Future physician-scientists: let's catch them young! unravelling the role of motivation for research

Ommering, B.W.C.

Author: Ommering, B.W.C.
Title: Future physician-scientists: let's catch them young! unravelling the role of motivation for research
Issue Date: 2021-09-08

1

General introduction

Introduction

Research – small word, great impact. According to Cohen, Manion and Morrison (1963, p. 4) research "must be regarded as the most successful approach to the discovery of truth".[1] Truth could be a debated word, as some scientists would say that truth is non-existent. However, one thing we can all agree on is the importance of research for developing knowledge. Within the medical field, research is imperative to make advancements. Physicians combining clinical work and conducting research (i.e. physician-scientists) are essential, but scarce at the same time. Over the last decades, medical education has been suggested to be part of the solution to rescue academic medicine. This thesis focuses on first steps within medical education to stimulate undergraduate medical students to pursue a physician-scientist career, by helping to unravel the role of motivation for research and extracurricular research programmes. With this thesis, I hope to provide insight into the important role early phases of medical education could play in developing the next generation of research oriented physicians – future physician-scientists: let's catch them young!

Problem description

The royal college of physicians and surgeons of Canada developed a framework to enhance physician training in 1990: the Canadian Medical Education Directives for Specialists (CanMEDS).[2] According to the CanMEDS, the physician has seven professional roles, one of which is the role of 'scholar'. Being a scholar is defined by four key competencies:

1. Continuous enhancement of professional activities through ongoing learning (i.e. lifelong learning);
2. Teaching of students, residents, and other healthcare professionals (i.e. teacher);
3. Integration of best available evidence in daily practice (i.e. evidence-informed decision making);
4. Contributing to creation, dissemination, application, and translation of knowledge within healthcare (i.e. conducting research).

A strong research focus can be found within the third and fourth key competency a scholar should master. All physicians should be able to practice evidence-informed decision making and conduct research. However, 'being able to' does not per definition equal 'doing'. In line with many others, I argue that *all* physicians should be able to *use research* in daily clinical work, thereby practicing evidence-informed decision making. Physicians should understand research, be able to critically appraise research, and consequently apply it within their daily practice. Therefore, they should be aware of the newest developments in their field of medicine and recognize uncertainty in practice. By identifying evidence relevant to their particular clinical questions and problems, they provide patients with grounded diagnosis. Moreover, by using research, physicians also contribute to the process of lifelong learning.[2-4]

When it comes to actually conducting research, the distinction between being able to and actually doing something becomes more apparent. According to the CanMEDS, every physician should be able to contribute to the creation, dissemination, application, and translation of knowledge within healthcare, but not every physician has the opportunity or motivation to actually conduct research in real life. However, *some* physicians *conducting research* are imperative to make advancements within the medical field.[4] So called physician-scientists have clinical degrees, provide daily clinical care, but also devote a substantial amount of their time to conducting research (in current literature also referred to as clinician-scientists or clinical researchers).[5]

By being involved in both clinical and research activities, physician-scientists have the unique ability to bridge the gap between medical research and clinical practice. Over the last decades, concerns have been raised regarding this gap: the two fields have become too disengaged and labelled as 'islands', which has serious consequences for the future of academic medicine.[6] The gap between (bio)medical research and clinical application has even been named 'the Valley of Death' – a result from the growing perception that resources are invested in medical research, without resulting in clinical application (e.g. new treatments, diagnostics and prevention for patients).[7,8] This is underpinned by the estimation that 85% of all research funding is wasted.[9] This problem is relatively recent and started around 1970, when biomedical research arose as a distinct discipline, resulting in a separation of clinical and basic research. Physician-scientists became a minority group. However, we have come to realise that physician-scientists do have the best starting point to connect practice and research. By being involved in daily clinical practice, physician-scientists encounter real life clinical problems and questions, which can then be easily translated into proper research designs. On the other hand, the physician-scientist has the opportunity to translate research outcomes into clinical practice and patient care, for instance by developing clinical guidelines. This process of 'bench to bedside' has been advocated by many and goes hand in hand with the appearance of the term 'translational research' – i.e. "the process of translating discoveries in the laboratory into clinical interventions for the diagnosis, treatment, prognosis, or prevention of disease with a direct benefit of human health".[8] In 1993, this term appeared in PubMed for the first time, multiplying ever since.[7] This reflects the growing consensus that translational research and physician-scientists are of crucial importance within medicine, as physician-scientists are fluent in two languages: basic sciences and clinical medicine.[8]

A pioneer in labelling physician-scientists as an endangered species in 1979 was James Wyngaarden, who later became the director of the National Institute of Health (NIH, United States). He elaborated on NIH's research grants and the decreasing number of applicants with an MD or MD/PhD degree, while the corresponding number of PhD applicants without an MD degree increased significantly.[10] The decline in physician-scientists remained a topic of debate in the following decades. The American Medical Association spoke of a 36% decline in physician-scientists from 1985 to 2003.[8] The NIH Physician-Scientist Workforce Working Group published a report in 2014, also elaborating on a significant decline in physician-scientists from 2003 to 2012. In addition, they specifically expressed their concerns regarding the ageing of the physician-scientist workforce, as the age profile has increased slowly over the past decades with a decline in physician-scientists aged 31-60 and an increase in physician-scientists aged 60 or above.[11] Although these numbers reflect on the United States, it has been documented that the physician-scientist problem is apparent in Canada and Europe as well.[3] A study conducted by Lopes and colleagues in the United Kingdom (UK), showed that only one third of the physicians completing a PhD pursued a clinical academic career after obtaining their PhD. Furthermore, they elaborated on findings from the Medical Schools Council stating that over half of the medical schools in the UK report difficulties to fill clinical academic posts.[12] Within the Netherlands, the Rathenau Institute published a report in 2018 showing that the amount of PhDs within medicine increased enormously: 256% in 25 years.[13] However, this is not reflected in the amount of MD/PhDs subsequently pursuing a research oriented career. Of all PhDs in the Netherlands, the medical PhD graduates are the least involved in research.[13] Furthermore, a recent Dutch national cohort study reported that less than half of the rapidly growing number of PhD candidates at medical faculties within the Netherlands was actually registered as a physician.[14] In addition, only few MD/PhDs take on a leading role in medical science after completing their dissertation. According to this study and other national studies, medical graduates perceive obtaining a PhD as a requirement to secure a competitive residency spot.[14-16] Hereby, many physicians view obtaining a PhD as part of a preliminary education trajectory to become a medical specialist, not to pursue a research oriented career.[13-16]

To summarize, unfortunately, the medical domain is currently still facing a global physician-scientist shortage.[5,17,18] What emerged as a problem 41 years ago, is still a topic of debate nowadays. Despite the well-known and increasing importance of physician-scientists, a declining interest in academic careers combined with the ageing of the current physician-scientist workforce poses a serious threat. This is also reflected in the emergence of scientific articles with urgent titles, emphasizing that physician-scientists are really becoming an endangered species and the time for action is now.

What kind of action is, then, necessary? This has been an important topic of debate and research. A possible solution to boost the physician-scientist workforce lies in medical education. Decades ago, taskforces established by the Association of American Medical Colleges recommended that clinical research should be introduced in undergraduate medical education curricula.[11] By making both using as well as conducting research clear goals in early phases of medical education, the connection between teaching and research may be strengthened. Furthermore, students get acquainted with research. This helps them to understand, critically appraise, and subsequently use research,[19] providing every student with an academic mindset to practice evidence-informed decision making (the third key competency of the CanMEDS 'scholar' role) in future professional practice. Additionally, it might help to identify a research career path for a subset of students. By being exposed to research during medical training, students' motivation and enthusiasm for conducting research could be triggered (the fourth key competency of the CanMEDS 'scholar' role). Lastly, it could also help educators to recognize and develop research talent.[4,20,21] Hereby, medical education could serve as a 'breeding ground' for physician-scientists.

The aim is clear: engaging students in research during medical school with the two-fold purpose of delivering graduates with an academic attitude and stimulate a subset of graduates to pursue a physician-scientist career. This can be established in two ways: intra- and extracurricular. When looking at the past decade, both ways to engage students in research are being implemented, though in diverse manners.[3,22-24]

Student involvement in research: core curriculum

By integrating research into medical curricula, every student can be engaged in research. Multiple frameworks to enhance student engagement in research have emerged.[25-27] Healey and colleagues have developed a framework to explain four ways in which students can experience research in the curriculum. Healey distinguishes a dimension of students viewed as audience versus active participants, while within the second dimension the emphasis can be on the research process or content. This leads to four quadrants to illustrate student experiences with research within the core curriculum.[25] This framework, however, could be interpreted in different ways. For instance, if a student individually conducts research from start to end, the emphasis is both on research content as well as research processes – making it hard to decide in which quadrant to place this activity. However, of crucial importance within this framework seems to be the distinction between students as audience or active participants. Students benefit from actively being involved in research. Active learning, or 'learning by doing', is seen as the most optimal way to engage students in activities. The idea of learning by doing, in which students are seen as active participants instead of passive consumers of information, was already advocated by John Dewey.[28] Since that time, many theoretical frameworks emerged, emphasizing the importance of active learning; for instance Healey's framework. In order to deliver capable 'scholars', it is imperative to actively involve students in conducting research.

Attempts to involve undergraduate students in formal research during medical education, however, remain inadequate.[22] Concrete translations of existing frameworks to educational practice might be helpful – I hope this thesis not only helps to clarify how such courses for large group of undergraduates contribute to cultivating future physician-scientists, but also provides some tools for how to implement such a course in one's medical curriculum as well.

Motivation for research in undergraduate medical education

The opportunities to engage students in research seem to exist, however, the question remains how to foster future physician-scientists at an early stage. In order to establish this goal, motivation for research seems key.

In general, motivation can be defined as what 'moves' people to action. Motivational theories emerged in the 20th century. These theories tend to view motivation as a unitary entity, focusing on the amount of motivation a person has.[29] An example is Bandura's Social Cognitive Theory (SCT), focusing on the level of motivation, differentiating between motivated versus unmotivated behaviour. SCT states that self-efficacy is the underlying mechanism for motivation and that a lack of self-efficacy results in unmotivated behaviour. Self-efficacy can be defined as a person's belief in his or her own ability to achieve certain outcomes.[30]

Ryan and Deci's Self-Determination Theory (SDT)[29] is different from other motivational theories, as it focuses on the *quality* (as opposed to solely quantity) of motivation. SDT is an empirically based theory of human behaviour, focusing on social conditions that support or hinder human flourishing. SDT distinguishes two types of motivation. The first is 'intrinsic motivation', which is defined as showing behaviour or being involved in a certain activity out of pure interest or enjoyment. In contrast, 'extrinsic motivation' represents behaviour or involvement in a certain activity because it is externally rewarding like avoiding punishment, gaining social approval, or achieving a valued outcome. Extrinsic motivation can be divided into four categories, depending on the level of self-determination: external regulation (i.e. behaviour is directly controlled by external forces like rewards or punishment), introjected regulation (i.e. external controls are taken in, but not fully accepted, there is a focus on approval from self and others), identified regulation (i.e. identification with and conscious valuing of an activity), and integrated regulation (i.e. identifications are integrated with a person's other values and beliefs). So, SDT distinguishes intrinsic from extrinsic motivation, while stating that intrinsic motivation is of better quality. Intrinsic motivation is believed to be related to general wellbeing, deep learning approaches, and better academic performance.

According to SDT, three basic psychological needs must be met in order to enhance intrinsic motivation. First, the need for autonomy – i.e. the need to self-regulate your actions or control the course of your life. Second, the need for competence – i.e. the need to feel effective in dealing with your important life contexts (note: the need for competence touches upon Bandura's concept of self-efficacy). Third, the need for relatedness – i.e. the need to feel socially connected to others.[29]

In recent years, SDT and many studies using SDT have made another distinction: autonomous versus controlled motivation. Here, intrinsic motivation, integrated regulation and identified regulation (the latter two being the most internalized forms of extrinsic motivation) are defined as autonomous motivation. In contrast, external regulation and introjected regulation are seen as controlled motivation.[29] A visual representation of the different continuums of the SDT is displayed in figure 1.

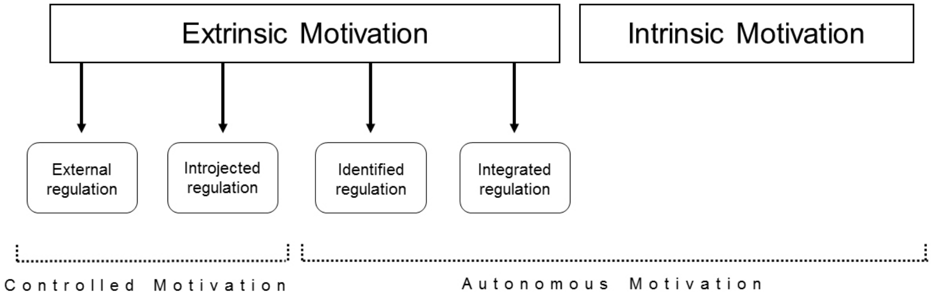

Figure 1. Overview of motivation continuum according to Self-Determination Theory

To some readers, this explanation of the theory might remain quite abstract. When applying this theory to the specific context of this thesis, namely medical student motivation for research, the following interpretations could be given:

1. Intrinsic motivation for research: conducting research out of pure interest or enjoyment;
2. Extrinsic motivation for research: conducting research because it is rewarding, for instance to distinguish yourself and secure a competitive residency spot.

In this context the four categories of extrinsic motivation could be interpreted as:

3. External regulation: conducting research because it is an obligation within the educational programme (e.g. 'I need to pass this course, so I need to conduct research');
4. Introjected regulation: conducting research to gain approval from others or avoid shame (e.g. 'My father thinks research is very important; I am conducting research to make him proud');
5. Identified regulation: conducting research because it is deemed personally valuable (e.g. 'I want to know if I am capable of conducting research, which is why I choose to conduct research');

6. Integrated regulation: conducting research because it is part of your value system as a physician (e.g. 'every good physician needs to be able to conduct research, I want to be a good physician, so I am choosing to conduct research').

The key difference between intrinsic motivation and integrated regulation seems to be the fact that, when intrinsically motivated, a student *likes* conducting research. Within integrated regulation, the student might value research and see the benefits, but this does not automatically mean students conduct research out of pure interest or the innate wish to do so.

In order to stimulate undergraduate medical students to pursue a physician-scientist career and continued engagement in life-long learning, promoting intrinsic motivation seems essential. As the aim is to foster continued engagement in research, working towards a physician-scientist career and identity, it seems key that the medical student actually enjoys conducting research: not only valuing it for professional practice but also invested in staying engaged in a life-long process of research and learning. This vision is in line with research of Ranieri and colleagues among medical professionals, elaborating on the importance of intrinsic motivation for career progression and persistence in academic medicine.[31] Within this thesis, SDT will be used as a theoretical framework and the emphasis will therefore be on the distinction between intrinsic and extrinsic motivation (and not autonomous versus controlled motivation), perceiving intrinsic motivation for research as the target outcome in medical students.

With regard to motivation in general, previous studies have shown that medical students are highly motivated. This is believed to be the result of their large investments to enter medical school.[32] However, less is known about medical students' motivation specifically for research. Vereijken and colleagues studied interest and motivation for research after a curriculum change in which research integration was strengthened. Their findings suggest that students' motivation for research increased when research was more integrated in the curriculum.[33] However, no distinction between type of motivation was made within this study. Some studies investigated motivation for research and suggested that medical students seem motivated to conduct research, but foresee many difficulties and barriers as well.[3,34-36] Studies relying on a sound theoretical framework are scarce. One study performed by Rosenkranz and colleagues did use a theory, namely SDT, and indicated that students view research as valuable for their future medical career. However, these results were mainly gathered among students in clinical phases of medical education.[37] To conclude, there seems to be a lack of studies with a theoretical foundation that focus on pre-clinical phases. Therefore, the first main focus of this thesis is unravelling the role of motivation for research among students in early phases of medical education, while using SDT and subsequently distinguishing intrinsic from extrinsic motivation.

Student involvement in research: extracurricular research programmes

Besides engaging students in research at the curriculum level, students can also be involved in research through extracurricular research programmes. Such programmes are emerging worldwide, though occurring under different names and in diverse formats. They do, however, share the goal to provide a selection of students with research experience and stimulate in-depth inquiry. Examples of such extracurricular research programmes are MD/PhD programmes, capstone programmes, summer research programmes, scholarly concentration programmes and Honours programmes.[3,23,38] For instance, Warren Alpert Medical School of Brown University offers an elective scholarly concentration programme, providing students with the opportunity to undertake a research project of approximately three years.[39] Another example is Vanderbilt University School of Medicine, which implemented an undergraduate medical research programme to provide students with early research experiences.[40] Many more of these programmes are emerging worldwide as a result of national initiatives to put student research on the map. For example, in the US, the National Institute of General Medical Sciences funds Medical Student Training Programmes – nowadays, 43 programmes exist as a result of this initiative.[11] According to Roberts, nearly all US medical schools offer some sort of joint MD/PhD programme.[8]

After performing a systematic review on the outcomes of such programmes, Chang and Ramnanan concluded that attitudes of medical students towards research are predominantly positive. Furthermore, such programmes contribute to enhancing research skills (though self-reported), which may stimulate a continued interest in conducting research. However, this is not reflected in increasing numbers of physician-scientists. According to Chang and Ramnanan's review study, there were multiple discouraging factors like high expectations despite the limited time, inappropriate acknowledgment, and lack of mentorship.[3] Havnaer and colleagues performed a systematic review as well and concluded that scholarly concentration programmes seem promising, however, the authors also emphasized the dearth of evidence with regard to the effectiveness of these programmes in promoting research productivity of medical students.[23]

In sum, some studies attempted to investigate the effectiveness of extracurricular research programmes. However, there is a need for longitudinal research with a control group as a comparison.[3,23,41] Therefore, the second main focus of this thesis is unravelling the role of extracurricular research programmes in contributing to developing future physician-scientists by using a longitudinal design with a comparable control group.

Research context

All studies in this thesis are conducted among undergraduate medical students at Leiden University Medical Center (LUMC) in the Netherlands. In the Netherlands, eight medical faculties (i.e. academic hospitals) offer medical education. All faculties are comparable in the structure of their educational programme, with six years of undergraduate medical education, divided in a three-year programme leading to a Bachelor's degree – which is the main context of the studies within this thesis – and a subsequent three-year programme leading to a Master's degree in Medicine. All eight faculties developed and implemented their educational programme in line with the Dutch National Blueprint for Medical Education, which is based on international educational frameworks like the CanMEDS. In the Netherlands, most students start medical school immediately after graduating from high school, at the age of 18-19 years.[42] Consequently, the population of first-year medical students in the LUMC is of young age and does not have any research-related experience prior to entering medical school.[43]

Research questions and focus of this thesis

To conclude, unravelling the role of motivation for research and extracurricular research programmes is valuable in order to gain insights into ways to develop future physician-scientists starting as early as undergraduate medical training. More insights into how intrinsic motivation for research could be promoted early on in medical school could help to determine possibilities for interventions and the implementation of evidence-based strategies, both intra- and extracurricular, to enhance motivation for as well as involvement in research among medical students. Thereby, first steps can be made to develop the physician-scientist workforce of the future – let's catch them young!

Following these gaps in our knowledge, the overall aim of this thesis is to provide insight into the important role early phases of medical training could play in developing the next generation of physician-scientists by focusing on unravelling the role of motivation for research and extracurricular research programmes. Through these studies we intend to contribute to the quality of undergraduate medical education and delivering graduates who comply to the 'scholar' role as proposed by the CanMEDS framework. To fulfil this aim, we conducted different studies which are described below and will be discussed in detail in the upcoming chapters.

1. Unravelling the role of motivation for research
In *chapter 2* we survey medical students at the start of medical training to identify their intrinsic as well as extrinsic motivation for research, and factors influencing their levels of motivation at the start of medical training. In *chapter 3* we identify conditions under which first-year medical students develop positive perceptions of and motivation for research, using a grounded theory approach. In *chapter 4*, we study the effect of first-year medical students' motivation for research on actual research involvement. In *chapter 5*, we investigate if a success experience within an obligatory research course is associated with an increase in motivation for research and research self-efficacy beliefs. In addition, we research whether the possible effect of a success experience differs when type of assessment is taken into account, looking at standard (i.e. written exam) versus more authentic (i.e. report and oral presentation) assessments. In *chapter 6* we examine if medical students who publish before graduation are more likely to publish after graduation, if they publish a greater number of papers after graduation, and if they publish papers with a higher citation impact after graduation. *Chapter 7* is a commentary, in which we argue around the nature of students' motivation for research as preparation for residency. In particular, we discuss core competencies of the scholar and our vision on the dynamic character of motivation.

2. Unravelling the role of extracurricular research programmes

In *chapter 8* we describe the research-based Honours programme of Leiden University Medical Center, which aims to engage future physicians in scientific research in early stages of medical training. In *chapter 9*, we report on the role of grades in selecting students for an extracurricular research programme. Here, we compare students within the extracurricular research programme with a first-year grade point average (GPA) below or above seven on academic performance, extracurricular research programme performance, and motivational factors. In *chapter 10*, we use a prospective, longitudinal design with a sound baseline measure and a comparable control group to investigate the effects of a research-based Honours programme. Students participating within the extracurricular research programme are compared to students that showed interest in the programme but eventually decided not to participate on academic achievement, intrinsic motivation for research, research self-efficacy beliefs, perceptions of research, and curiosity.

3. Connecting research to theory and practice

As mentioned before, the aim of this thesis was broader than helping to clarify in what way undergraduate courses and extracurricular research programmes contribute to cultivating future physician-scientists. In addition, within this thesis, we wanted to make a connection to both theory and practice. In *chapter 11* we focus on expanding our theoretical view on Self-Determination Theory by including an authenticity framework to shape undergraduate research experiences in such ways that student wellbeing is promoted. Furthermore, elaborating on how an undergraduate research course could be implemented within the medical curriculum seems valuable in order to make a connection to practice. Therefore, in *chapter 12* we provide twelve tips to offer a short authentic and experiential individual research opportunity to a large group of undergraduate students, based on theory, own experiences, and the previous chapters of this thesis.

A summary and in-depth discussion of the main research findings, directions for future research, and practical implications is discussed in *chapter 13*.

An overview of all chapters including the specific research questions is given in Table 1.

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

Chapter	Research aim or question(s)	Research method	Analyses
2	1. To what extent are first-year medical students intrinsically and/or extrinsically motivated for research? 2. What influence do self-efficacy, perceptions of research, curiosity, and need for challenge have on intrinsic and extrinsic motivation for research?	Student surveys (cross-sectional)	Multivariate linear regression analyses
3	1. How do first-year medical students perceive research? 2. Which factors contribute to motivation or demotivation for conducting research?	Interviews	Grounded theory approach: open, axial and selective coding
4	What is the effect of motivation for research on actual research involvement?	Student surveys (prospective cohort)	Multivariate logistic regression analyses
5	1. What is the influence of a success experience within an obligatory research course on motivation for research and research self-efficacy? 2. Is the effect of a success experience different for standard (i.e. written exam) versus more authentic (i.e. report and oral presentation) assessments?	Student surveys (prospective cohort)	Multivariate linear regression analyses
6	Are medical students who publish before graduation more likely to publish after graduation, do they publish a greater number of papers after graduation, and do they publish papers with a higher citation impact after graduation?	Bibliometric methods (retrospective cohort)	Chi square test, Mann-Whitney U test, independent samples t-test
7	Medical students' intrinsic versus extrinsic motivation to engage in research as preparation for residency	Commentary	n.a.
8	Using an extracurricular Honours programme to engage future physicians into scientific research in early stages of medical training	Monograph	n.a.
9	What is the effect of students' first-year academic performance on academic success within an extracurricular research programme, intrinsic motivation for research, self-efficacy beliefs, perceptions of research and curiosity?	Student surveys (prospective cohort)	Multivariate logistic and multivariate linear regression analyses
10	What is the effect of an extracurricular research programme on academic achievement, intrinsic motivation for research, research self-efficacy beliefs, perceptions of research, and curiosity?	Student surveys (longitudinal)	Multivariate logistic and multivariate linear regression analyses
11	How does engaging in authentic research at undergraduate level contribute to student wellbeing?	Theoretical essay	n.a.
12	Connecting research to practice: Twelve tips to offer a short authentic and experiential individual research opportunity to a large group of undergraduate students	Twelve tips article: practical tips based on theory, previous research, and own experiences	n.a.

References

1. Cohen L, Manion L, Morrison K. *Research methods in education*. Routledge; 2013.
2. Richardson D, Oswald A, Lang E, Harvey B, Chan M-K. *The CanMEDS 2015 Scholar Expert Working Group Report*. Ottawa: The Royal College of Physicians and Surgeons of Canada;2014.
3. Chang YJ, Ramnanan CJ. A Review of Literature on Medical Students and Scholarly Research: Experiences, Attitudes, and Outcomes. *Academic Medicine*. 2015;90(8):1162-1173.
4. Dekker FW. Science Education in Medical Curriculum: Teaching Science or Training Scientists? *Medical Science Educator*. 2011;21:258-260.
5. Sklar DP. We Must Not Let Clinician-Scientists Become an Endangered Species. *Academic Medicine*. 2017;92(10):1359-1361.
6. DeLuca GC, Ovseiko PV, Buchan AM. Personalized medical education: Reappraising clinician-scientist training. *Science translational medicine*. 2016;8(321):321fs2.
7. Butler D. Translational research: crossing the valley of death. *Nature*. 2008;453(7197):840-842.
8. Roberts SF, Fischhoff MA, Sakowski SA, Feldman EL. Perspective: Transforming science into medicine: how clinician-scientists can build bridges across research's "valley of death". *Academic Medicine*. 2012;87(3):266-270.
9. Macleod MR, Michie S, Roberts I, et al. Biomedical research: increasing value, reducing waste. *Lancet*. 2014;383(9912):101-104.
10. Wyngaarden JB. The clinical investigator as an endangered species. *The New England journal of medicine*. 1979;301(23):1254-1259.
11. NIH. Physician-scientist Workforce (PSW). Working Group Report. NIH Web site. http://acd.od.nih.gov/reports/PSW_Report ACD_06042014.pdf. Updated June 1, 2014. Accessed February 3, 2020. 2. NIH. Biomedical Research Workforce. 2014.
12. Lopes J, Ranieri V, Lambert T, et al. The clinical academic workforce of the future: a cross-sectional study of factors influencing career decision-making among clinical PhD students at two research-intensive UK universities. *BMJ open*. 2017;7(8):e016823.
13. Koier E, de Jonge J. *De zin van promoveren – Loopbanen en arbeidsmarktperspectieven van gepromoveerden*. Den Haag: Rathenau Instituut;2018.
14. Wolters FJ. Academische carrièreperspectieven van gepromoveerde dokters: een landelijk cohortonderzoek in de periode 1992-2018. *Nederlands Tijdschrift voor Geneeskunde*. 2020.
15. Witjes S, Schol R. Niet elke specialist hoeft te promoveren. *Medisch Contact* 2014.
16. Bontje W. Is een doctor een betere dokter? *Arts in Spe*. 2018.
17. Milewicz DM, Lorenz RG, Dermody TS, Brass LF, National Association of MDPPEC. Rescuing the physician-scientist workforce: the time for action is now. *The Journal of clinical investigation*. 2015;125(10):3742-3747.
18. Brass LF, Akabas MH. The national MD-PhD program outcomes study: Relationships between medical specialty, training duration, research effort, and career paths. *Jci Insight*. 2019;4(19).
19. Walkington H, Griffin AL, Keys-Mathews L, et al. Embedding Research-Based Learning Early in the Undergraduate Geography Curriculum. *Journal of Geography in Higher Education*. 2011;35(3):315-330.

20. de Jong PGM, Haramati A. Teaching to Develop Scientific Engagement in Medical Students. In: Huggett KN, Jeffries WB, eds. *An Introduction to Medical Teaching.* Dordrecht: Springer Science + Business Media; 2014.
21. Graham MJ, Frederick J, Byars-Winston A, Hunter AB, Handelsman J. Increasing Persistence of College Students in STEM. *Science.* 2013;341(6153):1455-1456.
22. Abu-Zaid A, Alkattan K. Integration of scientific research training into undergraduate medical education: a reminder call. *Medical Education Online.* 2013;18.
23. Havnaer AG, Chen AJ, Greenberg PB. Scholarly concentration programs and medical student research productivity: a systematic review. *Perspectives on Medical Education.* 2017;6(4):216-226.
24. Scager K, Akkerman SF, Pilot A, Wubbels T. Challenging high-ability students. *Studies in Higher Education.* 2014;39(4):659-679.
25. Healey M, Jordan F, Pell B, Short C. The research-teaching nexus: a case study of students' awareness, experiences and perceptions of research. *Innovations in Education and Teaching International.* 2010;47(2):235-246.
26. Willison J, O'Regan K. Commonly known, commonly not known, totally unknown: a framework for students becoming researchers. *Higher Education Research & Development.* 2007;26(4):393-409.
27. Verburgh AL, Schouteden W, Elen J. Patterns in the prevalence of research-related goals in higher education programmes. *Teaching in Higher Education.* 2013;18(3):298-310.
28. Dewey J. *Democracy and education.* Mineola, NY: Dover Publications, Inc.; 2004.
29. Ryan RM, Deci EL. *Self-determination theory: Basic psychological needs in motivation, development, and wellness.* Guilford Publications; 2017.
30. Bandura A. *Self-Efficacy. The Exercise of Control.* New York: Freeman; 1997.
31. Ranieri V, Barratt H, Fulop N, Rees G. Factors that influence career progression among postdoctoral clinical academics: a scoping review of the literature. *BMJ open.* 2016;6(10):e013523.
32. Ten Cate TJ, Kusurkar RA, Williams GC. How self-determination theory can assist our understanding of the teaching and learning processes in medical education. AMEE guide No. 59. *Medical Teacher.* 2011;33(12):961-973.
33. Vereijken MWC, van der Rijst RM, van Driel JH, Dekker FW. Student learning outcomes, perceptions and beliefs in the context of strengthening research integration into the first year of medical school. *Advances in health sciences education: theory and practice.* 2018;23(2):371-385.
34. Murdoch-Eaton D, Drewery S, Elton S, et al. What do medical students understand by research and research skills? Identifying research opportunities within undergraduate projects. *Medical Teacher.* 2010;32(3):e152-e160.
35. Nel D, Burman RJ, Hoffman R, Randera-Rees S. The attitudes of medical students to research. *South African Medical Journal.* 2014;104(1):32-36.
36. Burgoyne LN, O'Flynn S, Boylan GB. Undergraduate medical research: the student perspective. *Medical Education Online.* 2010;15(1):5212.
37. Rosenkranz SK, Wang S, Hu W. Motivating medical students to do research: a mixed methods study using Self-Determination Theory. *BMC Medical Education.* 2015;15(1):95.
38. Bierer SB, Chen HC. How to Measure Success: The Impact of Scholarly Concentrations on Students-A Literature Review. *Academic Medicine.* 2010;85(3):438-452.

39. Boninger M, Troen P, Green E, et al. Implementation of a Longitudinal Mentored Scholarly Project: An Approach at Two Medical Schools. *Academic Medicine.* 2010;85(3):429-437.

40. Brown AM, Chipps TM, Gebretsadik T, et al. Training the next generation of physician researchers - Vanderbilt Medical Scholars Program. *BMC Med Educ.* 2018;18.

41. Kool A, Mainhard T, Jaarsma D, van Beukelen P, Brekelmans M. Effects of honours programme participation in higher education: a propensity score matching approach. *Higher Education Research & Development.* 2017;36(6):1222-1236.

42. Wijnen-Meijer M, Burdick W, Alofs L, Burgers C, ten Cate O. Stages and transitions in medical education around the world: clarifying structures and terminology. *Medical Teacher.* 2013;35(4):301-307.

43. Ten Cate O. Medical education in the Netherlands. *Medical Teacher.* 2007;29(8):752-757.