required at a partner university with a similar research focus. For scientific literacy an early publication culture is cultivated.

Table 1: Core competencies for the Ph.D. students in the Graduate School Technology Innovations in Therapy and Imaging

Scientific literacy *(Knowledge, Action, Review)*	Journal Publications (>3)
	Conference Publications (>3)
	Subject-Specific Further Training (>300 h)
Clinical literacy *(Understanding Clinical Processes)*	OR- Observations
	Medical Co-Supervision
	Interdisciplinary Groups
Entrepreneurship/ Business Modelling *(Costs, financing, market)*	Start-up Projects
	Invention Disclosures/ Patents
	Industry driven projects
Management Skills *(communication, leadership, organization)*	Research proposals (>3)
	Master/ Bachelor Supervision
	Conference / Summer School organization

4. Discussion and Potential Clinical Impact

The aim of the graduate school is to bridge the gap between medicine and technology for products and services that have a clearly identified need. Students need to work more intimately with the medical users to gain a better understanding of their needs. This result in identifying much more useful equipment for the healthcare professionals. T²I² will also focus on the innovative and entrepreneurial aspect of healthcare and teach students to make those innovations marketable. They will act local and think global including specific needs through disruptive trends und healthcare 4.0.

New device and services should help patients and doctors, create value and market share or at least return investment and should lower the overall cost of healthcare. Bioengineers must recognize these sometimes conflicting drivers for an innovation process. In this process, the open minded mind-set of the learners and especially the teachers play a crucial role. Then innovation can significantly improve health outcomes:

Better procedures by – reduced procedure time, improved procedure outcomes, reduced procedure/ device costs and fewer the people in the procedure room or efficient use of facilities, equipment and man power.

Less hospitalization by – fast recovery, reduced re-hospitalization and a shift of patient care from clinic to home.

Improved patient satisfaction – back to daily life, homebased recovery and improved health.

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