The clinician-scientist pipeline: undergraduate and postgraduate supply, leaks and perspectives
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Part I: Undergraduate research training

Chapter 1

General introduction and outline of the thesis

1. Introduction

The high quality of medical care provided today is built upon years of effort by clinicians, clinician-scientists, PhD candidates, and other healthcare professionals investigating healthcare including the causes of, and potential treatments for, disease. Tireless efforts of healthcare professionals have made many once life-threatening conditions and diseases history. Even so in the future, development of medical knowledge and, hence, improvement of patient care will highly rely on medical professionals who are involved in medical research. In the past few decades, concerns are being raised about the academic workforce in medicine, with academic career pathways being referred to as 'the leaky pipeline'.[1-3] This thesis focuses on the leaky pipeline and studies undergraduate and postgraduate supply, leaks and perspectives.

The purpose of this introductory chapter is to illustrate how the recent situation in medical education and academic medicine have inspired the rresearch projects described in this thesis. Therefore, this chapter starts with a solid description and overview of medical undergraduate and postgraduate research education, as well as pathways based on medical education literature. Next, challenges, knowledge gaps and barriers in academic medicine are identified. At the end of this chapter, the research questions of this thesis are formulated and the research projects that together form this thesis are outlined.

1.1 The value of clinician-scientists in the medical field

The Royal College of Physicians and Surgeons of Canada developed a medical education framework in the 1990s aiming to improve patient care: the Canadian Medical Education Directives for Specialists (*CanMEDS*).[4] Revised in 2005 and 2015, the CanMEDS is currently the most widely adopted and applied medical education framework worldwide, from medical school to continuing professional development. This competency framework identifies and describes required abilities for medical doctors to successfully meet the healthcare needs of those they serve. These abilities are grouped under seven professional roles that a medical doctor must embody. One of these roles is the role of 'scholar'. Scholarly ability is defined by four key competencies. Scholars are able to:

1. Engage in the continuous enhancement of their professional activities through ongoing learning (i.e. lifelong learner);
2. Teach students, residents, the public, and other healthcare professionals (i.e. medical teacher);
3. Integrate best available evidence into practice (i.e. evidence-based medicine);
4. Contribute to the creation and dissemination of knowledge and practices applicable to health (i.e. conducting research).

In short, the role of a scholar entails learning (i.e. being a lifelong learner as well as teaching others) and research (i.e. using and doing research) competencies.[4] This thesis will mainly focus on the latter.

According to the CanMEDS framework, all clinicians should be able to practice evidence-based medicine and conduct research. However, *being able* to is not inherently linked to *actually* doing something. Nevertheless, it is a common belief that every clinician should not only be limited to be able to practice evidence-based medicine only, but should actually implement evidence-based medicine in (part of) their daily clinical practice.[5,6] The practice of evidence-based medicine means integrating individual clinical expertise and patient values with the best available scientific evidence (*Figure 1*).[5,7] It is a process of life-long, self-directed learning in which evidence-based medicine creates the need for clinically relevant and up-to-date information about diagnosis, prognosis, therapy, and other clinical and healthcare issues.[7] Therefore, all clinicians are expected to be skilled and knowledgeable in the utilization of research and scientific methods of enquiry as applied to medical practice. Indeed, clinician literacy in research improves critical thinking in guiding clinical judgement – necessary ingredients for effective implementation of evidence-based medicine in daily practice.[8]

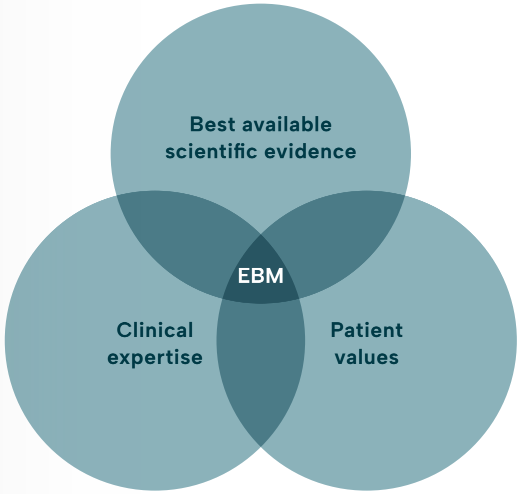

Figure 1. *Evidence-based medicine (EBM) in pursuit of the best possible health care outcomes*

To incorporate this information as best evidence in everyday practice, the following steps are required; (1) clinical care is translated into questions; (2) the best available evidence is tracked down; (3) this evidence is critically appraised for its validity (closeness to truth), impact (size of the effect), and usefulness (clinical applicability); (4) the appraisal is integrated with clinical expertise and applied within clinical practice; (5) the clinical practice is monitored and evaluated.[7,9] This should be an ongoing process in clinical practice and therefore it may also be illustrated as a circle (*Figure 2*).

Figure 2. *The cycle of practicing evidence-based medicine*

Furthermore, according to the CanMEDS framework, every clinician should be able to contribute to the creation, dissemination, application and translation of knowledge within healthcare. Thus, in addition to utilizing research, clinicians should be able to conduct research. However, as medical research is the driving force behind the practice of evidence-based medicine, it is important that a subset of clinicians actually conducts research. Clinicians who also devote a substantial amount of their time to conducting research next to their clinical care, i.e. clinician-scientist, are indispensable in medical research and, thus, the development of evidence-based medicine. Clinician-scientists, in current literature also referred to as clinical researchers, clinical investigators, physician investigators or physician-scientists, connect medical research with clinical care, and vice versa, as illustrated in *Figure 3*. This is a unique and valuable position in the translation of medical research, also referred to as translational research. The process of translational research comprises translating information or knowledge that

is created in one area to another and consists of two main translational stages.[10] One is the process of applying discoveries generated by basic research or preclinical studies to the development of clinical trials in healthy volunteers or patients. The second stage of translation involves clinical care and is applicable in two ways. In this stage, research findings find their way to clinical care, but also vice versa, with relevant clinical questions being converted to research questions.

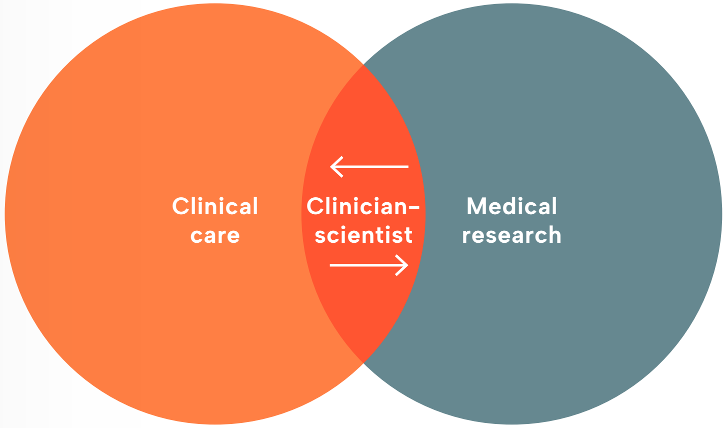

Figure 3. *Clinician-scientists linking clinical care with medical research and vice versa*

The value of clinician-scientists for translational research in medicine is more relevant than ever. Medical research has developed into a multidisciplinary field, as advances in the medical field are closely linked with scientific developments in other disciplines (e.g. biochemistry, pharmacology, health technology, etc.). These disciplines have one common goal: improving healthcare. This requires that scientific knowledge derived from these disciplines finds its way to clinical care, and vice versa. This need is enhanced by the rapid pace of developments in the multidisciplinary medical field. Clinician-scientists have the best position within both the research and clinical domain to connect clinical care and research.

To summarize, all medical doctors should utilize and be able to conduct research in order to provide evidence-based medicine. Additionally, some of them need to be engaged in research as clinician-scientist in order to develop and improve evidence-based medicine. However, there is a decrease in the number of clinician-scientists in many countries. This decrease has not diminished since over four decades when it first received attention.[11] Clinician-scientists are being referred to as 'endangered species' and clinician-scientist career pathways are described as 'the leaky pipeline'.[1-3] As a result, there is an urgent need to attract and support (future) medical graduates to become clinician-scientists and, subsequently, strengthen the connection that is needed between clinical care and medical research.

1.2 The clinician-scientist pipeline

The importance of evidence-based medicine together with concerns about the decreasing number of clinician-scientists emphasizes the need for promoting and encouraging research in medical education. Undergraduate medical education is the first step of each medical doctor's career and the only stepping stone in medicine that all medical doctors worldwide have in common. Hence, medical schools have a pivotal position in training scholarly doctors able to provide evidence-based medicine and conduct research. Consequently, undergraduate medical education is frequently recommended as part of the solution for the clinician-scientist shortage as it creates the opportunity for early cultivation, identification and recruitment of potential clinician-scientists.[8,12-15] In short, undergraduate research education is important in serving this dual purpose to (1) train all future medical doctors as scholars who practice evidence-based medicine and are able to conduct research, and (2) encourage a subset of future medical doctors to pursue a clinician-scientist career.

In order to train all medical doctors to reach the required level of a scholar and at the same time counteract the decline of the clinician-scientist workforce, medical curricula incorporate research courses. To this end, all medical students are theoretically educated in research e.g. research ethics, methodology and statistics, and, thus, are able to utilize research. In line with many others, I would like to argue that, as theory is different from practice, theoretical research courses might enable (future) medical doctors to utilize research, but are hardly sufficient to enable them to actually conduct research. This is captured in the famous quote attributed to Albert Einstein; "In theory, theory and practice are the same. In practice, they are not.". As example, knowing how to drive a car (theory) does not per definition equal being able to drive a car (practice). From an educational perspective, this is substituted by Healey and colleagues, who have developed a framework to illustrate the research-teaching nexus and explain four ways in which students can experience research in the curriculum.[16] This framework identifies students as audience or as active participants, while the emphasis can be on the research process or on the research content. Involving students as participants combined with an emphasis on the research content (i.e. research led learning: learning that occurs through engagement with research that goes beyond simply learning about research), is considered as a form of active learning.[17] Active learning, or 'learning by doing', is seen as the most optimal way to engage students in research training as it promotes deep rather than surface learning.[18] In this respect, research practising can help students to understand and utilize research, while at the same time they are trained as scholars being able to conduct research. In addition, it provides an opportunity to shed light on a possible research-oriented career. This highlights the potential of undergraduate practical hands-on research programmes in serving the dual purpose, as mentioned before, to (1) train all future medical doctors as scholars who practice evidence-based medicine and are able to conduct research, and (2) encourage a subset of future medical doctors to pursue a clinician-scientist career.

Although there is currently no consistent way in which medical students are engaged in research, globally, the perspectives medical students have on research in undergraduate medical education share many common themes. Most medical students acknowledge the necessity and importance of research training as part of their medical education and for their future career as reflected by many students reporting positive attitudes and interest in research endeavours.[8,13,19-21] In addition, there is a high-level of agreement in the literature on students' perceptions of research that, despite the importance of research, it is poorly represented in their medical curricula. An explanation for this perceived underrepresentation of research in medical curricula could be that research activities are time-consuming, require good organization and resourcing, and depend upon adequate supervision support. Additionally, curricula are often overloaded with basic and clinical subjects with little room for research instruction and learning.[22] As a consequence, research training is often placed beyond the core curriculum as an elective or extracurricular activity, and predominantly accessible to highly motivated students or students looking for an extra challenge.

Next to crowded curricula, other student and faculty related barriers for student participation in research are reported, e.g. lack of interest, self-efficacy, (protected) time, lack of or unaware of opportunities, research infrastructure, funding, or supervision.[20,21,23-26] As a result of these barriers, the number of students indicating research interest is larger than the number of students who are actually involved in research.[24] A scoping review by Murray and colleagues on research training during medical school described approximately half of undergraduate research training programmes being mandatory.[15] Barriers to participate in research combined with esearch, combined with research training not being a mandatory part of the formal curriculum, result in a subset of students graduating as doctor without any research experience, with reported rates between 30% to 70%.[21,24,27]

The question whether undergraduate medical research programmes should be made a mandatory part of undergraduate medical education has been discussed in the literature, and is a matter of debate.[15,24] Elective or extracurricular research programmes (e.g. summer courses or scholarly concentration programmes) attract students with prior research interest, talent, motivation and/or ambition, while mandatory research training reaches all medical students. Arguments against mandatory research incorporation revolve around the importance of focusing on clinical skills education, while arguments in favour of it revolve around the ever-increasing importance of evidence-based medicine needed to be practiced by all medical doctors.[24] In addition to this favour and mentioned earlier, learning by doing is considered the most optimal way to engage students in research activities. Indeed, successful research engagement (e.g. resulting in a publication) during medical school is widely reported to predict postgraduate research involvement.[15,20,24,28] Accordingly, it is not surprising that research-intensive medical schools are more successful in enhancing research-related learning outcomes compared to medical schools that integrate research less in their curricula.[29] In this way, besides developing scholarly doctors that practice evidence-based medicine, research engagement during medical school can serve as a breeding ground for clinician-scientists and, hence, might reverse the trend in declining numbers of clinician-scientists. In conclusion, mandatory research programmes seem to be perfectly in line with the dual purpose to train every doctor as a scholar and cultivate the next generation of clinician-scientists.

Once medical students obtain the medical doctor degree (MD), diverse and flexible career pathways can be chosen. Following graduation, many medical doctors further develop their professional identity, including perceptions on what career fits their talents and ambitions. Although there is a wide variation in postgraduate medical systems worldwide,[30] the number of graduates entering a medical PhD programme, considered the common pathway in training clinician-scientists, globally increases.[31-38] It is unknown whether and, if so, to what extent the increased investment in research training during medical schools contributes to this, or whether other causes declare this increase. However, contrary to the tremendous increase in graduates entering the clinician-scientist pipeline as medical PhD candidate, the number of MD-PhDs actually working as clinician-scientists still declines.[1,3,39]

At first glance, this seems to be a contradiction. How can an increased 'supply' of (future) clinician-scientists and a decrease in the clinician-scientist workforce coexist? There might be two possible explanations for this contradiction. First, during the PhD programme, PhD candidates could drop-out. Indeed, with the increase in medical PhD candidates, concerns about prolonged completion times and programme attrition rise as well with an average of six years for completing a PhD in the medical field and attrition rates of 30-50%.[40,41] This might be because, for example, the doctoral experience is not aligned with the PhD candidate's expectations, values and ambitions (anymore). Another reason for programme attrition could be that, although the supply of (future) clinician-scientists apparently seems to be sufficient when it comes to quantity of medical doctors that enrol in a PhD programme, the 'quality' of this supply (i.e. medical PhD candidates) is not meeting the required qualities needed to fulfil a PhD trajectory. The second explanation for the contradiction is that, once the PhD is completed, MD-PhDs are 'leaking out' the clinician-scientist pipeline. This is in line with several studies showing that shortly after obtaining the PhD-degree scientific production appears to decline and MD-PhDs often become scientifically inactive.[32,40,42,43] It could be that career ambitions change during the PhD or, perhaps, that they never aspired a clinician-scientist career, but obtained a PhD as a mean to achieve other goals. In addition, barriers to stay engaged in research after a PhD could deter MD-PhDs from continuing their career in academic medicine. Previous research identified obstacles to continue research oriented careers after obtaining a PhD degree, such as rising clinical responsibilities (e.g. postgraduate training), work-life balance, lack of funding, and insufficient supervision.[44-46]

To summarize, a shortage of clinician-scientists has been attributed to a lack of supply (e.g. lack of interest in research careers) or too many obstacles to stay actively engaged in research (e.g. drop-out during or soon after PhD trajectory), at both the undergraduate and postgraduate level, also considered as leaks in the clinician-scientist pipeline. As motivation is widely reported to be related to persistence, academic success, future research involvement and other desirable outcomes, also within the context of medical education, perhaps this could also contribute to the leaky clinician-scientist pipeline. Therefore, the following section will discuss the possible role of motivation in the pathway of (future) clinician-scientists.

1.3 The role of motivation in the (leaky) pipeline

In general, motivation can be defined as a force that drives a person to engage in certain behaviour. The development of theories of motivation is a fairly recent phenomenon emerging in the 20th century. These theories tend to conceptualise motivation as a unitary entity, focusing on the amount of motivation a person has.[47] An example is the Expectancy-Value Theory (EVT), including its further developed models, which basically focuses on the quantity of motivation as a sequel of expectancies to be successful in the task and the incentive value of (fulfilment of) the task. If both – expectancies and values – are lined up well, it is expected that the quantity of motivation to initiate and accomplish a task is higher.[48]

Different from EVT and many other theories of motivation emphasizing quantity of motivation, Ryan and Deci proposed Self-Determination Theory (SDT), nowadays one of the leading theories in human motivation.[49] According to this theory, it is not only quantity of motivation that is important, but also, or perhaps even more, quality of motivation that determines behaviour. Basically, the theory drives the idea that motivation is an interplay between the extrinsic forces acting on persons and the intrinsic motive and needs of human beings. SDT divides motivation into six categories of regulatory styles that sit upon a continuum from amotivation to intrinsic motivation. Based on different cut-offs of these regulatory styles, different divisions in quality of motivation can be made. First, motivation, next to amotivation, can be divided in two types of motivation; intrinsic and extrinsic motivation. Intrinsic motivation (IM), consisting of intrinsic regulation only, is defined as showing behaviour or being involved in a specific activity out of genuine interest or pure enjoyment (e.g. enjoy doing research). In contrast, extrinsic motivation (EM) represents behaviour or involvement in a specific activity for obtaining a certain reward or avoiding a certain loss or punishment, gaining social approval or achieving a valued outcome. Extrinsic motivation can be further subdivided into four types of regulations, depending on the level of self-determination:

- External regulation (i.e. behaviour is directly controlled by external forces like rewards or punishment), for example participating in research because it is mandatory within the curriculum and without participation a (desired) medical degree is not rewarded.
- Introjected regulation (i.e. external controls are taken in, but not fully accepted, there is a focus on approval from self and others), for example participating in research because of the belief that programme directors value this activity.
- Identified regulation (i.e. identification with and conscious valuing of an activity), for example participating in research for improving skills.
- Integrated regulation (i.e. identifications are integrated with a person's other values and beliefs), for example participating in research because this is consistent with own values (e.g. curiosity, ambition, success).

As SDT has been further developed over years, a second widely used distinction in motivation has been made in the literature: autonomous and controlled motivation.[50] *Autonomous motivation* (AM) consists of intrinsic, integrated and identified regulation (the latter two being the most internalized forms of extrinsic motivation). Thus, autonomous motivation is not only fuelled by intrinsic motivation (i.e. genuine interest or enjoyment in the activity or goal), but also driven by the value given to an activity or goal. *Controlled motivation* (CM) includes the least internalized forms of extrinsic motivation and consists of introjected and external regulation.

Controlled motivation is purely driven by external forces and controls. In short, controlled motivation is controlled by external factors, while autonomous motivation originates from within the individual itself.

SDT posits that higher levels of self-determination leads to better quality of motivation. Thus, intrinsic motivation is of better quality compared to extrinsic motivation, and, in the same way, autonomous motivation is of better quality then controlled motivation. Different quantities of motivational qualities can coexist within an individual and can change over time. An overview of the motivation continuum according to SDT is displayed in *Figure 4*.

Amotivation	Controlled Motivation		Autonomous Motivation		
	Extrinsic motivation				Intrinsic Motivation
Non-Regulation	**External Regulation**	**Introjected Regulation**	**Identified Regulation**	**Integrated Regulation**	**Intrinsic Regulation**
→ Lack of apathy → Lack of intention → Lack of value	→ External rewards (e.g. career opportunities → Avoiding external punishments	→ Internal rewards (e.g. pride, self-esteem) → Avoiding internal punishments (e.g. guilt, disapproval) → Focus on approval from self and others	→ Personal importance → Conscious valuing of activity → Self-endorsement of goals	→ Congruence → Values fully assimilated into self → Synthesis and consistency of identification	→ Pure interest → Enjoyment → Curiosity → Inherent satisfaction

Low quality → *High quality*

Figure 4. *The motivation continuum according to Self-Determination Theory*

According to SDT, three basic psychological needs must be satisfied in order to enhance intrinsic motivation, the highest quality of motivation. First, the need for autonomy, which is defined as the need to self-regulate your actions and feel in control of your own behaviour and goals. Feelings of autonomy are enhanced when students are given choice and are able to govern their own behaviour, rather than feeling controlled or threatened, or have to operate according to deadlines. Second, the need for competence, which is the need to feel capable in effectively dealing with your important life context and trust in having the skills needed for success to ensure that desired goals are achieved.

This can be satisfied when the demands of a task are optimally matched to a student's skills, or positive feedback is received. If tasks are too challenging or a student receives negative feedback, feelings of competence decrease. Third, the need for relatedness, which includes the need to feel a sense of belonging and socially connected to significant others. Feelings of relatedness are fostered when students feel respected and cared for by others, e.g. teacher or peers, and are part of an inclusive environment. Alternatively, these feelings can be undermined by competition, closed groups, and criticism from others. Personal well-being is a direct function of the satisfaction of these three basic psychological needs.[50,51]

Regardless of the education level, motivation has become a central concept in the understanding of academic persistence and achievement. Following the SDT, both quantity and quality of motivation could be particularly important in stimulating (future) medical doctors to pursue a clinician-scientist career. Although many students express interest towards research, the quality of motivation behind this interest varies. For example, some medical students or doctors view research as mean for personal development (according to SDT considered as high quality motivation), whilst others are interested in research to improve chances for a competitive residency spot (according to SDT considered as low quality motivation).[20,21,24,52–54] Previous studies showed the importance of high quality motivation in well-being, academic success, persistence, and many other favourable outcomes.[37,51,55,56] More specific, on the medical undergraduate level, it is known that intrinsic motivation for research fosters extracurricular research participation in bachelor students.[57] In turn, it is shown that undergraduate research participation results in research engagement after graduation.[24,26] However, there is a knowledge gap regarding the effect of mandatory research, in which all medical students are involved, on the quality and quantity of motivation for research and postgraduate ambitions and involvement. This is important as motivation for participating in a PhD are already formed during medical school.[53]

On the postgraduate level, motivation has often not been conceptualized as a multidimensional construct, neglecting the well-known importance of quality of motivation. In addition, previous studies on motivation for research amongst PhD candidates focusses on PhD candidates in other domains. A PhD in the medical field is more common than in any other domain.[41] Medical PhD candidates are medical doctors early in their clinical career, who commonly combine clinical tasks with their PhD trajectory, are mainly supervised by PhD-holding clinicians, and often (partly) return to clinical care after their PhD trajectory.[58] Thus, the medical doctoral context is different from many other domains and, therefore, different motivations might play a role. Despite many stating that medical PhD candidates are mainly driven by external regulations

as CV building, no previous study have touched upon this in the medical domain. To gain better insight in attraction, training and retention of clinician-scientists, this thesis partly focuses on quantity and quality of motivation for research during undergraduate mandatory research and postgraduate PhD programmes.

1.4 Research context

All Dutch medical schools developed and implemented their educational programme in line with the Dutch National Blueprint for Medical Education, based on the CanMEDS competency framework.[59] Hence, undergraduate medical education curricula are more or less comparable regarding learning goals and structure of their educational programme, with six years of undergraduate education, divided in a three-year bachelor's programme, and a subsequent three-year master's programme. This is based on the three-cycle system within European higher education consisting of three levels; undergraduate (i.e. bachelor's programme), graduate (i.e. master's programme) and doctoral (i.e. PhD programme) studies. In the Netherlands, there are two major research training programmes within undergraduate and postgraduate medical education. The first one regards a research training during the master's phase in medical school. The second major training programme is a medical PhD programme, which is (mostly) postgraduate and on a voluntary basis.

As in the Netherlands the educational programmes are aligned with the Dutch National Blueprint for Medical Education, similarities between institutes exist. For instance, within the bachelor's phase research theory and practice are introduced to develop research knowledge, skills, and attitude. Students are theoretically educated in research ethics, methodology and statistics. Although similarities in learning goals and procedures exist, medical schools are free to design their own curriculum. Studies in this thesis focussing on the undergraduate phase of the clinician-scientist pipeline are conducted among medical students at Leiden University Medical Center (LUMC), one of the eight medical schools in the Netherlands. In LUMC, students make their first steps in research practice during a first-year course, where students are provided with the opportunity to individually conduct research, and a critically appraised topic (CAT) project in the third year of the bachelor phase challenging students on utilization and critically appreciation of existing literature.

The master's phase includes an authentic fulltime mandatory research project of at least four months, next to clinical clerkships, and is the main context of the studies conducted on undergraduate research training. Different from many other countries, this research project is mandatory and, consequently, reaches all future medical doctors.

Students have much autonomy as they arrange their internship at a health institute and department of preference, choose a research domain, are able to extent their research with five or ten weeks and are free to choose the timing to conduct their research before or after clerkships. The programme starts with a two week course on research theory and practice in terms of designing, conducting, analysing, interpreting and reporting research. During the research project, students fulfil the role of primary investigator and are guided by one or few research supervisors, mostly (clinician-)scientists or PhD candidates. This research programme has a dual purpose and aims to (1) train all future medical doctors as scholars, who practice evidence-based medicine and are able to conduct research, and (2) cultivate the next generation of clinician-scientists.

After graduation, it is common in the Netherlands to gain working experience before applying for a specialty training position, mostly in a clinical setting as doctor not in training. Once the choice has been made to pursue a PhD degree, there are three pathways towards a PhD. First and foremost, medical doctors apply for a position as PhD candidate after graduation and before applying for a specialty training position. This can be before as well as after gaining clinical working experience as a doctor not in training. Second, a smaller part applies already during medical school and combines a PhD programme with the undergraduate medical education programme, also known as MD-PhD programmes. Lastly, a minority starts a PhD programme as residents already in training or as medical specialists. To summarize, a PhD trajectory can be initiated from any job position in the medical career pathway, simultaneously with other educational programmes or clinical activities, or as a fulltime paid job. Next to a medical school, all Dutch academic hospitals incorporate a graduate school as well. Medical PhD candidates have to be admitted to a graduate school until completion of their dissertation. Studies in this thesis focussing on the postgraduate academic pipeline are conducted nationwide and included all eight Graduate Schools.

The research in this thesis was conducted within the pragmatic research paradigm, meaning that different approaches of philosophy and reality were implemented using the research question as main guiding principle. Depending on what method fitted the research question best, constructivist or post-positivist stances were adopted, leading to quantitative and qualitative research designs. Within this thesis, Self-Determination Theory is used as theoretical lenses to conceptualise motivation. SDT was adopted as theory to investigate both quantity and quality of motivation during the task (i.e. conducting research), as medical student or PhD candidate. EVT was used to focus on the expectancies and values prior to a PhD, assuming that this leaded to a certain amount of motivation needed to actually initiate a PhD.

1.5 Outline of this thesis

In this thesis we explore outcomes and challenges of undergraduate (*part I*) and postgraduate (*part II*) research training, and the role of motivation in the supply, leaks and perspectives of the clinician-scientist pipeline, aiming to optimize the pipeline, and, eventually, contribute to a sustainable clinician-scientist workforce. Insight in the role of motivation for research during such research training programmes, and vice versa, the impact of research training programmes on motivation, can lead to practical implications to attract, train and retain the right person, at the right time and position within the clinician-scientist pipeline. To fulfil this aim, we conducted different studies which are described below and will be discussed in detail in the upcoming chapters.

Previous studies have shown that it is important to catch clinician-scientists young.[15,20,24,28] More specifically, motivation for research could and should be cultivated as early as possible; during medical school. Hence, when focusing on the clinician-scientist pipeline, undergraduate research training should be considered as the first step of a clinician-scientist career and possible stepping stone towards postgraduation research activities. Therefore, in **chapter 2**, we examine the scientific yield of undergraduate mandatory research training, including postgraduate research engagement. We use outcomes such as publication as a proxy for success, a well-known predictor for postgraduate research engagement. In understanding how best to foster high quality motivation for research, an essential step in the process of choosing a research-oriented career we study motivation for research during mandatory research training in **chapter 3**. We aim to unravel the effect of this undergraduate mandatory research on students' motivation for research, including students' research perspectives, psycho-cognitive needs (i.e. research self-efficacy, autonomy, relatedness) and research ambitions. Next, research skills, knowledge and attitudes as an essential part of a medical doctor are assessed to demonstrate scholarly competency. This can be done in several ways such as formative assessment (e.g. portfolios) or summative assessment (e.g. research reports). As students tend to focus on what is assessed, some scholarly learning goals are at risk to be considered as optional extra to the curriculum when not assessed. Therefore, in **chapter 4**, we will explore challenges in developing and assessing scholarly competencies, for example during mandatory research training. The role of scholar not only entails research competencies, but teaching competencies as well. Teaching is frequently judged inferior to research by academic leaders, resulting in a decline in medical teachers.[60] **Chapter 5** provides twelve tips to foster the next generation of medical teachers.

After graduation, medical doctors can enrol in a PhD programme on a voluntary basis. These programmes, also considered as the third cycle after a bachelor's and master's degree, globally aim to train clinician-scientists.[61] **Chapter 6** describes differences and similarities of medical PhD programmes in the top ten leading countries in life sciences research around the world. In **chapter 7**, we survey the quantity and quality of motivation for research, research self-efficacy, work engagement, drop-out intentions and ambitions for research among Dutch medical PhD candidates. In **chapter 8**, we investigate what factors affect motivation for research during a PhD trajectory.

An overview of all chapters including the specific research questions with corresponding research method and analyses is given in *Table 1.* A brief overview and in-depth discussion of the main research findings, practical implications for educational practice and directions for future research is discussed in **chapter 9**.

Table 1. *Studied research aim/questions with corresponding research methods and analyses*

	Chapter	Research aim or question(s)	Design	Research method	Analyses
Part I	**2**	**1.** What is the scientific output (i.e. publication rate, impact of publication, author position) of undergraduate mandatory esearch projects? **2.** Which student and project related factors are associated with this scientific output? **3.** Is this scientific output associated with postgraduate research activity?	Single centre retrospective cohort study (quantitative)	Bibliometric search strategies combined with cross-sectional alumni surveys	Descriptive statistics, T-tests, multivariate logistic and multivariate linear regression analyses
	3	**1.** How does motivation for research, its determinants (i.e. research perceptions, research self-efficacy, autonomy, relatedness) and research career ambitions develop during undergraduate mandatory research? **2.** What is the effect of development of motivational deteraminants on development of motivation for research during mandatory research? **3.** What is the effect of (development of) motivation for research on (development of) research career ambitions during mandatory research?	Single centre prospective study (quantitative	Student surveysa	Descriptive statistics, T-tests, multivariate logistic and multivariate linear regression analyses
	4	Challenges in developing and assessing scholarly competenciesa	Monograph	Perspective based on literature and own experiences	n.a.
	5	Twelve tips for fostering the next generation of medical teachers	Twelve tips article	Practical tips based on theory, previous research, and own experiences	n.a.
Part II	**6**	What are differences of and similarities in medical PhD programmes around the world?	Survey study (qualitative)	Stakeholder surveys combined with literature review	Content analyses
	7	**1.** What is the effect of expectancies and values for success on motivation for research in medical PhD candidates? **2.** What is the effect of motivation for research on (perceived) doctoral outcomes (i.e. work engagement, delay, expected delay, drop-out intentions, research career ambitions) in medical PhD candidates? **3.** Does motivation differ in PhD candidates who are in different positions in their career, in different doctoral phases, and in less versus highly competitive specialties? **4.** What motivational profiles can be identified among medical PhD candidates and how do these profiles relate to motivational determinants and (perceived) doctoral outcomes?	National multicentre survey study (quantitative)	PhD candidate surveys	Descriptive statistics, T-tests, multivariate logistic regression analyses
	8	What factors affect motivation for research during a medical PhD programme?	National multicentre interview study (qualitative)	Interviews with timeline mapping	Thematic analysis

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