BUILDING BRIDGES BETWEEN TECHNOLOGY AND MEDICINE: DESIGN AND EVALUATION OF THE TECHNICAL MEDICINE CURRICULUM

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ABSTRACT

Background. Technology takes an increasingly central role in healthcare. Rapid technological developments, complex problems and a labour market shortage requires healthcare professionals who can adapt successfully to these changes. Healthcare professionals using medical technology can no longer rely on monodisciplinary knowledge and skills. Therefore, a curriculum was developed to educate a new healthcare professional who can translate medical technology use into improved patient-specific procedures, the Technical Physician.
Objective. Qualitative analysis of the curriculum design, curriculum effectiveness and impact on Technical Physicians' practice in relation to quality of direct patient care.
Methodology. An educational design model was followed. Cognitive integration, self-directed learning, and technical-medical design projects were selected as main instructional principles. The impact of the curriculum was evaluated by 1) internal evaluation and accreditation reports and 2) semi-structured interviews with 30 alumni about the impact of Technical Physicians' practice on quality of direct patient care.
Results. The internal evaluation and accreditation reports showed that changes in the curriculum were required to ensure adaptive expertise development, enhance reflection and support continuing faculty development. Preliminary analysis of the interviews showed that alumni reported increased patient safety and more efficient and effective implementation of technology.
Discussion. Technical Physicians report that they are able to translate and use technology for safe, efficient and effective solutions for patient-specific problems in

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direct patient care. An important question that remains to be answered is whether our theory-inspired instructional principles result in adaptive expertise development in practice.

1 INTRODUCTION

Medical technologies are prominent in the top 10 most important innovations in medicine, according to a 2001 study by Fuchs and Sox [1]. A recent study by Aarts et al. [2] showed that physicians working in a high-tech clinical environment anticipated a further increase of technology use in healthcare. However, healthcare organizations and professionals are still often insufficiently aware of the risks associated with medical technology use [3,4]. Inappropriate use of medical technology by healthcare professionals who are unskilled but unaware of it leads to inefficient health care at best, or adverse events at worst [3,4]. The increasingly crucial role of technology in healthcare, combined with complex challenges and a labour market shortage, requires healthcare professionals who can adapt successfully to these changes [5].

1.1 Technical medical expertise

Healthcare professionals using medical technology can no longer rely on monodisciplinary knowledge and skills [6]. The challenges that healthcare professionals encounter when applying new technology or existing technology in a novel way are fundamentally different from the traditional diagnostic problems they were trained to tackle [7]. These problems where technology is used to innovate healthcare can be characterised as design problems [8]. Solving design problem requires conceptual knowledge, i.e. understanding the underlying principles used, knowing the functional requirements and knowing *why*. Also, for successful technology use with a specific patient, healthcare professionals need to be able to assess the consequences of the interaction between technology and the human body. These patient-specific, technological solutions should therefore be provided by professionals specifically trained to do so. A new healthcare professional is needed with specific technical-medical expertise to translate medical technology use into improved patient-specific procedures. These developments have led to the start of a new healthcare profession, the Technical Physician. As De Haan et al. [9] stated, it was assumed that the introduction of Technical Physicians in healthcare would increase the overall effectiveness and efficiency of direct patient care when using technology in innovative ways.

This concept paper reports on the qualitative findings regarding a) the design of a curriculum for Technical Physicians (TPs), b) curriculum effectiveness and c) perceived impact of the curriculum on TPs’ practice in relation to the quality of direct patient care.

2 METHODOLOGY

2.1 Study setting and curriculum design

The curriculum was developed in The Netherlands at the University of Twente and implemented in 2003 (see Groenier et al. [10] for a more detailed description of the curriculum). A common and generic educational design model was followed [11]. Author HM was responsible for the design of the curriculum. A needs assessment was performed consisting of a literature review and interviews. Adaptive expertise theory [12] and research-based design [13] form the foundation of the professional profile. Three instructional principles were derived from the literature: cognitive integration to stimulate conceptual understanding and knowing *why* (cf. Lisk et al. [14]), self-directed learning to support students in developing their competencies (cf. Birney et al.[15]) and technical-medical design projects to practice solving complex, authentic technical-medical problems (cf. Carbonell et al. [16]). The content and core competencies of the curriculum were derived from the interviews with subject matter experts from various disciplines (e.g., physics, electrotechnical engineering, pathology, internal medicine, psychology). The curriculum spans six years: three undergraduate years and three graduate years, see Figure 1.

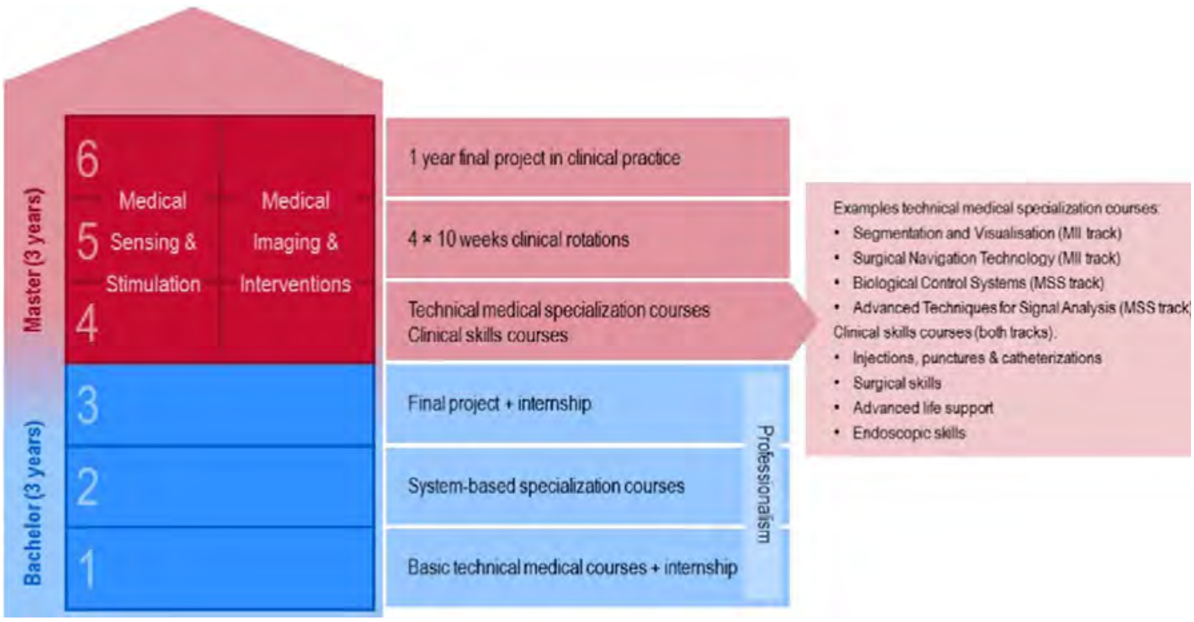

Fig. 1. Structure of the six year Technical Medicine curriculum (from Groenier et al., 2017)

2.2 Curriculum evaluation

Curriculum effectiveness was evaluated by examining internal evaluations and accreditation reports of the first years after the start of the curriculum in 2003. The perceived impact of the curriculum on TPs' practice in relation to quality of direct patient care was evaluated with semi-structured interviews with alumni of the Technical Medicine educational program.

2.2.1 Data collection interviews

Semi-structured, in-depth interviews were conducted in 2017-2018 with 30 TPs to explore the role and impact of TPs in healthcare. Practicing TPs were contacted through the Technical Medicine program of the University of Twente and the Dutch Association for Technical Medicine (NVvTG). The interview questions consisted of pre-structured and open-ended questions. They were divided into three sub-categories: daily work, impact indicators and additional comments. Impact indicators of TPs' practice on quality of direct patient care were: efficiency and effectiveness, safety, innovation and task shifting. Efficiency was defined as the degree to which actions of the Technical Physician resulted in reduced use of resources, e.g., equipment or staff, time to perform a medical intervention or time spent in the hospital, e.g., fewer visits to the hospital per patient. Effectiveness was defined as the degree to which actions of the Technical Physician resulted in more accurate, targeted or comfortable patient care, e.g., regarding diagnosis or treatment. Innovation was broadly defined as all actions of a Technical Physician that resulted in a new idea for improving patient care. Safety was also broadly defined as all actions of a Technical Physician that affected patient safety. All questions were constructed in consultation with a senior Health Sciences researcher. Six research assistants conducted the interviews, in person or by video call and all interviews were audio-recorded.

2.3 Data analysis

All available internal evaluations and accreditation reports of the early years of the curriculum were reviewed and summarized by HM. Recurring themes were extracted from the reports.

Each interview was reviewed by a different pair of research assistants. The first research assistant created a list of keywords mentioned by the interviewee for each impact indicator. The second research assistant reviewed the work of the first and revised the keywords if necessary. Next, the keywords were categorized into broader themes by three of the research assistants for each impact indicator across all interviewees. In case of disagreements between the research assistants, the differences were discussed until consensus was reached. The analysis resulted in a set of keywords for each category for each of the impact indicators.

3 RESULTS

3.1 Internal evaluations and accreditation reports

The internal evaluation and accreditation reports showed that changes in the curriculum were required to ensure adaptive expertise development, enhance reflection and support continuing faculty development (see Groenier et al. [10] and Miedema [17] for a more elaborate discussion). First, adaptive expertise development needed to be supported more for clinical skill acquisition, such as surgical skills. Instead of focusing on skill automation, innovating the medical intervention in which these skills are needed should be encouraged. Second, students needed more practice in critical reflection through experience-based learning, such as reflecting on professional development during internships. Finally, faculty needed continuous support in translating their knowledge and skills to the technical-medicine domain and integrating core concepts from different domains into the curriculum.

3.2 Interviews

3.2.1 Characteristics of Technical Physicians

There are currently over 450 alumni of which 63% worked in a hospital in 2018. Thirty TPs (22 male) agreed to participate in the interview study (average number of years since graduation = 4.3 years; standard deviation = 2.0; range = 0 – 9 years). Most TPs worked as a PhD student (n = 9) or in the position of Technical Physician (n = 8).

3.2.2 Effectiveness and efficiency

TPs mentioned an increase in effectiveness and efficiency for several aspects of healthcare as a result of their practice. They related an increase of effectiveness to more effective clinical processes involving the use of medical technology, an increase in quality of care and more patient-specific interventions. An increase in efficiency was attributed to being able to combine technical and medical knowledge in clinical practice, shorter duration of interventions and increased accuracy of interventions. Not all TPs noticed an increase in effectiveness or efficiency. This was mostly due to their work being part of research rather than care and because they felt it was hard to quantify effectiveness or efficiency.

3.2.3 Safety

The majority of TPs reported an increase in safety of the clinical interventions they were responsible for. They related this increase in safety to their mastery of technical knowledge, the application of safety margins and outcomes, and risk management during the interventions. Some TPs stated that they were not certain if safety had increased as a result of their practice. Also, some mentioned that the safety precautions they put in place could also be safeguarded by other healthcare professionals.

3.2.4 Innovation

All TPs stated that they contributed to innovation in healthcare. The innovations consisted of, among others, the development of new tools for diagnosis and therapy, finding new applications for existing technology and establishing standards and protocols for safe and effective use of technology in healthcare.

3.2.5 Task shifting

TPs also commented on the possibilities to shift their tasks to other healthcare professionals, in other words: can someone else do their job? Most agreed that it was possible to shift (some of) their tasks to others, but only at a cost. They mentioned that task shifting would result in more manpower and resources or that the quality of work would be reduced. Others stated that their tasks could not be replaced because others lack the required technical-medical competencies. Also, some TPs indicated that they felt it was hard to quantify.

4 CONCLUSIONS AND FUTURE DIRECTIONS

The Technical Medicine curriculum aims to prepare their graduates for building bridges between engineering and medicine, that is to be able to “translate medical technology into effective, safe and innovative patient care.” (Groenier et al. [10], p. 629). From our preliminary analysis of the interviews with practicing TPs, we conclude that, from their perspective, they contribute to more efficient and effective clinical processes, to increased patient safety and to innovating medical interventions. However, there was also a number of TPs who did not perceive a clear impact of their practice on improving the quality of healthcare. One of the reasons for not observing an impact was that indicators such as effectiveness and safety are hard to quantify. Also, the majority of TPs work on research projects in hospitals and those TPs state that they see a potential for impact of their work in the future instead of already having an impact on current clinical practice. We agree with De Haan et al. (2019) who state that barriers of the social setting, in this case hospitals, negatively influence the impact of TPs practice. Our results should therefore be viewed in light of these barriers that TPs might experience in clinical practice.

From our analysis of the evaluation and accreditation reports we learned that supporting the integration of and translating between the engineering and medical domain is not only relevant for educating TPs, but also for professional development of our faculty who have diverse disciplinary perspectives. This implies that educational program management needs to actively provide tools and support for faculty to translate between domains when designing education for Technical Medicine students.

4.1 Future directions

To better equip future TPs for their clinical practice, we need to understand how the barriers and facilitators mentioned in the De Haan et al. [9] study are related to our TPs perception of their impact on quality of direct patient care. Do TPs who experience few social barriers feel that they can contribute more to quality of direct patient care? How do TPs in different social settings cope with the challenges and barriers of an emerging profession? Also, in the current study we only examined the TPs’ perspective. In a follow-up analysis, we will explore medical specialists’ perception of the impact of TPs’ practice on the quality of direct patient care in their organisation. Furthermore, an important educational question that remains to be answered is whether our theory-inspired instructional principles result in adaptive expertise development in practice.

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REFERENCES

[1] Fuchs, V.R. and Sox Jr. H.C. (2001), Physicians' views of the relative importance of thirty medical innovations, *Health Affairs*, Vol. 20, No. 5, pp. 30-42.

[2] Aarts, S., Cornelis, F., Zevenboom, Y., Brokken, P., van de Griend, N., Spoorenberg, M., ten Bokum, W. and Wouters, E. (2017), The opinions of radiographers, nuclear medicine technologists and radiation therapists regarding technology in health care: a qualitative study. *Journal of Medical Radiation Sciences*, Vol. 64, No. 1, pp. 3-9.

[3] World Health Organization, (2010), Medical Devices: Managing the Mismatch: An Outcome of the Priority Medical Devices Project, World Health Organization, Geneva.

[4] Health Care Inspectorate, (2008), Risico's van medische technologie onderschat [risks of medical technology underestimated], The Hague, The Netherlands. Downloaded from: http://www.igz.nl/actueel/nieuws/medischetechnologiebiedtgrotekansenmaarrisicosonderschat.aspx

[5] Mylopoulos, M., Kulasegaram, K., and Woods, N. N. (2018), Developing the experts we need: Fostering adaptive expertise through education, *Journal of Evaluation in Clinical Practice*, Vol. 24, No. 3, pp. 674-677.

[6] Boon, M., van Baalen, S., and Groenier, M. (2019), Interdisciplinary expertise in medical practice: Challenges of using and producing knowledge in complex problem-solving, *Medical Teacher*, Vol. 41, No. 6, pp. 668-677.

[7] Goel, V., and Pirolli, P. (1992), The structure of design problem spaces, *Cognitive Science*, Vol 16, No. 3, pp. 395-429.

[8] Dijkstra, S, and van Merriënboer, J.J., (1997), Plans, procedures, and theories to solve instructional design problems, In: Dijkstra, S., Seel, N., Schott, F., and Tennyson, R.D., editors, *Instructional design international perspective: Solving instructional design problems*, Vol. 2, Lawrence Erlbaum Associates, Mahwah, pp. 23–43

[9] de Haan, M., van Eijk-Hustings, Y., Bessems-Beks, M., Dirksen, C., and Vrijhoef, H.J. (2019), Facilitators and barriers to implementing task shifting: Expanding the scope of practice of clinical technologists in the Netherlands, *Health Policy*, Vol. 123, No. 11, pp. 1076-1082.

[10] Groenier, M., Pieters, J.M., and Miedema, H.A.T. (2017), Technical medicine: designing medical technological solutions for improved health care, *Medical Science Educator*, Vol. 27, No. 4, pp. 621-631.

[11] Gustafson, K. (2002), Instructional design tools: A critique and projections for the future, *Educational Technology Research and Development*, Vol. 50, No. 4, pp. 59-66.

[12] Hatano, G., and Inagaki, K. (1986), Two courses of expertise, In: Stevenson, H., Azuma, H., and Hakuta, K., editors, Child development and education in Japan, WH Freeman, New York, pp. 27–36.

[13] Edelson, D.C. (2002), Design research: what we learn when we engage in design, *The journal of the learning sciences*, Vol.11, No. 1, pp. 105–121.

[14] Lisk, K., Agur, A.M., and Woods, N.N. (2016), Exploring cognitive integration of basic science and its effect on diagnostic reasoning in novices, *Perspectives on Medical Education*, Vol. *5*, No. 3, pp. 147-153.

[15] Birney, D.P., Beckmann, J.F., and Wood, R.E. (2012), Precursors to the development of flexible expertise: Metacognitive self-evaluations as antecedences and consequences in adult learning, *Learning and Individual Differences*, Vol. 22, No. 5, pp. 563-574.

[16] Carbonell, K.B., Stalmeijer, R.E., Könings, K.D., Segers, M., and van Merriënboer, J.J. (2014), How experts deal with novel situations: A review of adaptive expertise, *Educational Research Review*, Vol. 12, pp. 14-29.

[17] Miedema, H.A.T. (2015), Arts en ingenieur: And ever the twain shall meet: Analyse en ontwerp van de opleiding Technische Geneeskunde (Doctoral dissertation). Retrieved from http://doc.utwente.nl/96952/