Pedagogical Essays, The unit for Pedagogical Development and Interactive Learning (PIL)
University of Gothenburg, December 2015
www.pil.gu.se/publicerat/texter

# Do Swedish Higher Educational Programs in Medical Physics Provide a Sufficient Basis for Students to Conduct a Master's project in Predictive Modelling of Normal Tissue Response to Ionizing Radiation?

Caroline Olsson[1,2]

[1]Department of Radiation Physics, Institute of Clinical Sciences, Sahlgrenska Academy at the University of Gothenburg, Sweden

[2]Regional Cancer Center (RCC) West, the Western Sweden Healthcare region, Göteborg, Sweden

## ABSTRACT

**Background and purpose** Predictive models of normal tissue response to ionizing radiation exposure are emerging as computational aids to assist in avoiding side effects after modern radiation therapy for different cancers. The subject is indirectly covered in the five-year long Swedish educational programs in medical physics and this paper addresses the question if this provides sufficient prior knowledge for students to perform such a Master's project.

**Material and methods** Course curricula for two Medical Physics university programs in Sweden were surveyed for contents relating to nine previously determined learning outcomes necessary for the chosen subject. In addition, a structured literature search in the educational sciences was conducted.

**Results** Eight of nine learning outcomes were found in the investigated course curricula for the latter three years of both Medical Physics programs. The literature search resulted in six relevant publications.

**Conclusion** Although there seems to be a limited interest in the proposed question from the Educational Science perspective, this work suggests that Swedish students in medical physics are well equipped to tackle a Master's project in predictive modelling of normal tissue response to ionizing radiation.

## ABSTRAKT

**Bakgrund och syfte** Prediktiva modeller för normalvävnadssvar vid exponering av joniserande strålning framträder alltmer som beräkningsmässig hjälp att undvika biverkningar efter modern strålbehandling för olika cancersjukdomar. Ämnet behandlas indirekt i de femåriga, svenska sjukhusfysikutbildningarna och det här arbetet addresserar frågan om detta ger studenterna tillräckliga förkunskaper för att genomföra ett magisterprojekt i ämnet.

**Material och metod** Kursplaner från två sjukhusfysikerutbildningar i Sverige granskades för innehåll relaterande till nio tidigare fastställda lärandemål som identifierats som nödvändiga för ämnet. Dessutom genomfördes en strukturerad litteratursökning inom utbildningsvetenskaperna.

**Resultat** Åtta av nio lärandemål hittades i de undersökta kursplanerna för de sista tre åren av båda sjukhusfysikerutbildningarna. Litteratursökningen resulterade i sex relevanta publikationer.

**Konklusion** Trots att det tycks finnas ett begränsat intresse för den föreslagna frågan inom utbildningsvetenskaperna, antyder det här arbetet att svenska sjukhusfysikerstudenter är väl rustade för att angripa ett magisterprojekt inom prediktiv modellering av normalvävnadssvar vid exponering av joniserande strålning.

## INTRODUCTION

Radiation therapy is commonly used in the treatment of cancer. It is a technique where tumour cells are killed by ionizing radiation, but this effect is not specific to cancer cells and it is inevitable that cells in healthy tissue surrounding the tumour will be incidentally irradiated. This can lead to side effects. Depending on cancer site, various normal tissue responses will present differently. For pelvic cancers, major concerns are gastrointestinal and genitourinary side effects; for cancers of the head and neck region, difficulties with eating, chewing, maintaining oral hygiene, and malnutrition are other concerns. With proper treatment, including radiation therapy, more than 50% of cancer patients are cured today, which is leading to increased numbers of cancer survivors. Side effects of cancer treatments are, therefore, a growing problem that can lead to long-term disability, poor quality of life for cancer survivors, and escalating costs for society.

Predictive models of normal tissue response (NTCP models) have during the last decade emerged as computational aids to assist in reducing radiation therapy side effects. The output from such models can be used when planning the treatment to avoid critical doses in normal tissue where there is a high risk for side effects. Together with information on tumour effects at such doses, risks of causing side effects can then mathematically be balanced against the possibility of cure (when possible) and the calculated dose distribution in the patient adjusted accordingly. To perform predictive modelling of normal tissue response to ionizing radiation, knowledge from several disciplines are required, e.g. radiation oncology, radiation therapy, radiobiology, mathematics/statistics, and computer science. The subject is receiving growing attention both academically and clinically, and it is increasingly taught in postgraduate university courses for physicians and medical physicists in Sweden. Being multidisciplinary in nature, a project in this subject can be challenging to a Master's student regardless of his or her background. In this work, I want to address the question if the five year long Medical Physics programs in Sweden provide a sufficient basis for students to conduct a Master's project in predictive modelling of normal tissue response to ionizing radiation. Another objective is to discuss related pedagogical challenges in supervising these kinds of students. The study was designed according to guidelines of how to conduct projects in scholarship of teaching and learning (*Bishop-Clark&Diez-Uhler 2012*), and to my knowledge, the identified question has not previously been addressed for Swedish conditions.

## STUDY DESIGN

The individuals in focus for this work are students in medical physics who perform a Master's project in the final year of their studies. The project is typically conducted during one term (20 weeks full-time, equivalent to 30 Swedish högskolepoäng (HP); *cf.* credits) and the students are examined by the means of a structured report that they present and defend for fellow students, teachers, and faculty members at the end of the term. The grades are "pass" or "fail" with a grade being decided by an appointed examiner at the department where the Medical Physics program is held (typically, Radiation Physics). Additional specific requirements for conducting a Master's project in predictive modelling of normal tissue response to ionizing radiation were identified by the author and an expert colleague and researcher at the Department of Physics and Biomedical Engineering at the Sahlgrenska University Hospital in Göteborg, Sweden[1]. In their earlier years at the university, the students have taken courses addressing various aspects of medical physics including diagnostic imaging and nuclear medicine. To identify the prior knowledge these students can be

[1] Both researchers have academic/clinical experience of predictive modelling of normal tissue response to ionizing radiation and have, between them, published 25 papers on the subject during the last ten years as well as taught more than 100 hours in the Medical Physics program at the University of Gothenburg (GU)/Sahlgrenska University Hospital in Göteborg, Sweden. The identified specific requirements for a Master's project in the suggested subject were partly presented in the course HPE102 at GU during the Spring of 2013.

expected to have, course curricula from two universities in Sweden were investigated. These were collected from university websites and through direct contact with directors of studies (http://www.lu.se/lubas/i-uoh-lu-NASJF and http://www.sahlgrenska.gu.se/utbildning/ program/sjukhusfysikerprogrammet/). The documents were specifically analysed for courses with learning outcomes that included topics that could be related to the specific learning outcomes of the proposed Master's subject. Focus was on course curricula for the latter three years of the program where clinical radiation physics is taught (advanced level); course curricula for the first two year's courses in physics and mathematics were not investigated (undergraduate level).

To discuss the pedagogical challenges in supervising these kinds of students from the perspective of balancing possibly limited prior knowledge in the proposed Master's subject with student independence and external requirements (passed report and limited departmental resources), a structured literature search in the educational sciences were conducted. The search tool "*education research complete*", available at the University of Gothenburg (www./ub.gu.se/sok), was used. The search was performed on October 10, 2014, using various combinations of the search terms "*higher education*", "*teaching*", "*supervision*", "*undergraduate/Master's dissertation/research project*", and "*medical physics*". Truncations and extensions of search terms were applied as appropriate.

## FINDINGS

### Requirements for a Master's project in predictive modelling of normal tissue response to ionizing radiation

The general requirements for a Master's project in medical physics as given by the course curricula of the two universities are presented in ***Table 1***. There were five learnings outcomes 1 4 for University 1 and eleven for University 2, in total 16 learning outcomes. The emphasis was on topics related to students' knowledge and skills. Besides the overall goal of achieving a deeper understanding for the selected Master's subject, the learning outcomes primarily focused on abilities of independence and communication. The former related to the planning and execution of a research project (6/16) and the latter to the explanation of findings in a scientifically sound manner (4/16).

The specific requirements for a Master's project in predictive modelling of normal tissue response to ionizing radiation are presented in ***Table 2.***

***Table 1.*** *General learning outcomes for a Master's project in medical physics at two universities in Sweden.*

| University | Educational objective(s) | Learning outcome |
|---|---|---|
| 1 | Knowledge and skills | Plan a research project and identify own need for additional knowledge |
| | | Independently solve a scientific problem in the selected subject where previous knowledge can be integrated |
| | | Explain and discuss new facts and results orally and in English writing on a scientific level |
| | | Present the scientific question and results in a popular scientific manner |
| | | Demonstrate an understanding of the medical physicist professional role by interacting and collaborating with other professionals when executing the project |
| 2 | Knowledge and understanding | Describe how scientific information is structured and how different sources of information are organized |
| | | Create a search strategy for the project and explain the choice of keywords, search strategy, and sources |
| | | Use relevant terminology and concepts in the selected subject |
| | | Integrate knowledge from relevant fields |
| | | Plan a research project according to ethical rules and guidelines |
| | Skills and abilities | Plan and perform a research project within the given timeframe |
| | | Scientifically and independently communicate the project orally and in writing |
| | | Communicate new questions and facts with different groups |
| | Judgement and approach | Critically evaluate own and others projects using a scientific approach |
| | | Reason about good ethics from the researcher's perspective |
| | | Identify own need for additional knowledge |

Note: The presented information is an English translation of the original Swedish documents by the author.

***Table 2.*** *Specific learning outcomes for a Master's project in predictive modelling of normal tissue response to ionizing radiation.*

| Educational objective(s) | No. | Learning outcome |
|---|---|---|
| Knowledge and understanding | 1 | Demonstrate a general understanding of radiation-induced injury development and a specific understanding of how this manifest as symptoms from various organs or tissue for the selected subject |
| | 2 | Describe how absorbed dose is represented in 1D, 2D, and 3D, how these dose representations are related, and how they are used in predictive modelling |
| | 3 | Describe effects by the fractionation effect on normal tissue response to ionizing radiation |
| | 4 | Describe relevant toxicity scoring systems for the selected subject and how such endpoint data are used in predictive modelling |
| Skills and abilities | 5 | Independently extract dose data from a treatment planning system and organize these for further processing in predictive modelling |
| | 6 | Independently extract endpoint data from a research database and organize these for further processing in predictive modelling |
| | 7 | Given a set of already collected data, perform predictive modelling using basic statistical method(s). |
| Judgement and approach | 8 | Be able to draw relevant conclusions from results by own predictive modelling and critically evaluate own and others predictive modelling results |
| | 9 | Be aware of potential weaknesses and sources of uncertainty in collected dose and endpoint data as well as their impact on presented results |

Abbreviation: No., number.

Nine learning outcomes were identified of which four related to students' knowledge and understanding (numbers 1-4), three to students' skills and abilities (numbers 5-7), and two to students' judgement and approach (numbers 8-9). In four of nine learning outcomes (numbers 1, 4, 8, and 9) , it was acknowledged that a student is to reach a given goal by setting it in context to his or her 5 selected topic, e.g. '*Describe relevant toxicity scoring systems for the selected topic…*' emphasises that the student is expected to be familiar with the toxicity scoring systems in question for his or her project, not toxicity scoring systems in general.

## Prior knowledge relating to predictive modelling of normal tissue response to ionizing radiation according to curricula of completed courses

According to the course curricula for the higher educational programs in medical physics at the two universities, there were six and eight courses, respectively, which included topics relating to various aspects of the proposed Master's subject (***Table 3***). The topics of the courses were to a large extent similar between the universities, but could be arranged

***Table 3.*** *Overview of topics relating to predictive modelling of normal tissue response to ionizing radiation according to the learning outcomes of the course curricula for medical physics programs at two universities in Sweden.*

| University | Course id, HP (Number of learning outcomes) | Topic |
|---|---|---|
| 1 | MSFM11: Part I. Origins of ionizing radiation, interactions, and measurements, 21 (9) | 1. How ionizing radiation arise naturally and artificially as well as the characteristics of different radiation types and radiation sources<br>2. Overview of the occurrence of ionizing radiation and use in society<br>2. Basic radiometric terms (activity and dose) according to ICRU<br>3. Individual processes and energy transfer mechanisms when charged particles' interact with matter<br>4. The quantities which macroscopically describe how interactions with matter affect an incident ray of photons/particles and the values of these quantities (e.g. different energies and materials for calculations or problem solving) |
| | MSFM11: Part III. Medical terminology and basic terms, 7 (8) | 1. Basic cell and tumour biology<br>2. Basic human anatomy<br>3. Organ physiology overview<br>4. Medical relevant terms for planes and directions of the body and latin/greek for the most common organs<br>5. Symptoms, diagnostics, and treatment of the diseases relevant for the work of a medical physicist<br>6. Medical law regulations, confidentiality, and ethics |
| | MSFM11: Part IV. Radiobiology, 7 (7) | 1. The effect of ionizing radiation on the cell, the tissue, the organ, and the whole body<br>2. Mechanisms for radiation-induced injury and repair of DNA damage<br>3. Models of cell survival<br>4. Factors modifying the response to ionizing radiation |
| | MSFM21: Part III. Physics of radiation therapy, 16 (10) | 1. Absolute and relative dose distributions of radiation fields in EBRT and BT<br>2. Clinical treatment planning and optimization with consideration of biological and physical aspects of EBRT and BT and relevant dose calculation algorithms<br>3. The international recommendations for reporting radiation therapy |
| | MSFM21: Part IV. Biostatistics, 4 (4) | 1. Designing an experiment/research project<br>2. Basic terms for hypothesis testing, parametric and nonparametric tests, and how to display survival data<br>3. Different methods of estimation<br>4. Calculations using statistical software |
| | MSFM23: Clinical internship, medical ethics, law regulations, imaging communication, procurement, and patient safety, 30 (9) | 1. Communicating information about ionizing radiation and radiation safety as well as about specific diagnostic examinations or therapeutic approaches to colleagues, patients and their relatives.<br>2. Information systems for imaging, examinations, and patient data |
| 2 | RFA331: Nuclear physics and radiation sources, 7.5 (13) | 1. Units and quantities in radiation physics<br>2. Naturally arising radioactivity |
| | RFA332: Interaction of radiation with matter, 7.5 (7) | 1. Interactions between ionizing radiation and matter<br>2. Terms for interactions |
| | RFA338: Radiation biology, 7.5 (6) | 1. Basic terminology in biochemistry and cell biology<br>2. Biological effects by ionizing radiation on molecules, cells, and organisms<br>3. Consequences of radiation-induced biological effects |
| | RFA841: Medicine for physicists, 6 (8) | 1. The human anatomy<br>2. Anatomy and physiology of human tissue and organs<br>3. Tumour mechanisms and tumour categorization<br>4. Relevant parts of medicine for physics applications in medical diagnostics and therapy<br>5. Medical terminology<br>6. Communicating with colleagues in adjacent medical fields |
| | RFN848: Physics in radiation therapy, 15 (7) | 1. Physical applications in radiation therapy<br>2. Treatment planning<br>3. Clinical issues in radiation therapy |
| | RFA857: Scientific methodology I, 7.5 (9) | 1. Methods for data collection and statistical methods for data analysis<br>2. Ethical principles for research projects<br>3. Planning and executing a research project<br>4. Basic epidemiological terminology |
| | RFA947: Scientific methodology II, 7.5 (11) | 1. Qualitative and quantitative research studies<br>2. Data analysis using statistical methods<br>3. Critically revising research results<br>4. The value of scientific methods and results as given by their theoretical basis |
| | RFA100: Clinical radiation physics, 22.5 (10) | 1. Physical conditions for radiation therapy<br>2. Biological and technical conditions for radiation therapy<br>3. Applying results from relevant radiation-related research in organizations where ionizing radiation appear |

Note: The presented information is an English condensed translation of the original Swedish documents by the author; Abbreviations: BT, brachytherapy; DNA, deoxyribonucleic acid; EBRT, external beam radiation therapy; HP, "högskolepoäng" – cf. credits; ICRU, international commission of radiation units and measurements.

differently, e.g. similar topics were covered in the course *Biostatistics* at University 1 and in the course *Scientific methodology I and II* at University 2. Furthermore, the contents of the aforementioned courses, together with the contents of the clinical courses in each program, covered all topics related to the general requirements for a Master's project in medical physics at both universities.

When relating the specific requirements as presented in ***Table 2*** of the previous paragraph to the contents of the courses in ***Table 3***, it can be noted that most requirements were covered to some extent. Specific learning outcomes 1 and 3 relating to radiation-induced injury and symptom manifestation as well as the effects of fractionation were found in the courses addressing *Medical terminology and basic terms/Medicine for physicists* as well as in the courses on *Radiobiology/Radiation biology*. Specific learning outcome 2 relating to dose representations and their use in predictive modelling was found in the courses addressing *Physics of/in radiation therapy*. Specific learning outcomes 5-9 relating to dose/endpoint data handling, the actual performance of predictive modelling, and the interpretation/potential weaknesses of results were found in the courses addressing *Biostatistics/ Scientific methodology I and II*. Only specific learning outcome 4 on toxicity scoring systems was not clearly covered by the contents of any listed course.

### Publications in the educational sciences addressing supervision of Master's students in medical physics

The structured literature search in the educational sciences on supervision of Master's students in medical physics resulted in eight publications of which six were considered relevant for this work. The latter concerned supervision of undergraduate science students in general (*Armstrong&Shanker 1983, Cook 1980, Goodland 1998,* and *Todd et al. 2006*), and were, if dedicated to medical physics students, focused on their research interests (*Dempsey&Warren-Forward 2011*) or concerns regarding Medical Physics programs (*Lombardo 2006*). The two excluded publications focused on educational programs for Radiation Therapists and were judged to be outside the scope of this work.

## DISCUSSION

According to the two investigated course curricula for educational programs in medical physics, eight of the nine identified specific requirements for a Master's project in predictive modelling of normal tissue response to ionizing radiation were present in the advanced level courses. Since only a few publications on related subjects were found by the structured literature search in the educational sciences, it can be noted that the interest for supervision of Medical Physics students in the proposed Master's subject has been limited in this field so far. One explanation for this can be that the subject in itself stems from a young discipline. Also, a majority of the specific requirements for the proposed Master's subject were found in previous courses of Medical Physics programs. Another reflection is, therefore, that that the pedagogical challenges in supervising students in this multidisciplinary subject are probably similar to the challenges of supervising students in "traditional" Medical Physics Master's projects. Thus, the proposed subject may not need specific attention in the educational sciences since its supervisory issues are in line with the supervisory issues in Master's projects of higher educational programs in general.

The results of this work suggest that students in medical physics have sufficient prior knowledge in topics related to predictive modelling of normal tissue response to ionizing radiation from their previous courses and they can be expected to need as much or little "hands-on" supervision in such a Master's project than in any other Medical Physics Master's project. When undergraduate science students are asked their preference in supervisory approach, they prefer a more guiding role (*Armstrong&Shanker 1983*). Still, a Master's project is a prolonged engagement with a clear goal of a product that is expected to adhere to academic standards at this level (*Cook 1980, Elmgren&Henriksson 2010*, and *Todd et al. 2006*). Supervisors are expected to assist the student in obtaining the objectives specified within the given time limits and with the available resources, e.g. time for supervision or laboratory access (*Cook 1980*). Supervisors are also expected to be flexible to students' needs at various time points of the project and will be taking roles with both intellectual/educational qualities as well as with counselling/emotional qualities (*Cook 1980* and *Todd et al. 2006*). In this context, it has been reported that a more guiding supervisory approach generally works well in the initial parts of an undergraduate or graduate project but a more firm hand (*cf.* direct supervision) may be needed as the project progresses towards the project report or dissertation (*Handal&Lauvås 2008*). In addition, the level of project difficulty will also affect the supervisory role (*Cook 1980*). Projects in predictive modelling of normal tissue response to ionizing radiation can, as any other subject, be made more or less challenging and can, therefore, demand different kinds of supervisory approaches for different students. A project could for instance focus on the collection of primary data and the associated requirements for these; another project could instead focus on the usage of secondary/existing data for more advanced modelling purposes. The former would be more challenging for students not familiar with the human anatomy and the planning of radiation therapy whilst the latter would be more challenging for students not familiar with the required skills in mathematics/statistics and computer science. For both situations, a supervisor must be aware of students' abilities and must remember to take a more guiding role for the parts of the project where the student is stronger theoretically or practically and where he or she can work more independently. With direct supervision throughout any Master's project, it will be difficult for a student to reach one of the main learning objectives of the educational learning activity, achieving autonomy and independence.

When generalising the results of this work, it must be kept in mind that two specific educational programs were surveyed for course content and that the presented results pertain to the learning outcomes as decided by their respective university. There are two additional Medical Physics programs in Sweden and the course curricula for these may diverge somewhat from the ones investigated here. In addition, the identified specific requirements for the proposed subject were decided by the author and a colleague researcher. Additional input from a broader audience could have changed the learning outcomes to some extent, although it is unlikely that the overall results would have been radically changed from what has been presented here. There is also no information on how the presented results fare internationally. It would be interesting to further investigate the proposed question on a broader national scale as well as in an international setting. Furthermore, including students' perspectives on the expectations and perceptions concerning predictive modelling of normal tissue response to ionizing radiation before and after a completed Master's project in this subject would add further insights to the plausible needs for specific supervisory tools. With this perspective added, structured guidelines (personal or departmental) suggesting how to conduct the supervision for these students in the proposed Master's subject could prove to be helpful in avoiding potential problems in the longer perspective (*Todd 2006*).

In conclusion, students in medical physics can be expected to have sufficient prior knowledge in topics related to predictive modelling of normal tissue response to ionizing radiation and are likely to conduct a Master's project in this subject as successfully as in any other Master's project in medical physics. The results from this work can be used to improve the general understanding of this subject in students, teachers, clinical staff, and researchers, but can also increase the interest for the subject in both higher educational programs and in research.

## REFERENCES


Armstrong, M. and Shanker, V. *The supervision of undergraduate research: student perceptions of the supervisor role.* Studies in Higher Education 1983:8(2):177-183.

Bishop-Clark, C. and Diez-Uhler, B. *Engaging in the scholarship of teaching and learning*. Stylus publishing, LLC, Sterling, Virginia, US 2012.

Cook, M.C.F., *The role of the academic supervisor for undergraduate dissertations in science and sciencerelated subjects.* Studies in Higher Education 1980:5(2):173-185.

Dempsey S.E. and Warren-Forward, H.M. *An analysis of the professional and academic interest of medical radiation science students.* Radiography 2011:17:145-151.

Elmgren, M. and Henriksson, A-S. *Universitetspedagogik.* Nordsteds Förlagsgrupp AB, Bookwell AB, Finland 2010

Goodland, S. *Research opportunities for undergraduates.* Studies in higher education 1998:23(3):349-356.

Handal, G. and Lauvås, P. *Forskarhandledaren.* Studentlitteratur, Holmbergs i Malmö, Sweden 2008.

Lombardo P. *Concerns for medical radiation programs in Australian universities.* Radiography 2006:12:332- 338.

Todd, M.J., Smith, K., and Bannister, P. *Supervising a social science undergraduate dissertation: staff experiences and perceptions.* Teaching in higher education 2006:11(2):161-173.