EVALUATION OF THE RADIOLOGY TEACHING SYSTEM IN THE MEDICAL SCHOOL CURRICULUM AND IN AN INTERNATIONAL CONTEXT

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Elena Vladimirovna Kourdioukova
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**Promoters**

Prof. dr. K. Verstraete, Faculty of Medicine and Health Sciences

Prof. dr. M. Valcke, Faculty of Psychology and Educational Sciences

**Members of the Examining Committee:**

Prof. dr. Th. J. ten Cate, UMC Utrecht

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**Supervisory Board:**

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Prof. Dr. A. Derese, University of Ghent


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LIST OF ABBREVIATIONS

AGFI  Adjusted Goodness-of-Fit-Index
ANOVA Analysis of Variance
CMC  Conventional Medical Curriculum
CSCL Computer Supported Collaborative Learning
ERTeCS Evaluation Radiology Teaching Concept Scale
ESR  European Society of Radiology
GFI  Goodness-of-Fit-Index
GLM  General Linear Model
ICMC Integrated Contextual Medical Curriculum
PACS Picture Archiving and Communication System
PBL  Problem Based Learning
RMSEA Root Mean Square Error of Approximation
RO   Research Objective
SPSS Statistical Package for Social Sciences
TH   Teaching Hours
UGent Ghent University
SUMMARY

Aim
The general research problem of the current dissertation centers on (1) an international benchmarking of radiology curricula in Europe, and (2) the evaluation of the innovative radiology curriculum as implemented at Ghent University (UGent). Four research objectives (RO) were put forward:

RO 1: To describe how undergraduate radiology teaching is organized in Europe and to identify important characteristics of undergraduate radiology curricula.

RO 2: To investigate how do students perceive the innovative undergraduate radiology curriculum at Ghent University, and what explains differences in student perception.

RO 3: To explore the perceived value of clinical clerkships in the radiology curriculum as well as the impact of radiology clerkship on students’ beliefs about the radiology profession and radiology as a career.

RO 4: To explore whether case-based learning within a computer supported collaborative learning (CSCL) setting results in student satisfaction and helps to develop and improve radiologic problem-solving abilities of medical students.

Methods
In view of this dissertation, two specific questionnaires were developed. To map radiology undergraduate curricula in an international context, the “ESR (European Society of Radiology) questionnaire on undergraduate radiology teaching” was developed. In view of evaluating the UGent innovative radiology curriculum, a questionnaire “Evaluation Radiology Teaching Concept Scale” (ERTeCS) was designed. A qualitative and quantitative analysis of online collaborative learning discussions was performed to investigate radiology case based learning in a CSCL setting.

Results
The descriptive results of the ESR questionnaire show large differences in the organization of undergraduate radiology curricula in Europe. The results from the evaluation of the UGent innovative radiology curriculum show that students -both during pre-clinical and clinical years - appreciate particular curriculum components such as ex-cathedra lessons with syllabus, E-learning, E-testing, the use of E-cases, etc. During clinical years when students are oriented to the application of knowledge and skills, a high appreciation is expressed for practice linked curriculum components. The results show that students highly appreciate the radiology clerkship to learn to order and to interpret imaging studies. The clerkship provides students a unique possibility to attend various radiological examinations and to get access to a variety of radiology software systems. They develop a better understanding of radiology and improve their image interpretation skills. The clerkship experiences affect positively student perceptions about radiology as a profession. The results about case-based learning via computer supported collaborative learning groups show that this approach is effective in terms of process and learning performance. Critical is the role of scripting. The CSCL approach proves to be useful for students of different grade levels in view of developing their radiology diagnostic skills and problem solving abilities.

Conclusions
The differences between the radiology curricula in medical training in Europe introduces a focus on standardization of curricula in view of credit transfer between countries and different medical programs. This comparative study can be extended further by focusing on the analysis of instructional practices, internships, rewards systems, etc.

Also the positive findings about the UGent curriculum innovation induce a further reflection. Next to the implementation of qualitative studies about the curriculum innovation and the adoption of a true longitudinal perspective, it also seems critical to center on the teaching staff that is responsible for the curriculum implementation. Only when a continuous critical evaluation perspective is adopted, we will be able to attain and maintain the potential benefits of the curriculum innovation.
GENERAL INTRODUCTION

Introduction

The current state of radiology education

Radiological curriculum model of innovating teaching at Ghent University

Central research objectives

Overview of the studies in the dissertation

References
Introduction

The topic of this dissertation is the evaluation of an innovative radiology teaching system within the context of the medical school curriculum. In addition, an international perspective is adopted to position the local innovation within a broader frame of references. Depending on a particular medical school, educational programs and in particular the undergraduate training of radiology are different in terms of the curricular content, instructional formats (teaching approach, course design, evaluation approaches) and available human resources. Considering the influence of good teaching on learning performance, student satisfaction and future career choice\(^1\textendash}^2\), a better understanding of the content and nature of traditional and innovative instructional formats used in radiology is expected to be helpful to direct the current and future design of adequate learning and teaching environments and appropriate, state-of-the-art curricula. This introductory chapter presents an overview of earlier research in the field of the radiology curriculum as it is related to the medical curriculum. This overview will provide a rich background to ground the central research problem of this dissertation. The chapter therefore starts with an overview of literature about the current status of radiology education. Next, a descriptive perspective will be adopted to analyze critical features of the radiology curriculum at Ghent University. This will help to state the main research objectives and to develop an advance organizer about the different studies, conducted in the context of this dissertation to address the research problem.

The current state of radiology education

In the medical literature reviewing the status and innovation of medical education in Canadian and US medical schools, the main focus is on changes in organizational structures, staffing patterns, and educational approaches. The specific position of undergraduate radiology education in these educational programs is not clear. Mostly radiology is presented as an elective course, only a few medical schools include radiology as a requirement\(^3\textendash}^4\). Though the situation in Europe is more varied, we again observe that radiology is hardly a part of the formal undergraduate medical curriculum\(^5\textendash}^8\). In addition, thorough information about the current status of radiology teaching in Europe is lacking and also a comprehensive educational strategy to make radiology qualifications transferrable within Europe is not available. The latter is peculiar since recommendations for an innovative radiology curriculum design are on hand\(^9\).
Despite a lack of standards related to good educational practices in undergraduate radiology education, currently, a lot of research has been carried out regarding reorientations in the content and instructional design of the radiology teaching and learning experiences. Some clear trends can be derived from the related literature.

- Several authors explain why radiology should play a vital role in the medical school curriculum and advocate the need to improve undergraduate education in field of radiology. Educational research stresses to move away from a focus on single and/or isolated radiology learning experiences towards a stronger emphasis in on radiology in the undergraduate radiology curriculum and/or towards a fully integrated approach of radiology education.

- The current literature emphasizes the adoption of evidence-based approaches in the field of radiology education. Research additionally emphasizes the psycho-social aspects of learning and teaching in medical education. The particular interest is the role of Gestalt principles related to visual perception in radiology practices and education. Research acknowledged that Gestalt theory conceptions such as the figure–ground relationship and a variety of “grouping principles” (the laws of closure, proximity, similarity, common region, continuity, and symmetry) are underappreciated, but invaluable in radiology training. Applying these conceptions can help students to better understand and interpret radiology images. Research also centers on broad conceptions of learning as advocated in the medical education literature: “the ultimate goal of education is not to teach well, but for learners to learn well”. This stresses the importance of learning subdomains such as the cognitive (what we think and believe), the affective (what we feel and experience), and the psychomotor (what we do) subdomain in medical education. The affective learning domain is not to be underestimated in relation to clinical competences and clinical performance. Affective attitudes as reflected in emotional responses and personal experiences are sensitive to personal feelings and the context. As a result, instructional research increasingly focuses on the design and innovative features of learning environments as reflected in action learning and group work, the interactivity of the learning environment, the expansive use of multimedia, and the adoption of e-learning. The latter results in the implementation of
“blended” learning approach in which face-to-face instruction is mixed with e-learning, resulting higher efficiency, better learner achievement and higher learner satisfaction\textsuperscript{31, 39}. In this context, a large body of research evidence emphasizes that these innovations are only beneficial when they are perceived as such by the students\textsuperscript{40-41}.

- A specific part of the research literature discusses the adoption of problem based learning (PBL) in medical education\textsuperscript{42}. PBL especially builds a number of theoretical learning perspectives mainly rooted in (social) cognitive psychology\textsuperscript{43}. The literature also inspires future educational practices advantages and disadvantages of problem based learning in the field of radiology education\textsuperscript{44}. The available evidence especially centers on the potential of computer based case-based learning in radiology learning\textsuperscript{45-48}.

- Case based learning, set up via computer supported collaborative learning (CSCL) settings is a well established approach in the medical literature. But, it is a less studied domain in radiology education. CSCL approaches are assumed to be effective in terms of attaining learning goals and to enhance student satisfaction\textsuperscript{49-50}. Though a large number of studies report positive empirical evidence about CSCL\textsuperscript{51}, recent studies also point at critical issues to be considered in setting up advanced CSCL applications. First, authors address the non-conclusive results of a number of studies\textsuperscript{52-53}. Researchers also point to low or uneven levels of participation\textsuperscript{54-55}, low average levels of cognitive processing\textsuperscript{56-57}, the detrimental impact of weak levels of prior knowledge\textsuperscript{58}, and struggles with the structure in the discussions\textsuperscript{59}. These issues underscore the statement that online collaboration does not automatically lead to improved learning performance\textsuperscript{60}. This has resulted in a new generation of CSCL research and practices that stress the need to add structure to the collaborative tasks. Authors – in this context - have advanced the concept of scripting to refer to a variety of ways to structure the collaborative tasks\textsuperscript{61}.

These trends in recent research about medical education in general and the radiology curriculum in particular have inspired the innovation of the radiology learning and teaching approach at Ghent University, as discussed below.
The innovative radiological curriculum model of Ghent University

At Ghent University a large scale curriculum reform was introduced in 1999 building on a major shift from a conventional medical curriculum (CMC) to an integrated contextual medical curriculum (ICMC). The main features of the latter are: patient centered, student centered, community oriented, problem based and evidence based learning and teaching. Within an ICMC curriculum, attention is paid to a horizontal integration by linking different disciplines to a central theme (e.g., the cell), and a vertical integration by embedding four long term curriculum “lines”: the medical skills line, the social health system exploration line, the medical problem solving line, and the individual scientific project line.

The position of radiology in an ICMC curriculum has been well defined. An analytical way to conceptualize the Ghent university radiology curriculum is to build on the curriculum model of Coles and Grant.

This descriptive model describes a curriculum with three overlapping circles (Figure 1):

- The curriculum as it has been developed “on paper”
- The curriculum “in action”
- The curriculum “as experienced” by the students

Figure 1. A descriptive curriculum model, adapted from Coles and Grant.
Table 1. Ghent Faculty of Medicine and Health Sciences: Radiology curriculum

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SEMESTER 1</th>
<th>SEMESTER 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radiology</td>
<td>Radiology</td>
</tr>
<tr>
<td></td>
<td>Within Teaching Block</td>
<td>Within Teaching Block</td>
</tr>
<tr>
<td>1</td>
<td><strong>NO RADIOLOGY</strong></td>
<td><strong>NO RADIOLOGY</strong></td>
</tr>
<tr>
<td></td>
<td>Radio-anatomy of nervous system</td>
<td>Radio-anatomy of abdomen</td>
</tr>
<tr>
<td></td>
<td>Nervous System and Sense Organs</td>
<td>Gastrointestinal System, Endocrine Glands, Metabolism</td>
</tr>
<tr>
<td></td>
<td>*TH: 5h 15min</td>
<td>*TH: 96h</td>
</tr>
<tr>
<td>2</td>
<td>Radio-anatomy of musculoskeletal system</td>
<td>Radio-anatomy of thorax</td>
</tr>
<tr>
<td></td>
<td>Musculoskeletal System and Skin</td>
<td>Cardiovascular System, Respiratory System, Urinary Tract and Kidneys</td>
</tr>
<tr>
<td></td>
<td>*TH: 2h 30min</td>
<td>*TH: 2h 30min</td>
</tr>
<tr>
<td>3</td>
<td>Radio-anatomy genitourinary system</td>
<td>Reproduction and Sexuality</td>
</tr>
<tr>
<td></td>
<td>Basic principle of radiology</td>
<td>Diagnostic and Therapeutic Methods</td>
</tr>
<tr>
<td></td>
<td>*TH: 1h 15min</td>
<td>*TH: 11h 15min</td>
</tr>
<tr>
<td>1</td>
<td>Radiology of Heart, Lungs, Hematopoietic Organs and Kidneys</td>
<td>Problems of Heart, Lungs, Circulation, Hematopoietic Organs and Kidneys</td>
</tr>
<tr>
<td></td>
<td>*TH: 18h 15min</td>
<td>*TH: 172h</td>
</tr>
<tr>
<td>2</td>
<td>Radiology of Nervous system and eyes</td>
<td>Problems of Mental Health, Nervous System and Eyes</td>
</tr>
<tr>
<td></td>
<td>Pediatric radiology</td>
<td>Problems of Clinical Genetics, Obstetrics, Pediatrics and Adolescence</td>
</tr>
<tr>
<td></td>
<td>*TH: 6h</td>
<td>*TH: 97h</td>
</tr>
<tr>
<td>3</td>
<td>Radiology of the Locomotor System</td>
<td>Problems of the Locomotor System</td>
</tr>
<tr>
<td></td>
<td>TH: 17h 45 min</td>
<td>TH: 97h</td>
</tr>
<tr>
<td>4</td>
<td>Radiology: Capita Selecta</td>
<td>Capita Selecta from Hospital Medicine</td>
</tr>
<tr>
<td></td>
<td>*TH: 12h</td>
<td>*TH: 45h</td>
</tr>
<tr>
<td></td>
<td>Radiology: focused on Emergency Medicine</td>
<td>Specialist Care and Hospital Medicine focused on Emergency Medicine</td>
</tr>
<tr>
<td></td>
<td>*TH: 8h</td>
<td>*TH: 40h</td>
</tr>
</tbody>
</table>

* TH=Teaching Hours (the total of teaching hours: theory and practice (skills) hours)
The radiology curriculum “on paper”

The first circle represents “the curriculum as developed on paper” and comprises what has been written down in program descriptions, prospectuses, course descriptions, ECTS files, etc.

In the Ghent University pre-clinical and clinical part of the medical curriculum, radiology has been integrated into different learning modules. The time and attention, paid to radiology, varies between 1% to 27% of the overall module curriculum load. Table 1 and Figure 2 describe in detail the place of radiology courses within the medical curriculum and provide a quantitative analytical overview of the curriculum modules in terms of the specific content focus, and the proportion of teaching hours spent treating radiology content and skills. Students are exposed to radiology from year 2 to year 7 of their training. This implies they already get in touch with radiology during their preclinical years. Although only a small proportion of teaching and learning time is explicitly linked to radiology, radiology is nevertheless a consistent part of every curriculum year.

Figure 3 analyses the relative attention paid to radiology teaching throughout the entire curriculum, and considering the consecutive years in the medical training. Radiology plays a dominant role in the fourth and fifth year of medical training, due to the position of a number of completely radiology-oriented courses, e.g., “Introduction to radiology of diseases”. The total of teaching hours in medical curriculum devoted to radiology is 104 hours, with the exclusion of clerkship hours.
GENERAL INTRODUCTION

Fig 2. Overview of the integrated position of radiology throughout the medical curriculum.
The latter implies that radiology is an obvious part of the general Ghent University integrated medical curriculum. It is expected that this will contribute positive to perceptions about radiology in general and the radiology profession in particular.

The curriculum in action

The second circle in Figure 1 represents the “curriculum in action”, defined as how the curriculum on paper has been implemented during educational practice. To put the undergraduate radiology curriculum into operation, a variety of didactical components have been adopted: formal ex-cathedra sessions, a set of e-learning applications, computer-based assessment, radiology clerkships, radiology related scientific research activities, and radiology case-based learning. We outline the key characteristics of these six components.

1. Formal ex-cathedra lessons

Formal ex-cathedra lessons, building on a printed radiology syllabus, are the backbone of the didactical design in every year of the medical training, starting in year 2. Prior to the lecture students receive handouts of all slides. A handbook, underpinning the syllabus and recommended for future reading is available.
2. **E-learning applications**

Also e-learning applications are a well integrated component of the radiology teaching and learning approach at Gent University. A homemade e-learning system for radiology teaching and learning has been implemented since 2003. A key element is the self-assessment environment developed with the e-learning system. This system has been especially designed to be able to tackle a rich variety of medical images. Different types of questions can be developed (multiple choice, click-on the required structures or pathologic findings, fill-out word(s), open questions), based on cases and radiology images. Automated specific student feedback can be given to individual users testing their mastery of radiology knowledge and image interpretation skills.

3. **Radiology exams on PC**

At Ghent university, all radiology exams are set up via computer. This is a consistent evaluation approach during all curriculum years, with the exception of year 6 where – in addition - a interdisciplinary oral examination is set up. Specific and separate radiology exams are set up to assure that students do not “skip” radiology as a key component in the interdisciplinary context. Even when radiology is embedded within a large teaching block, a separate radiology exam is set up; e.g., in view of radiology anatomy, radiology of diseases, etc.

4. **Radiology clinical clerkships**

A fourth key component of the innovative ICMC curriculum – from year 5 on - is the clinical clerkship. Different types of radiology clerkships are in the clinical phase of the medical curriculum.

For students in year 5, an observation-based visit of the radiology department is planned during half a day. Clear **goals** guide this compulsory clerkship:

1. To experience the working of a radiology department (equipment, patient flow, image flow, reporting activities, administrative and logistic work, personnel involved, timing, waiting room, etc.).
2. To learn manipulating radiological CD’s from radiology units from different hospitals.
3. To learn working with a web-based Picture Archiving and Communication System (PACS) and solve radiological cases.
4. To answer related e-learning exercises.
Students of year 6 stay for a longer period - usually for one week - in a radiology department, and they get specific tasks to carry out. This compulsory radiology clerkship is a key ingredient of an interdisciplinary experience, that is additionally dealt with during an oral test at the end of the year.

The goals of this clerkship are:

1. To follow a selected number and types of radiological patient examinations.
2. To improve skills related to the interpretation of radiological images.
3. To work with web-based PACS (case-based learning) and CD’s.
4. To participate in routine clinical checkups.
5. To learn prescribing radiology examinations (Belgian and European guidelines for appropriate use of radiology: “when to order and what”).
6. To attend clinical-radiology conferences and multidisciplinary team meetings.

Students of the last training year (year 7) are split into two groups: (1) potential radiology residency candidates staying for a period of 12 weeks at a radiology department, versus (2) candidates opting for other medical specializations. The latter stay for a period of 3-6 or 9 weeks in a radiology department depending on their specialization option. The goals of these clinical elective clerkships are:

1. To attain a high level in the interpretation of radiology images.
2. To adopt in an efficient and effective way the prescription guidelines in view of radiology examinations (Belgian and European guidelines for appropriate use of radiology: “when to order and what”).
3. To experience and deal with a variety of radiology cases.

5. Radiology related scientific research

As a fifth component, students get the opportunity to carry out a radiology related scientific study (such as developing a literature research review, or setting up a small scale experimental study). The latter is possible from the fourth year on and can be part of the master thesis.

6. Radiology cases

Solving “radiology cases” is introduced in year 5 and 6, in the context of the clinical radiology clerkships.
Additionally, since 2008-2009, “Web-based” cases have also been introduced in year 5 and 7 in the context of interactive guided work sessions. The students solve the cases in small groups discussions, using the electronic discussion forum that is part of the electronic educational learning platform of Ghent University. Teaching staff gives feedback about the case solutions, and focuses on the accuracy and the rationale presented to ground the case related decisions. These case solutions are also essential part of the content to be studied in view of a final exam and for clinical exams.

**The curriculum as the students experience it**

The third circle in Figure 1 refers to “The curriculum as it is experienced by the students”. This stresses the central role of student perceptions about the key curriculum components presented above. These perceptions influence what students do and how they study, what they believe they should be doing, and the resulting learning outcomes.

Since the innovative radiology curriculum has been implemented, anecdotal evidence points at positive student perceptions in relation to the new instructional design. But a formal, and systematic evaluation of the radiology curriculum innovation has - until now - not been set up.

This brings us to the twofold central research problem dealt with in this PhD dissertation. The first research problem centers on the need to develop an in-depth understanding of the characteristics of the way European undergraduate radiological curricula have been implemented and what educational formats have been adopted. The second research problem centers on the perceived impact of the innovative didactical curriculum components as they have been implemented in the medical curriculum at Ghent University.

**Research objectives**

As described above, in view of developing a comprehensive strategy to develop and to standardize undergraduate radiology education, it is critical to develop a thorough understanding of the related curriculum content, and the instructional formats currently being used in European medical education. This will help the international benchmarking of radiology teaching systems in general and the innovative radiology curriculum of Ghent University in particular.
The related research objective (RO) as it is dealt with in the present dissertation, is

**RO 1:** To describe how undergraduate radiology teaching is organized in Europe and to identify related characteristics of the undergraduate radiology curriculum *(Chapter 1.1).*

Building on the second research problem, a number of research objectives are put forward that help to evaluate the implementation of the Ghent University approach to radiology teaching and learning in the contact of the medical curriculum:

**RO 2:** To investigate how students perceive the innovative undergraduate radiology curriculum at Ghent University, and what helps to explain differences in student perception *(Chapter 2.1).*

**RO 3:** To explore the perceived value of clinical clerkships in the radiology curriculum as well as the impact of radiology clerkship on students’ beliefs about the profession of radiology as a whole and as career *(Chapter 2.2).*

**RO 4:** To explore whether case-based learning, set up in a computer supported collaborative learning (CSCL) setting, results in student satisfaction and helps to develop and improve radiologic problem-solving abilities of medical students *(Chapter 2.3).*

**Overview of the studies in this dissertation**

A series of studies was conducted to tackle the four research objectives. Table 2 documents the chapters, study design, research instrument and related research techniques used in the different studies.

The general introduction provides an overview of the literature to develop an understanding of the current state of radiology education in general. Secondly, this chapter describes the particular radiology innovating teaching conceptions as they have been implemented in the Ghent University medical curriculum.

*The four original research studies*, presented in this thesis, can be divided into two parts.

*The first part* focuses on an international descriptive and comparative analysis of radiology curricula in a number of European countries. This study was based on a new research instrument: the “Questionnaire on undergraduate radiology teaching”.
This international survey-based benchmarking study (Chapter 1.1) describes how undergraduate radiology teaching is organized in Europe and identifies important differences in the characteristics of undergraduate radiology curricula.

The second part of the research builds on three studies—reported in three consecutive chapters—that study in a profound way the evaluation of the innovative radiology teaching and learning approach as it is implemented in the Ghent University medical curriculum.

Chapter 2.1 describes how the questionnaire “Evaluation Radiology Teaching Concept Scale” (ERTeCS) was developed. After testing the ERTeCS’s validity and reliability, this study gives an account of how students experience and perceive the innovative undergraduate radiology curriculum at Ghent University, and what helps to explain differences in student perceptions.

The next chapter (Chapter 2.2) centers on the importance of radiology clerkships in radiology education. The study focuses on the perceived value of clinical radiology clerkships as well as the impact of radiology clerkship on students’ beliefs about the profession of radiology as a whole and as a career.

Chapter 2.3 combines a quantitative and a qualitative research approach. The study initially builds on part of data from the ERTeCS survey with a particular focus on student perceptions about radiology case-based learning within a computer supported collaborative learning (CSCL) setting. Further, the study presents an analysis of the collaborative learning process, and the impact of the collaborative work on solving radiology cases in the CSCL setting.

Finally - in the concluding chapter - the general discussion summarizes the main findings and presents a structured discussion of the findings related to the research objectives, presented above. Limitations of the different studies, and practical implications, and directions for future research are addressed, before coming to a final conclusion.
Table 2. The overview of the chapters, study design, research instruments and research techniques.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Central research problem</th>
<th>Study design</th>
<th>Research instrument</th>
<th>Research design</th>
<th>Statistic tests</th>
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</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>The current state of radiology education</td>
<td>Descriptive survey based study</td>
<td>An electronic survey “Questionnaire on undergraduate radiology teaching”</td>
<td>Descriptive statistics</td>
<td></td>
</tr>
<tr>
<td>Radiological curriculum model of innovating teaching at Ghent University</td>
<td>To describe how undergraduate radiology teaching is organized in Europe and to identify related characteristics of the undergraduate radiology curriculum.</td>
<td>Quantitative cross-sectional longitudinal survey based study</td>
<td>A questionnaire “Evaluation Radiology Teaching Concept Scale” (ERTeCS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central research objectives</td>
<td>To investigate how students perceive the innovative undergraduate radiology curriculum at Ghent University, and what helps to explain differences in student perception.</td>
<td>Quantitative cross-sectional longitudinal survey based study</td>
<td>Questionnaire ERTeCS: Part “Clerkship” and Part “General radiology knowledge test”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overview of the studies in the dissertation References</td>
<td>To explore the perceived value of clinical clerkships in the radiology curriculum as well as the impact of radiology clerkship on students’ beliefs about the profession of radiology as a whole and as career</td>
<td>Quantitative cross-sectional longitudinal survey based study</td>
<td>Questionnaire ERTeCS: Part “Clerkship” and Part “General radiology knowledge test”</td>
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</tbody>
</table>

Part 1: Evaluation of the radiology teaching system in the international context

Part 2: Evaluation of the innovating approach of radiology teaching in medical curriculum at Ghent University

The literature is organized in line with the curriculum model of Coles and Grant.
Chapter 2.3
To explore whether case-based learning, set up in a computer supported collaborative learning (CSCL) setting, results in student satisfaction and helps to develop and improve radiologic problem-solving abilities of medical students.

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<td>Quantitative cross-sectional longitudinal survey based study</td>
<td>Questionnaire - ERTeCS: Part &quot;Radiology cases&quot;</td>
<td>Qualitative and quantitative study of group discussions (group level)</td>
<td>Content analysis of online group discussions</td>
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<th>1. Comparison of groups means from group discussions</th>
<th>1. Mann-Whitney U test</th>
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<td>1. Independent sample T test, Cohen's d</td>
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GENERAL DISCUSSION

Research focus of this dissertation
Overview of the research objectives and the related results
General discussion and conclusions
Strength and limitations
Implications of the research findings for educational practice
Directions for future research
References

Integration of the research findings

References


ORIGINAL RESEARCH

PART 1: EVALUATION OF THE RADIOLOGY TEACHING SYSTEM IN THE INTERNATIONAL CONTEXT
Chapter 1.1: Analysis of radiology education in undergraduate medical doctors training in Europe

Elena V. Kourdioukova\textsuperscript{a}, Martin Valcke\textsuperscript{b}, Anselme Derese\textsuperscript{c}, Koenraad L. Verstraete\textsuperscript{a}

\textsuperscript{a} Department of Radiology, Ghent University Hospital (UZG), MR/-1K12, De Pintelaan 185, B-9000 Ghent-Belgium
\textsuperscript{b} Department of Educational Studies, Ghent University, H. Dunantlaan 2, B-9000 Ghent-Belgium
\textsuperscript{c} Centre for Education Development, Faculty of Medicine and Health Sciences, Ghent University, De Pintelaan 185, B9000 Ghent-Belgium

PART 1: Chapter 1.1: Analysis of radiology education in undergraduate MD training in Europe

Analysis of radiology education in undergraduate medical doctors training in Europe

Elena V. Kourdioukova,*, Martin Valcke, Anselme Derese, Koenraad L. Verstraete

Abstract

Objectives: The purpose of the present study is to describe how undergraduate radiology teaching is organized in Europe and to identify important characteristics of undergraduate radiology curriculum.

Methods: An electronic survey on undergraduate teaching was distributed by the European Society of Radiology (ESR) to 38 national delegates of the ESR Education Committee.

Results: The "classic type" of radiology teaching method is more frequently than the "modular type". In 38% of medical training centres the first experience with radiology is in pre-clinical years. The students enrolled in the fourth medical year experience the largest involvement in radiology education. The total number of teaching hours (mean 89 h, median 76 h) varies across the countries and differs depending on the radiological topic (mean across all topics 14.8 h, median 13). Written tests and oral exams were the most frequently used examination modes. Clerkships are reported as a key part of training.

Conclusion: This first international comparative study of undergraduate radiological curriculum in Europe identifies a large number of differences in curriculum content and teaching methods throughout Europe. More research is needed to establish the radiological educational competences resulting from these differing curricula's to improve and to standardize the teaching according to (inter)national and institutional needs.

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1. Introduction

Medical school educational programs and undergraduate training of radiology in particular are not standardized throughout Europe [1–3] and United States (US) [4,5]. The mandatory nature of a formal radiology curriculum [6–9] and the needs for a formal, clearly structured radiology curriculum [6,9–12] have been widely discussed in the medical literature. However, only a few US schools include radiology as a required course. Mostly radiology is presented as an elective course with additional sporadic exposure to imaging techniques during medical education [4,5,12]. This is in contrast to research pointing at the increasing interest for an integrated approach towards radiology education as well as towards the content of an innovative radiology curriculum [10,11,13–19]. This has led to recommendations as to new frameworks for radiology curriculum design; such as the one provided by the Royal College of Radiologist (UK) [20]. Research has also shown the benefits of incorporating evidence-based practice education in radiology [21,22]. A positive effect has been reported in the US of early exposure to radiology in the early years of medical training or even in premedical years [11,19,23–25]. Lastly, radiology clerkship has been identified as an essential part of radiology curriculum. The educational benefits of different types of radiology clerkships point at improvement of students’ knowledge and interpretation skills as well as students’ satisfaction [8,26–29].

In view of developing a comprehensive strategy to develop undergraduate radiology education, it is critical to develop a thorough understanding of the broad curriculum content related to radiology, and to understand the instructional frameworks applicable to radiology education (teaching approaches, course set up, evaluation approaches, ...). Most research in this field originates from US based medical schools. Inclusive information about the current status of radiology teaching in Europe is lacking. Therefore, the present study describes how radiology teaching is set up in European medical schools to identify important characteristics of the European undergraduate radiological curriculum and the educational formats being adopted.

Considering this problem statement, the following research questions are formulated:

1. How is undergraduate teaching set up: what teaching methods are being used?
PART 1: Chapter 1.1: Analysis of radiology education in undergraduate MD training in Europe

2. In what year(s) of medical school do students study radiology?
3. What proportion of the curriculum focuses on radiology or radiology topics?
4. What type of staff is responsible for radiology education?
5. What radiology topics are examined and how are they being examined?
6. What is the nature and extent of radiology clerkships?
7. How many students are involved in radiology-related scientific work?
8. Is there an educational policy attracting students considering radiology as a career option?

2. Materials and methods

A questionnaire was developed under the umbrella of the Educational Committee of the European Society of Radiology (ESR). It was electronically distributed by European Society of Radiology (ESR) to 38 national member delegates of the Educational Committee. Each country was represented by one national delegate, who filled out the questionnaire about their own country, building on information obtained from their national educational board, radiology teaching staff, and chiefs of teaching hospitals. Responses were obtained from 34 respondents (89%) (Appendix A). The questionnaire (Appendix B) was developed to explore the duration of medical and radiology training, the curriculum content, the nature of instructional strategies, the human resources involved in radiology teaching, the assessment and evaluation approaches, the nature of clerkships in radiology departments, opportunities for students to participate in radiology research and the educational policy attracting students to consider radiology as a career option.

2.1. Statistical analysis

The questionnaire data were entered, and analyzed with SPSS version 15 software (Statistical Package for the Social Sciences, SPSS; Chicago, IL, USA). Mainly descriptive statistics were applied and a variety of tools to develop graphical representations of the results. Answers to open-ended questions were answered in view of identifying key themes.

3. Results

3.1. How is undergraduate teaching set up: what teaching methods are being used?

The duration of medical undergraduate education in 29 out of the 34 countries (85%) is 6 years. In some countries medical undergraduate education only takes 5 years (IE, UK, SE) 7 years (BE) or 7.5 years (NO).

The average number of the students enrolled in the last year across all countries is 326. Countries such as BY, EE, TR and UA report more than 500 students being enrolled in last year medical education.

In our questionnaire, we focused on the nature of the building blocks in undergraduate medical education: “classic building blocks” in which radiology is studied and evaluated independently versus “modular building blocks” that integrate and assess radiology within thematic modules covering e.g., body systems (e.g. thorax, abdomen, nervous system, . . .) and focuses on a variety of medical perspectives (e.g. internal medicine, surgery, pharmacology, . . .). In more than half of the countries (ES, IT, CZ, GE, HR, PT, BA, GR, HU, RO, PL, SI, BY, ME, NO, BG, UA, LV, LU, FR) classic building blocks dominate the curriculum, in about 18% (AT, TR, IE, DK, UK, NL) modular building blocks dominate. In about 20% of the countries both classic and modular building blocks are combined in the undergraduate curriculum (IS, BE, SE, EE, LT, MK, DE).

3.2. In what medical school year(s) do students study radiology?

Twenty six percent of the countries (AT, NL, TR, LU, UK, FR, CZ, PL, RO) reported that students receive their first radiology experience in the first year of medical training. In countries such as BE, DE, IE, ES, SE, LT, DK, BG, HU (26%), radiology starts in the second year. Very different are about 18% of countries where radiology is only presented for the first time in the fourth year (GR, IS, HR, BA, SI, MK). In IT radiology is only part of the medical curriculum in the fifth year.

In five countries (AT, NL, TR, LU, UK) radiology is a consistent part of the medical curriculum in every medical training year. On average, the largest proportion of radiology is presented during the fourth in most countries (73.5%).

3.3. What proportion of the curriculum focuses on radiology or radiology topics?

The total number of the teaching hours focusing on radiology varies considerable between countries (mean 89 h, median 76 h, minimum 19 h, maximum 212 h). It also varies depending the radiology topic. The average number of teaching hours for each topic is 14.8 (median 13 h) with a minimum of 3 h and a maximum of 40 h. Some trends can be observed when focusing on the attention paid to particular radiology topics.

The topic “Radiology of diseases” receives most attention (mean 38.6 h; median 28 h), followed by “Radiology techniques” (mean 19.4 h; median 10 h), and “Radiology anatomy” (mean 18.6 h; median 12). The teaching hours for specific topics of radiological education for each country are summarized in Table 1. The table also documents separately outliers and extreme values.

A graphical overview of composition of the radiology curriculum in all countries is shown in Fig. 1. As mentioned earlier, specific trends can be observed across the countries. A large proportion of teaching hours related to radiology of diseases is typical in most countries. There are some exceptions. For example, in AT the number of radiology anatomy hours (30 h) and hands-on: interpretation skills (26 h) are higher as compared to radiology of diseases (16 h). In EE, the radiology curriculum pays much more attention to hands-on (interpretation skills) teaching hours (70), radiology anatomy (36 h) and radiology techniques (30 h). And in BE the proportion of attention paid to the following topics is balanced: radiology anatomy (30 h), radiology of diseases (30 h) and hands-on (30 h). It is remarkable that LT reports a significant higher number of hours spent in relation to the guidelines for appropriate use of radiology (50 h), hands-on: interpretation skills (40 h), and the same level of attention (20 h) to radiology diseases, radiology anatomy and radiology techniques. In the curriculum of FR, we observe higher proportion of time linked to interventional radiology (32 h). The information of HR, HU and LU contains missing data, and ES only reported quantitative data in relation to radiology anatomy (40 h) and radiology diseases (80 h). The information of DK and NO suggest that the focus was on the total number of hours, since next the down break to radiology topics reflects a completely balanced picture.

Next to the differences in proportional attention paid to radiology topics, it is interesting to note that the variation in topics is different across the countries. In the questionnaire, seven radiology topics were presented to be analyzed in view of the national undergraduate medical curriculum: radiology anatomy, radiology techniques, radiology of diseases, interventional radiology, radiation protection, guidelines for appropriate use of radiology and hands-on: interpretation skills. In 17 countries, such as MK, BA, GR, HU, LV, PT, CZ, IS, ME, IT, PL, BE, SE, AT, DE, LT, EE (55%), all topics seem to be part of the curriculum. The topic hands-on: interpretation skills is lacking in 10 countries (32%: IE, RO, TR, UK, BG, UA, ES,
### Table 1

Proportion of the curriculum focusing on radiology topics in different European countries.

<table>
<thead>
<tr>
<th>Radiological topic</th>
<th>Mean (SD) hours</th>
<th>Median (hours)</th>
<th>Min. (hours)</th>
<th>Max. (hours)</th>
<th>Interval [25–75%] (n, %)</th>
<th>N countries answered</th>
<th>Outliers/extreme values (n)</th>
<th>N countries NOT answered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiology anatomy</td>
<td>16 (13.9)</td>
<td>12</td>
<td>2</td>
<td>52</td>
<td>2–6h (n = 6; 19%)</td>
<td>31</td>
<td>100 (n = 1)</td>
<td>2</td>
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<td></td>
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<td></td>
<td>5–20h (n = 18; 58%)</td>
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<td>21–52h (n = 7; 23%)</td>
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<td>AT BE BG EE ES GE NO</td>
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<tr>
<td>Radiology techniques</td>
<td>12.8 (10.0)</td>
<td>10</td>
<td>2</td>
<td>36</td>
<td>2–5h (n = 7; 23%)</td>
<td>30</td>
<td>76–100h (n = 3)</td>
<td>1</td>
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<td></td>
<td>21–36h (n = 5; 17%)</td>
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<td></td>
<td>DE DK EE ES GE SE</td>
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<tr>
<td>Radiology of diseases</td>
<td>20.5 (17.8)</td>
<td>26</td>
<td>4</td>
<td>70</td>
<td>4–15h (n = 6; 20%)</td>
<td>30</td>
<td>100–250h (n = 2)</td>
<td>2</td>
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<td></td>
<td>BA GR HU IE LV MK</td>
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<td></td>
<td></td>
<td>42–70h (n = 7; 23%)</td>
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<td>BG DE NO PL RS UA UK</td>
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<tr>
<td>Interventional radiology</td>
<td>4.0 (2.3)</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>1h (n = 3; 12.5%)</td>
<td>24</td>
<td>32–100h (n = 5)</td>
<td>5</td>
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<td>BA BE RO</td>
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<td></td>
<td>7–8h (n = 3; 12.5%)</td>
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<td></td>
<td>BA BY DE</td>
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<tr>
<td>Radiation protection</td>
<td>2.7 (1.4)</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>1h (n = 5; 18%)</td>
<td>27</td>
<td>10–40h (n = 3)</td>
<td>4</td>
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<td>BA BE BG BY DE EE GR HU IE LT LV ME NL PL PT RS SI TR</td>
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<td>5–8h (n = 7; 23%)</td>
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<td>IT SE</td>
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<tr>
<td>Guidelines for appropriate use of radiology</td>
<td>7.2 (5.8)</td>
<td>5</td>
<td>1</td>
<td>20</td>
<td>1–2h (n = 4; 17%)</td>
<td>24</td>
<td>35–52h (n = 3)</td>
<td>7</td>
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<td>BA BE CZ DE FR HU IS LT LV ME NL PL PT RS SI TR</td>
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<td></td>
<td>3–10h (n = 15; 62%)</td>
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<td></td>
<td>11–20h (n = 5; 21%)</td>
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<tr>
<td>Hands-on Interpretation skills</td>
<td>11.6 (11.5)</td>
<td>6</td>
<td>1</td>
<td>40</td>
<td>1–2h (n = 4; 20%)</td>
<td>20</td>
<td>70h (n = 1)</td>
<td>13</td>
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<td>BA GR MK NL</td>
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<td>22–40h (n = 6; 20%)</td>
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<td>IT SE</td>
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<tr>
<td>Total number of radiology teaching hours</td>
<td>89.2 (51.7)</td>
<td>76</td>
<td>19</td>
<td>212</td>
<td>19–43h (n = 6; 19%)</td>
<td>31</td>
<td>300h; 570h (n = 2)</td>
<td>1</td>
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<td>44–116h (n = 18; 58%)</td>
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<td></td>
<td>117–212h (n = 7; 23%)</td>
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<tr>
<td>Mean number of radiology teaching hours</td>
<td>14.8 (9.3)</td>
<td>13</td>
<td>3</td>
<td>40</td>
<td>3–6h (n = 8; 24%)</td>
<td>33</td>
<td>19–40h (n = 8; 24%)</td>
<td>1</td>
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PART 1: Chapter 1.1: Analysis of radiology education in undergraduate MD training in Europe

BY, DK, NO), the topic guidelines for appropriate use of radiology is lacking in 5 countries (16%: SI, UK, RS, BG, ES) and interventional radiology in 4 countries (13%; NL, UK, UA, ES).

The fourth year of medical training is reported to be the most important year for teaching all radiological topics except radiology anatomy and protection that dominate the third year curriculum. In year 3 and/or 5, some countries also focus on radiology techniques (38.2%; 26.5% respectively), radiology of diseases (47.1%; 32.4% respectively), interventional radiology (23.5%; 32.4% respectively) and hands-on: interpretation skills (23.5%; 17.6% respectively). Guidelines for appropriate use of radiology is taught as well in the fifth (29.4%), third and sixth year (26.5%, equal for both years).

Countries teaching radiology in the first year pay great attention to topics as radiology anatomy (77.8%) and radiology techniques (55.6%).

In the second year, radiology anatomy is still a hot topic (80%), in the third year radiology of diseases becomes more important (84%), but not in BE, NO and SE. The topic radiation protection seems to be an essential part of the third year curriculum in most of countries (73.7%) with exception of AT (taught in year 4), FR and LU (do not taught at all). NL (taught in years 1 and 4) and TR (taught in years 2, 4, 5). In the fifth year, dominant topics are interventional radiology (68.8%) but not in C7 (taught in year 4). NL and UK (do not taught at all). In most countries, guidelines for appropriate use of radiology is a key topic in year 6 (81.8%) except GR (taught in year 5) and TR (taught in years 3, 4 and 5).

It has to be stressed that the comparison of teaching hours is somewhat marred by the lack of a standardized total number of teaching hours in each country. This makes it less easy to understand the relative value attached to specific topics in the broader context of the medical curriculum.

3.4. What type of staff is responsible for radiology education?

In most European medical training centers radiology topics are taught by more than two staff members (85%). The average total number of radiology-related teaching staff is 12. In countries such as ES and GR (8%), only a single specialized staff member is reported. Medical training centers in IE, SE, ME (9%) prefer two specialized teachers for radiology.

It is apparent that radiology topics in the medical training centres of Europe are preferably taught by general or specialized radiologists. Also other medical experts participate in the teaching process, with the exception of interventional radiology that is only taught by radiologists. Radiology anatomy is taught by anatomist (23.5%), as well as by radiology trainees (14.7%). Radiology techniques are also introduced by physicist (20.6%), radiology diseases by radiology trainees (11.8%), radiation protection by physicist (29.4%), guidelines for appropriate use of radiology by radiology trainees (11.8%) and clinicians (11.8%). Hands-on: interpretation skills are also introduced by radiology trainees (20.6%).

3.5. What radiology topics are examined and how are they being examined?

Radiology exams mostly focus at the same time on different radiology topics and as such a part of a broader as part of larger exams ("modular" together with other disciplines) (44%). Exceptions are exams in relation to radiology techniques (38%), radiation protection examination (32%) and hands-on exams (18%), which are set up separately. Writing tests and/or oral examinations (65.6%); are the most commonly used methods for student evaluation. Computer-based evaluation and/or Objective Structured Clinical Examination (OSCE) evaluation are also set up, but are not widely used (25% and 21.5%, respectively). In LV, IT, PL, GE, DK, SI, NL (22%) all assessment is based on written exams. In BA, HR, MK, NO, LU, CZ (19%) most exams are set up orally. In the following countries both types of exams are combined: ME, PT, HU, UA, IS, DE, RO, RS (25%). BE is special in this way that all radiology exams are set up via a computer. In TR, 86% of the exams is OSCE based; this is 14% in PC. In AT, GR and BY, a mixture of the different types of assessment approaches is adopted (written exam, oral exam, on PC and OSCE). Again, different assessment type combinations are observed in IE, FR, SE, UK, and IT.

PC based exams are mostly organized in relation to radiology of diseases (25%), radiology anatomy (18.8%), and for radiology techniques (15.6%). OSCE is only applied for radiology diseases (18.8%) and interventional radiology (15.6%) to a lesser extent for other topics (9.4% equal for radiology anatomy, radiology techniques, radiation protection and guidelines for appropriate use of radiol-
ogy). Interpretation skills (hands-on) are mostly examined orally (21.9%).

3.6. What is the nature and extent of radiology clerkships?

Clerkships are reported as a key part of undergraduate radiology teaching (88%; no answer for LU and PL), with the exception of UK and DK where no clerkships are scheduled, but where students have a possibility to participate in clinical-radiology conferences and multidisciplinary meetings.

The curriculum position and the duration of radiology clerkships varies across European countries. In none of the countries, clerkships are reported during the second year. In NL and SE students already visit the radiology department in their first year. This visit helps them to observe daily practice in a radiology department. Students of the third (47%) and fourth (53%) year are increasingly involved in radiology clerkships for an average duration of 4 weeks (median 0.7 weeks) and 5 weeks (median 3.9 weeks) respectively. Countries such as MK, ME and RS report the longest clerkship period in the third year (24, 15 and 10 weeks). Countries such as HU, RO (14 weeks), CR (13 weeks) and NL (10 weeks) report the longest clerkships in the fourth year. In year 5, the longest clerkships is observed in GR (13 weeks) and IT (12 weeks). In year 6, the longest clerkship period is 16 weeks in DE. In a number of countries the radiology clerkship only takes only a single day (LV, EE, NO, AT, CZ) or two days (PT, BY, UA) during the entire medical training period.

The questionnaire did not focus on the type of the radiology clerkship. As a result, it is unclear whether there are required and/or elective clerkships. Additionally, little information was gathered about the tasks and responsibilities during the clerkships. The list of available information in this context contains: theory-based tasks such as reading, interpretation of images resulting from different radiological diagnostic modes: X-ray, MR exams, CT, etc., working cases (guided or unguided), observation of daily activities in the radiology department, taking part in routine clinical practices, or participating in conferences and/or multidisciplinary meetings.

3.7. How many students are involved in radiology-related scientific work?

Most institutions reported the opportunity to carry out the independent scientific work in radiology (85%, no answer for ES, HR, IS, EE, MK). The average number of students performing scientific work in radiology is 7, the median is 4. Involvement of a single student is reported in DK and NO. A maximal number of 28 students is reported in FR. Considering the fact that that the average number of students in the national medical training centre is 326 (27 countries), the average percentage of students involved in the scientific radiology work is only about 4%.

3.8. Is there an educational policy attracting students considering radiology as a career option?

Forty-four percent (15 countries) indicate the presence of a policy attracting students to consider radiology as a career option. The following typical policies were used:

- facilitating radiology courses;
- participation in scientific meetings;
- optional visits to the department;
- radiology brochures;
- scientific team working;

but also

- attracting students via interesting lectures and tutorials;
- presentation of the rapid developments in radiology and it is importance in patient care.

4. Discussion

As stated earlier, medical educational programs lack uniformity [1–5,30]. Analysis of the descriptive results of the ESR questionnaire, results in a comparable picture about the big differences in the organization of the undergraduate radiology curriculum in Europe. The differences start with the length of the undergraduate medical study. In most European countries, a medical education program takes 6 years, in some countries only 5 or 7 years are required. This is a striking difference with US based medical schools where the, undergraduate curriculum requires a 4-year program, based on 156 teaching weeks. This duration can be expanded with 2 to 3 years of “pre-med” courses [4,5]. European medical school duration is shorter than the program set up in the United Arab Emirates. Their 8-year program includes a compulsory 1-year internship [18]. It also has to be stressed that the size of training centre in Europe is very varied (average number in the last curriculum year is 326). Though the present study focuses on radiology undergraduate teaching, this information is important as a background to discuss the particular radiology education setting.

The findings of the present study confirm that radiology is taught via different types of medical undergraduate curricula, depending on the nature of the building blocks being used [16]: The Conventional Medical Curriculum based on the “classic building block”, the PBL Problem Based Curriculum based on “modular building blocks”, and the Hybrid Medical Curriculum that takes a position between the former two [31].

The Conventional Medical Curriculum mostly consists of a pre-clinical and a clinical part, where instruction is based on disciplines like anatomy, physiology, histology, internal medicine, surgery, pharmacology, and radiology. Assessment is linked to these individual disciplines and spread over one or more curriculum years. Radiology is usually presented and assessed in the clinical part where it is linked to the imaging of diseases. Radiology is sometimes also presented (as an extra) in anatomy course, with or without a specific evaluation part.

In Problem Based Curriculum, the building blocks are part of both the pre-clinical and clinical part of the curriculum. Instruction is based on comprehensive “modules” covering systems or parts of the body like thorax, abdomen, musculoskeletal system, nervous system, urogenital system, etc. Usually these modules cover “the normal human” in the pre-clinical years and the “patient” in the clinical years. In the pre-clinical phase; disciplines – including radiology – are combined to develop an understanding of different healthy human system (e.g. the gastro-intestinal system), until the whole “healthy” body has been covered. In the clinical phase, additional disciplines like internal medicine, surgery, pharmacology, radiology, etc. are combined. Each module is closed with an examination that focuses on all the disciplines covered in a specific module. In this building block approach, radiology is hardly approached as a separate discipline and therefore relatively underrepresented in the exams. This can lead to students “skipping” radiology and radiology anatomy, unless specific radiology exams have been set up.

Our analysis results show that the “classic” type of undergraduate teaching is dominantly used in European medical centres. This neglects the findings from research showing that an integrated approach of radiological education leads to more effective radiological education and helps to develop a positive attitude towards
radiology. The latter has implications for their future career choice [11,13-15,17-19]. In the present study, only 18% of centres adopt a "modular building block" type of curriculum and about 20% adopt a combination of classic and modular building blocks in their curriculum, suggesting an orientation towards a Hybrid Medical curriculum.

Early exposure – in the pre-clinical training years – to radiology education is expected to result in a more positive perception of radiology, increased interest in radiology as a carrier option and a reduction of negative stereotypes about radiologist [11,19,23-25]. The results of the present study indicate that early exposure is found in most European medical curricula. In 78% of the medical curricula, the first experience with radiology is already in the pre-clinical phase. However, in a small number of countries, radiology is introduced rather late in the curriculum: the fourth or fifth year.

Lee et al. [9] from the University of British Columbia stress that students benefit more from radiology instruction during a first curriculum year. Important is their additional finding that all students participating in their study expressed a desire to opt for radiology as an elective course in their final training year (4-year medical curriculum). This implies that it is important to make radiology visible throughout the curriculum [7,18,20]. From our research we understand that only in 15% of countries radiology is a consistent part in every curriculum year. This questions the situation in countries where radiology is only taught during one single year of the entire medical curriculum. The fourth year of medical training is seems to be very important year for teaching radiology, radiology was present in most of countries.

The results of our study show that the number of radiology teaching hours varies largely between European countries (countries mean 89 h, median 76 h, min 19 h, max 212 h) and depends on the radiological topic (Table 1). This large fluctuation is similar to results from a study focusing on undergraduate nuclear medicine teaching in European universities [3]. An important question arises from our observations: what is the required optimal numbers of radiology teaching hours in order to develop sufficient radiology competences in medical undergraduates? Unfortunately it is difficult to develop a clear answer to this question. Though sufficient information about the critical contents of a radiological curriculum are found in the literature, as well as a variety of curriculum framework [10,16,20], less is known about the efficiency of radiology teaching in terms of teaching hours and proportion of the medical curriculum. Data from curricula in non-European countries can help to develop some benchmarks. A Canadian Undergraduate Radiology Survey reported an average of 19.9 h of radiology lectures and an average of 45.6 h of radiology-related small group sessions [9]. Gundeman et al. reported 165 h of focused radiology instruction next to clinical rotation at Indiana University [7]. In the integrated curriculum of the United Arab Emirates University [18] radiology is present in the whole curriculum (8 teaching modules).

In the present ESR questionnaire seven radiology topics were presented as critical components of a radiology curriculum: radiology anatomy, radiology techniques, radiology of diseases, interventional radiology, radiation protection, guidelines for appropriate use of radiology and hands-on: interpretation skills. It is a reassuring finding that in 55% of countries all topics are present in their radiology curriculum. Some radiology topics are less represented in the curricula: hands-on: interpretation skills, guidelines for appropriate use of radiology and interventional radiology. But, due to the nature of our questionnaire it might be possible that these topics are taught within the context of radiology of diseases.

The trends across the countries are also determined in our research: the topic radiology of diseases deserves the most teaching hours because of the involvement of different organ systems in this topic, followed by radiological techniques due to wide spectrum of used imaging techniques and radiological anatomy. These topics are reported in all countries as a compulsory part of their curriculum. Moreover, radiological anatomy and imaging techniques (explanations of what is radiography, CT, ultrasound, MRI, angiography, interventional radiology and contrast media) in most of the countries incorporated in the pre-clinical part of the training because it is a required knowledge for further radiology teaching, for example, for teaching of radiology of diseases which are taught mostly in the clinical part of the training.

As to human resources involved in radiology education, 85% of European training centres involve more than two radiology staff members, and is interesting to see that the country average is twelve staff members. This finding reflects the situation in the Canadian Undergraduate Radiology Program where on average 10.9 radiology staffs are involved in teaching activities [9]. In the literature the importance is stressed that radiology staff adopt a consistent educational approach: compatible teaching methods, clear learning objectives pursued throughout the different curriculum years and taking into account the progressive level in radiology competences of undergraduate students [7]. This is also recognized as critical to extend multidisciplinary collaboration within the teaching context [20]. In most European medical training centers, the radiology topics are mainly taught by general or specialized radiologists or radiology trainees. Radiology techniques and radiation protection are additionally taught by physics, radiology anatomy is especially taught by anatomist. The latter is not surprising and even preferred in the literature due to the close linkages and needed level of integration between these disciplines [15,17,32]. The fact that specialized radiologists are involved is also favored in the literature. Radiologist have proven to be successful radiology educators [12,18,24,33,34]. As professionals, radiologists are able to develop a deeper level of understanding in students to interpret radiology issues, to answer in-depth questions and to solve the clinical queries from a comprehensive patient perspective. We therefore agree with the statement of Gunderman et al. that: “Radiologists teach diagnostic imaging better than anyone else” [7]. But attention should be paid to the adequate level of radiology teaching. There is a risk that specialized radiologists teach at a too high level and prefer to focus on rare diseases and advanced techniques, thus forgetting about first line radiology.

The involvement of specialized radiologists is a point of concern in the literature [12,27]. Concerns are raised about actual staff participation and the reward system adopted for teaching activities in radiological departments in e.g., US medical schools. In the current system, an appropriate remuneration system is lacking. Moreover, in short-staffed departments, staff will be hardly geared to be involved in teaching activities when the workload gets higher and there is hardly sufficient time for teaching. Unfortunately, this situation seems to be mirrored in European schools where clinical activities compete with involvement in teaching activities. Our research has some limitations in this context, since questions were included about the balance between teaching and clinical work of radiologist staff or about the incentives and reward system to foster an educational orientation of radiology staff. This could be taken up in a future study.

As part of the instructional design, evaluation is an important component of the educational experience. Both teachers and students benefit when learning objectives are clearly defined, learning activities are clear structured and systematically evaluated [35]. Building on the findings of the present study, it is clear that radiology-related evaluation is high on the agenda of all institutions. Radiology seems to be dominantly evaluated as part of a broader examination. But, when radiology is entirely incorporated within a broader examination setting (e.g. linked to evaluation
related to thorax disease, internal medicine, surgery, pharmacology, pathology), a risk exists that radiology assessment is limited to a few number of the questions and that (some) students will hardly learn radiology. To ensure that students master radiology-related competences, a separate radiology examination is required.

Written tests and oral examinations were the most commonly used methods to set up student evaluation. It is striking that computer-based assessment PC or/and OSCE evaluation are not widespread. But, these results are similar to the assessment methods adopted by US medical schools [27,36]. The important advantage of PC is the possibility to make appropriate questions with different levels of difficulty and with a high quality of images. For example, the type of questions as: “click on this or that anatomic structure” or “give the name of the anatomic structure/pathology” or “what is differential diagnosis?” can be used for testing of image interpretations skills or knowledge of radiological anatomy or radiology of diseases. The type question as “choose most appropriate imaging technique to solve this clinical question…” can be used for testing of knowledge of radiological techniques or appropriate use of imaging techniques.

The research results demonstrate the importance of radiological clerkships in medical undergraduate teaching. In 88% of the European teaching centers an opportunity to be involved in radiological clerkship is provided. Next to the observation that this clerkship is mostly set up during the third or the fourth year, we observe a number of countries were the radiology clerkships is limited to a couple of days. In the questionnaire, we did not focus on the nature of the radiology clerkship, so it is less clear whether clerkships are set up as a required or elective curriculum component. Results from research related to radiology clerkships at teaching hospitals in the US [27] show that less than one third of medical schools include required radiology clerkships in their program. These clerkships have a median length of 3 to 4 weeks, depending on the number of fourth year students involved.

Differences in duration of clerkships between countries can be linked to different types of radiology clerkships and the curriculum year they are being organized. This can also explain the different planning of observational visits versus active radiology clerkships throughout the medical curriculum.

The educational impact of different types of radiology clerkships has clearly been established. Researchers refer to an impact on knowledge of imaging modalities, interpretation skills and attitudes towards radiology [8,13,26,28,29,37,38]. Also, clerkships can be helpful to induce the interest for radiology among students, and the possibility to be involved in related scientific work. According to the Bologna declaration (The Bologna Declaration of June 1999, Prague communiqué of May 2001, Berlin communiqué of September 2003) scientific research is a key characteristic of the academic higher education curriculum. It is therefore encouraging that all institutions involved in the present study reported opportunities for students to carry out independent scientific work in the radiology field. As expected, the percentage of students interested in this area is rather low (4%).

There are several limitations to the present study. First, we have to point at the impact of response bias that is typical for survey-based studies. Though our response rate of 89% is acceptable, we nevertheless have to consider that only one representative of each country filled out the survey. This can be questioned considering the differences in country size, volume of the national health care system, and the number of medical training centers in a country. This implies that it was possible to determine between-country variation, but not the potentially large within-country variation.

Second, due to the nature of our study, analysis of the data was restricted to an exploration of quantitative data. No inferential statistical tests have been carried out. Thus, in future studies, it is advisable to involve more training centers for each country to get a clearer and more complete picture about radiological education across different training centres in Europe.

Thirdly, the quantitative results show some strikingly large differences, for example, the differences in teaching hours related to radiology teaching. This implies that a focus on means and the median is less relevant. Future studies should focus on these large differences and set up analysis of outliers and extreme values. As suggested in the results section, some survey data suggest that respondents might have interpreted questions in a particular way (mixing up total hours spent on radiology teaching and hours devoted to specific radiology topics). A cross-validation of the data by adding e.g., qualitative interviews could help to develop a more in-depth and controlled picture. Additionally, analysis results could be fed back to respondents for cross-checking.

The future research could also take an inventory of the teaching activities during clerkships and staff participation on it, and used rewards systems across Europe. These topics were not intended in this research but will be very useful for better understanding of curricular difference and institutional needs across the European countries. In addition, the student perspective could be considered by involving representative samples of students in the study. This would help to develop a picture of student perspectives on radiology teaching.

Acknowledgements

Special thanks go to E. Breanach, Chairman ESR Education Committee for his cooperation and essential contribution in the distribution of this cross-national survey. Great thanks are due to all members of the ESR educational committee who responded to the questionnaire.

Appendix A. List of countries in the “ESR survey on undergraduate teaching”

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<tr>
<th>Country</th>
<th>Description</th>
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<tr>
<td>AT</td>
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<td>BA</td>
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<td>United Kingdom</td>
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Appendix B.

Questionnaire on Undergraduate Radiology Teaching (ESR Education Committee)

Country (eventually + region) : ....................................................

Name of Teaching Centre : ....................................................

1. How is undergraduate teaching done – “method”:
   □ classic type = radiology as independent discipline with own exam
   □ modular type = radiology within module (e.g. abdomen, neuro, ...) and part of large
     exam (e.g. with internal medicine, surgery, pharmacology, ...)
   □ other teaching method: specify: ...................................................
   □ Is e-learning available? : ? No ? Yes + specify method and facilities .................................

2. In which year(s) of medical school do students encounter “radiology” ? (Choose 1 or more)
   □ Y1 □ Y2 □ Y3 □ Y4 □ Y5 □ Y6 □ Y7

3. Contents and human resources: "Who teaches what and when?"
   Select topic + mention number of hours + in which year(s) + who is teaching it. (Choose 1 or more)
   Who is teaching: select RSTCGPAO and underline the teacher who is teaching majority of this topic.
   Example: RSTCGPAO = Radiologist and anatomist are teachers in this topic, but radiologist teaches majority of this topic

<table>
<thead>
<tr>
<th>Codes “teacher” : Radiologist and/or</th>
<th>Non-radiologist</th>
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<tbody>
<tr>
<td>General Radiologist (R)</td>
<td>Clinician (C)</td>
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<tr>
<td>Subspecialised radiologist (S)</td>
<td>Physicist (P)</td>
</tr>
<tr>
<td>Radiology trainee (T)</td>
<td>Other teacher + specify (O)</td>
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</tbody>
</table>

□ Radiological anatomy .......... hours/year(s) ............ by RSTCGPA

□ Radiological techniques .......... hours/year(s) ............ by RSTCGPA

□ (x-ray; CT, MRI, US, contrast media, ...)

□ Radiology of diseases .......... hours/year(s) ............ by RSTCGPA

□ Interventional radiology .......... hours/year(s) ............ by RSTCGPA

□ Radiation protection .......... hours/year(s) ............ by RSTCGPA

□ Appropriateness criteria .......... hours/year(s) ............ by RSTCGPA

Criteria for appropriate use of radiology (what to order when) ~ “guidelines”

□ “hands-on” .......... hours/year(s) ............ by RSTCGPA

Specify: US, (web)pacs training, work with CD, other , .....................

□ other + specify .......... hours/year(s) ............ by RSTCGPA

4. Human resources: How many are involved in “teaching radiology”?
   □ 1 dedicated teacher
   □ More teachers + specify : ............
   □ 2 dedicated teachers

5. Exams: Which topics are examined and how are they examined? (Choose 1 or more)
   - Specify separate (S) or oral / written / pc / OSCE
   - with other disciplins (D) (O) / (W) / (PC) / OSCE
PART 1: Chapter 1.1: Analysis of radiology education in undergraduate MD training in Europe

References

ORIGINAL RESEARCH

PART 2: EVALUATION OF THE INNOVATING APPROACH OF RADIOLOGY TEACHING IN MEDICAL CURRICULUM AT GHENT UNIVERSITY
Chapter 2.1: The perceived long-term impact of the radiological curriculum innovation in the MD training at Ghent University

Elena V. Kourdioukova\textsuperscript{a}, Martin Valcke\textsuperscript{b}, Koenraad L. Verstraete\textsuperscript{a}

\textsuperscript{a} Department of Radiology, Ghent University Hospital (UZG), MR/-1K12, De Pintelaan 185, B-9000 Ghent-Belgium

\textsuperscript{b} Department of Educational Studies, Ghent University, H. Dunantlaan 2, B-9000 Ghent-Belgium

The Perceived long-term impact of the radiological curriculum innovation in the medical doctors training at Ghent University

Elena V. Kourdioukova\textsuperscript{a,*}, Martin Valcke\textsuperscript{b}, Koenraad L. Verstraete\textsuperscript{a}

\textsuperscript{a} Department of Radiology, Ghent University Hospital (UGZ), MR-1, 3000 Gent, Belgium
\textsuperscript{b} Department of Educational Studies, Ghent University, P. De Pinteelaan 185, B-9000 Ghent, Belgium

\textbf{ABSTRACT}

Objectives: How do students experience and perceive the innovative undergraduate radiology curriculum at Ghent University, and what explains differences in student perception?

Methods: A survey was presented to the 2008 cohort of students enrolled in the undergraduate medical curriculum at Ghent University. The survey focused on their experiences and perceptions in relation to the innovative undergraduate radiology teaching.

Results and conclusion: The present research results point at a favorable perception of the innovative radiology curriculum components. The study points – both during pre-clinical and clinical years – at the appreciation for curriculum components that combine traditional curriculum components (e.g. cathedral lessons with syllabus) with distance learning components such as E-learning and E-testing. In clinical years – as expected – students switch to the application of knowledge and skills and therefore heavily appreciate practice linked curriculum components.

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1. Introduction

In recent years, many medical schools have undergone curricular reforms and have implemented innovations regarding the content and instructional design of the teaching and learning experience. A main goal of these curriculum innovations is to enhance the efficiency and efficacy of the teaching approach, resulting in better learning performance. Consequently, research importance to reconsider the nature of the learning environment \cite{1,2,3}. In this context, Hutchinson \cite{4} points out that "the teaching methods should build on learners’ experience, creating collaborative environment". Other authors point at different innovative features of the learning environment, such as action learning and group work \cite{5}, an emphasis on the interactivity of the learning environment \cite{6}, the expansive use of multimedia \cite{7,8,9,10,11,12,13,14,15,16}, the adoption of E-learning \cite{8,10,16}, etc. The approach of "blended" learning \cite{9,17} – in which face-to-face instruction is mixed with E-learning – appears to be particular useful and efficient in terms of learner achievement and satisfaction. Although there are a lot of variation in radiological education across institutions in US, Canada and Europe \cite{18,19,20}, the value of effective and efficient radiology teaching \cite{21,22,23}, based on sound principles derived from evidence based learning theories \cite{24} is very important for the future of radiology as a profession.

Kratwohl, Bloom, and Masia \cite{25} have found that educational objectives can be structured along three learning domains: cognitive (what we think and believe), affective (what we feel and experience), and psychomotor (what we do). They described the affective learning as "emphasizing a feeling tone, an emotion, or a degree of acceptance or rejection" (p.7). It is known that attitudes are strong predictors of behavior \cite{26,27} and that they play a mediating role in the relationship between clinical competences and performance \cite{28}. The redesign of a learning environment will not automatically influence its efficiency and efficacy and/or result in better learning performance. Research consistently emphasizes that the way students experience and perceive their learning environment mediates the efficiency and efficacy of an innovative design \cite{29,30}. In addition, these perceptions differ depending on the specific learning needs of students in the pre-clinical or clinical phase of their medical training \cite{31}.

The emphasis on student experiences and perceptions introduces the relevance of studying student attitudes towards curriculum innovations. The present study builds on the critical role of student perceptions as it is linked to the evaluation of a large scale innovation project in radiology teaching at Ghent University, Belgium. The originality of the present study is that the entire radiology curriculum is studied as it is interwoven with the seven-year medical curriculum. As such, also the long-term effects on student perceptions of the different key elements of the curriculum innovation can be unveiled and analyzed.

* Corresponding author. Tel.: +32 0 9 332 1099; fax: +32 0 9 332 4099, E-mail address: elena.kourdioukova@ugent.be (E.V. Kourdioukova).
1.1. Description of the undergraduate radiology curriculum at Ghent University

At Ghent University a large scale curriculum reform was introduced in 1999 with a switch from a conventional medical curriculum (CMC) to an integrated contextual medical curriculum (ICMC). The main features of the latter are: patient centered, student centered, community oriented, problem and evidence based learning and teaching [32]. Within an ICMC curricula attention is paid to a horizontal integration by linking different disciplines to a specific central theme and vertical integration by embedding four continuous curriculum “lines” in the program: medical skills, exploration of the health system, medical problem solving, and an individual scientific project.

The place of radiology in an ICMC curriculum is well defined. Radiology is integrated in different modules covering body systems or body part (like thorax, abdomen, musculoskeletal system) in the pre-clinical and clinical part of the training. The basic structure of the Ghent University undergraduate radiology curriculum is shown in Fig. 1. At the same time, also the different didactical approaches are highlighted: a radiology syllabus, radiology teaching sessions, an E-learning environment, radiology PC based assessment, radiology clerkships, radiology related scientific research activities, and radiology cases. We give an outline of the key characteristics of these six components.

Formal ex-cathedra lessons building on a radiology syllabus persist throughout all years of medical training starting in year 2. Students receive prior to the lecture handouts of all slides. A handbook, underpinning the syllabus and recommended for future reading is available.

Also E-learning applications are a well integrated component of the radiology teaching approach at Gent University. An open-source E-Learning system is in use since 2003. A key element in this environment is the self-assessment exercises developed with Telrad system. The system developed is especially designed in view of working with a rich variety of medical imaging output. Different types of questions can be adopted (multiple choice, click-on, fill-out word(s) and open questions); building on cases, and radiology images. Students get automated individual feedback in view of updating their knowledge and skills. In the Ghent contest, all radiology exams are set up via PCs and this consistently in all curriculum years; with the exception of year 6 where an interdisciplinary oral examination is adopted. This focused radiology exam is set up to assure that no students “skip” radiology as a key component in the interdisciplinary context.

A fourth key component of the innovative ICMC curriculum – from year 5 on – is the clinical clerkship. Different types of radiology clerkships are provided for clinical years students.

For the students of year 5, an observation-based visit of the radiology department is planned during half a day. Clear goals guide this required structured, and guided clerkship:

1. To demonstrate the working of radiology department (the equipment, patient flow, image flow, reporting, administrative and logistic work, personnel involved, timing, waiting rooms, etc.).
2. To learn to work with radiological CDs from different hospital settings.
3. To learn to work with web-based PACS and solve radiological cases.
4. To answer E-learning exercises.

Students of year 6 stay for a longer period in the radiology department; usually for 1 week and they get specific tasks to be carried out. This required radiology clerkship is a key ingredient that contributes to their involvement in the interdisciplinary oral examination at the end of year. The goals of this clerkship are:

1. To follow a selected number and type of radiological examinations.
2. To improve the skills related to the interpretation of radiology images.
3. To learn working with web-based PACS (case-based learning) and CDs.
4. To participate in routine clinical practices.
5. To learn developing radiology prescriptions (Guidelines for appropriate use of radiology: “when to order and what”).
6. To attend clinical-radiology conferences and multidisciplinary team meetings.

Students of the last training year (year 7) are split into two groups: (1) potential Radiology Residency candidates staying for a period of 12 weeks at the radiology department, and (2) candidates opting for other medical specializations. The latter stay for a period of 3–6–9 weeks depending on their specialization option. The goals of these clinical elective clerkships are:
Table 1
Measurement of reliability of the Evaluation Radiology Teaching Concept Scale (ERTecS).

<table>
<thead>
<tr>
<th>Subscale</th>
<th>α</th>
<th>Statements</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiology teaching</td>
<td>0.81</td>
<td>Radiology is well integrated into the medical training as a whole</td>
<td>977</td>
<td>4.36</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radiology courses is well integrated in whole of the block-system, which makes it easier for me to place, interpret and process the learning substance</td>
<td>977</td>
<td>4.14</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The lecturer is aware of the contents of the curriculum and the lesson benefit from this (no overlap, reference to other courses)</td>
<td>977</td>
<td>4.08</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The knowledge of the radiology lecturer goes beyond radiology in strict sense (topic matters, clinic, etc.)</td>
<td>977</td>
<td>3.92</td>
<td>0.89</td>
</tr>
<tr>
<td>Radiology syllabus</td>
<td>0.72</td>
<td>Learning objectives of radiology syllabus are clearly formulated</td>
<td>977</td>
<td>3.94</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The radiology syllabus is clear structured (main and second points are distinguished, syllabus is easy to process)</td>
<td>977</td>
<td>3.38</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radiology syllabus contains sufficient references to further sources where background information can be found</td>
<td>977</td>
<td>3.64</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The reference book for radiology has well chosen (comprehensible, student friendly, practical oriented, etc.)</td>
<td>977</td>
<td>3.47</td>
<td>0.89</td>
</tr>
<tr>
<td>Radiology E-learning</td>
<td>0.91</td>
<td>E-learning is very useful</td>
<td>977</td>
<td>4.35</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E-learning exercises are accessible (from home or elsewhere)</td>
<td>977</td>
<td>4.26</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E-learning exercises are a good addition to the radiology syllabus</td>
<td>977</td>
<td>4.30</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I am familiar with E-learning exercises</td>
<td>977</td>
<td>4.64</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I am able to perform E-learning exercises independently</td>
<td>977</td>
<td>4.18</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The feedback during E-learning exercises is useful</td>
<td>977</td>
<td>4.14</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I use the feedback during the E-learning exercises</td>
<td>977</td>
<td>4.03</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E-learning exercises are essential to the preparation for my exams</td>
<td>977</td>
<td>4.26</td>
<td>0.91</td>
</tr>
<tr>
<td>Radiology E-testing</td>
<td>0.84</td>
<td>The E-test is corresponds to the learning objectives</td>
<td>977</td>
<td>4.13</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>There was clarity in advance concerning the E-test (multiple choice questions, open questions, interpretation of images, theory, etc.)</td>
<td>977</td>
<td>4.06</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The exam questions on E-test correspond to the expectations (both in terms of degree of difficulty and type of questions, etc.) lecture creates by with example questions, method of teaching, and e-teaching</td>
<td>977</td>
<td>3.72</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The E-test questions are worded such that if you have studied the subject, you can come away from exam satisfied</td>
<td>977</td>
<td>3.71</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I think that E-testing is a good, reliable way of taking exams (the result reflects my knowledge and skills)</td>
<td>977</td>
<td>4.07</td>
<td>0.72</td>
</tr>
<tr>
<td>Radiology clerkship</td>
<td>0.88</td>
<td>During the radiology clerkship I was able to attend various radiological examinations</td>
<td>355</td>
<td>3.90</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I was able to solve the clinical questions posed during radiological examinations</td>
<td>355</td>
<td>3.32</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>My skills to interpret radiological images improved during the clerkship</td>
<td>355</td>
<td>3.32</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>During the clerkship I learned to work with radiological CDs from the various hospitals</td>
<td>355</td>
<td>3.33</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I was able to work independently with radiological CDs from the various hospitals</td>
<td>355</td>
<td>3.33</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>During the clerkship I learned to work with PACS system</td>
<td>355</td>
<td>3.33</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I was able to work independently with web-PACS system</td>
<td>355</td>
<td>3.33</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>During the clerkship I learned to correctly prescribe a radiological examination</td>
<td>355</td>
<td>3.33</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I was able to correctly prescribe a radiological examination independently</td>
<td>355</td>
<td>3.33</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I believe taking part in multi-disciplinary staff meetings during the radiology clerkship offers added value to the clerkship</td>
<td>355</td>
<td>3.22</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I found my participation in multi-disciplinary staff meetings during the radiology clerkship informative and fascinating</td>
<td>355</td>
<td>3.32</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>There is sufficient variation in tasks the student must perform during the clerkship</td>
<td>355</td>
<td>3.25</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I improved my knowledge of radiology during the clerkship</td>
<td>355</td>
<td>3.24</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I believe the supervision by doctor and radiologists was optimal during clerkship</td>
<td>355</td>
<td>2.88</td>
<td>0.65</td>
</tr>
<tr>
<td>Radiology cases</td>
<td>0.69</td>
<td>The sufficient number of cases are offered to solve</td>
<td>355</td>
<td>3.60</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Working in small groups on a particular radiology case is interesting because you learn from each other by discussing things together</td>
<td>355</td>
<td>3.28</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Working in small groups on a particular radiology case interesting because the problem is solved more quickly</td>
<td>355</td>
<td>3.30</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Working in small groups on a particular radiology case interesting, because we can solve the case using hours on the university's electronic learning platform</td>
<td>355</td>
<td>2.90</td>
<td>0.93</td>
</tr>
<tr>
<td>Radiology research</td>
<td>0.95</td>
<td>The research task was very interesting, I found it fascinating and informative</td>
<td>355</td>
<td>3.92</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I received enough support and supervision from my promoter and co-promoter</td>
<td>355</td>
<td>3.96</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I have adequately helped to find suitable sources of information (internet, periodicals, books, etc.) to be able to carry out my research</td>
<td>355</td>
<td>3.97</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I had sufficient time to be able to carry out my research carefully</td>
<td>355</td>
<td>3.92</td>
<td>0.18</td>
</tr>
</tbody>
</table>

N = number of respondents, M = mean, SD = standard deviation, α = Cronbach's α.
* The items are scored from “total disagree” (1) to “total agree” (5).
1. To attain a high level of radiology image interpretation.
2. To learn developing prescription according to the guidelines for appropriate use of radiology.
3. To deal with a variety of radiology cases.

As a fifth component, students get the opportunity to carry out a radiology related scientific study (such as developing a literature research review or setting up a small scale experimental study). The latter is available from the fifth year on.

Lastly, the curriculum innovation entails working with radiology cases. This was usually introduced in year 5 and 6, in the context of the clinical-radiology clerkships. Since 2008–2009, “web-based cases” have been introduced in year 5 and 7 in the context of interactive guided working sessions. The students are expected to work together in small groups to discuss and to solve the cases using the electronic discussion forum that is part of an electronic educational learning platform at Ghent University. Teaching gives feedback about the case solutions, and focus accuracy and the rationale presented to ground the decisions. These case solutions are also essential part of the subject to be studied in view of final exam.

Since the start of the curriculum, anecdotal evidence points at positive student attitudes towards this new instructional program. But a formal, and systematic evaluation was – up till now – not set up. The present article centers on the results of a cross-sectional longitudinal study to study the perceived impact of the new curriculum as derived from student attitudes.

1.2. Research questions

In view of this study, one key research question is studied: What is the nature of student attitudes towards the key components of the innovative radiology curriculum. In addition, we explore to what extent student perception shifts depending on their training year.

2. Materials and methods

2.1. Participants and procedures

The students enrolled as second to seventh year medical students at Ghent University were invited to participate in the study. A total of 1117 students were asked to complete questionnaire, focusing on their attitudes towards the different radiology curriculum components. First year students were not asked to participate in this survey since radiology is only part of the curriculum from the second year on.

Participants filled out the questionnaire anonymously after obtaining informed consent. The questionnaire was accompanied by a letter giving background information about the objectives of the study. Participation was voluntary and students were informed that neither participation nor non-participation would affect their grades. Ethical approval was granted by the Human Investigation Ethical Committee of the Ghent University Hospital.

2.2. Design and development of the Evaluation Radiology Teaching Concept Scale (ERTeCS)

The Evaluation Radiology Teaching Concept Scale (ERTeCS) consists of 104 items focusing on background variables, student perceptions in relation to radiology curriculum components, mastery of radiology knowledge and skills, and the orientation towards the radiology profession. This new questionnaire was developed after analysis of the literature, observation of radiology teaching activities and on the base of focus groups interview results. Two focus group sessions were set up [33] with students from different training years, to identify the way they perceive the curriculum, what they consider to be critical to learn and to be taught. This resulted in a preliminary framework that – in combination with the literature review results – was discussed with radiology teaching experts and academic staff from Ghent University and Maastricht University to assure the appropriate content focus of the questionnaire.

Of the 104 items, 74 focus on radiology curriculum components. Out of these 74 statements, 63 items focused in particular on student attitudes towards specific undergraduate radiology curriculum components. Each item was developed as a statement, and respondents were invited to indicate their level of agreement on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). Eight open ended questions were presented to give students the opportunity to give comments and suggestions about different aspects of the radiology learning environment. For example “give further comments or explain your answer choice on certain item about radiology E-learning”. Lastly, seven knowledge test radiology multiple choice questions and three radiology image interpretation questions were presented to the students. Lastly, items were added centering on demographics, such as study year, gender, type of student (regular student versus student with an Individualized Study Trajectory), academic performance indicators (pass grades of former academic year).

2.3. Psychometric quality of the ERTeCS attitude scale

In the present article, we mainly focus on the 63 items capturing student attitudes towards the radiology curriculum components. These items were developed to develop a better understanding of student perceptions about the learning environment. Seven subscales can be distinguished, considering what component is being focused upon: “Radiology teaching”, “Radiology syllabus”, “E-learning”, “E-testing”, “Radiology clerkship”, “Radiology cases” and “Radiology research”. Standardized sum-scores were calculated for the entire attitude scale and for each specific subscale (min 1–max 5). The exploratory and confirmatory factor analyses were applied to study the factor structure and fit of the subscales. Using exploratory factor analysis we eliminated items with weak factor loadings. This led to the final 44-item scale. Table 1 lists the items, structured according to the seven components. The scale structure, obtained on the base of the exploratory factor analysis was next analyzed on the base of confirmatory factor analysis. Building on the criteria presented by Bentler [34], the resulting goodness-of-fit indices reflect a moderate to good fit of the model (Table 2). Nevertheless, we have to stress large RMSEA indices that will require special attention in subsequent research about the instrument. In Table 1, we also report Cronbach’s α for each subscale. This reliability coefficient ranges from 0.72 to 0.95 reflecting acceptable to very good reliability scores.

For the purpose of this report, an independent English translator rendered the original Dutch questionnaire to English. A native speaker translated the statements back to Dutch.
PART 2: Chapter 2.1 The perceived long-term impact of the radiological curriculum innovations in the MD training at Ghent University

Table 3
Results of the general linear model (ANOVA) in relation to the differences in student attitude towards components of the radiology curriculum according to training year.

<table>
<thead>
<tr>
<th>Curricula component</th>
<th>Mean scores (SD) – N</th>
<th>ANOVA</th>
<th>Test between subjects ( F )</th>
<th>Effect size (partial eta squared)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( N = 9/1 )</td>
<td>( N = 152 )</td>
<td>( N = 219 )</td>
<td>( N = 211 )</td>
</tr>
<tr>
<td>Radiology teaching</td>
<td>4.05 (0.69)</td>
<td>3.56 (0.61)</td>
<td>3.06 (0.69)</td>
<td>4.21 (0.66)</td>
</tr>
<tr>
<td>Radiology syllabus</td>
<td>3.61 (0.68)</td>
<td>3.13 (0.60)</td>
<td>3.69 (0.65)</td>
<td>3.71 (0.67)</td>
</tr>
<tr>
<td>E-learning</td>
<td>4.19 (0.69)</td>
<td>3.57 (0.64)</td>
<td>4.26 (0.63)</td>
<td>4.17 (0.59)</td>
</tr>
<tr>
<td>E-testing</td>
<td>3.94 (0.59)</td>
<td>3.90 (0.16)</td>
<td>4.04 (0.66)</td>
<td>3.85 (0.65)</td>
</tr>
<tr>
<td>Radiology clerkship</td>
<td>3.29 (0.41)</td>
<td>N = 355</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Radiology cases</td>
<td>3.50 (0.61)</td>
<td>N = 355</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Radiology research</td>
<td>3.94 (0.69)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

\* \( p < .001 \).

4. Statistical analysis

In views of studying our research questions, statistical analyses were carried out with SPSS version 15 (Statistical Package for the Social Sciences, SPSS, Chicago, IL, USA). Quantitative data were initially analyzed with descriptive statistics after controlling accuracy of data entry, missing values and outliers. Analysis of variance (ANOVA) and multiple pairwise comparison (Tamhane’s T2 post hoc test) were used to compare attitude scores of students enrolled in different training years. \( P \) value was set at .05 to decide about the significance in differences. Effect sizes were calculated using Cohen’s \( d \).

3. Results

3.1. Response rate and profile of respondents

A total of 977 (response rate 87.5%) completed and returned the questionnaire: year 2 (\( n = 192/235; 81.7\% \)), year 3 (\( n = 219/250; 87.6\% \)), year 4 (\( n = 211/223; 94.6\% \)), year 5 (\( n = 161/188; 85.6\% \)), year 6 (\( n = 122/147; 82.9\% \)), year 7 (\( n = 72/84; 85.7\% \)). Sixty-five percent of the respondents are female (\( n = 634 \)) and 35% are men (\( n = 343 \)). Most of the respondents were regular students (94%) and only 6% were enrolled with an Individualized Study Course program.

3.2. Student perceptions of the undergraduate radiology curriculum

Table 3 documents the mean standardized sum-scores in relation to the overall ERTES5 attitude scale and in relation to the seven subscales. Average perceptions are larger than 3, indicating rather high student appreciation levels for the different curriculum components. The highest average appreciation level is expressed in relation to E-Learning (\( m = 4.19 \)). The lowest appreciation level is found in relation to the radiology clerkship (\( m = 3.29 \)). The latter is of course only based on input of fifth to seventh year students.

3.3. Differences in student perception about the components of the radiology curriculum

Table 3 reports – next to standardized sum-scores and standard deviations for the perceptions in relation to the subscales – the results of the analysis of variance with year of training as factor. The results show significant differences across the training years in relation to all radiology curriculum components, with the exception of radiology research: radiology teaching (\( F = 39.90, p < .001 \)), radiology syllabus (\( F = 27.72, p < .001 \)), E-Learning (\( F = 54.61, p < .001 \)), E-testing (\( F = 5.12, p < .001 \)), radiology clerkships (\( F = 5.38, p < .001 \)), and radiology cases (\( F = 7.04, p < .001 \)). The post hoc pairwise comparison results are reported in Table 4. Only significant pairwise differences are included in the table.

The effect sizes (Cohen’s \( d \)) tell us about the magnitude of these differences. The results show an overall increase of mean attitude scores from year 2 to year 7 for all significant concepts of radiology education. No significant differences are observed in year 4 and year 5 students for concepts of radiology teaching, radiology syllabus, and E-testing. But the mean perception scores towards these concepts and additionally for the radiology clerkship peaks in year 6 students. This seems to be increasingly important for these students in view of their radiology education.

Fig. 2 illustrates the changes in student perceptions towards the radiology curriculum components. Perceptions about the E-learning component are already very positive in year 2 with mean 3.57 and rise consistently in nearly every training year, up to year 7 (mean 4.54). This curriculum component reflects the highest perception score (mean across training years = 4.19) and reflects a very strong and nearly consistent significant increase (mean to high effect size). The perception of the component radiology teaching is also very positive (mean 4.05), and also increases significantly and consistently in students of subsequent training years (medium or even large effect size). The perception of the radiology syllabus is rather neutral in year 2 (mean 3.13), but perceptions slightly evolve in a positive way up to year 7 (mean 3.64). Nevertheless, it remains the least – nevertheless positive – appreciated curriculum component. Perceptions about the E-testing component show a positive pattern across the training years, with only minor significant differences between training years (see overall small effect sizes). Studying the perceptions of fifth year students and older, additional curriculum components become central in the educational approach. Right from the start, radiology research is perceived as a very important curriculum component. This high appreciation does not change through the different training years (\( m > 3.54 \)). The component radiology clerkship is perceived in a rather neutral way in the fifth year (mean 3.13), but perceptions become gradually more positive in year 6 (mean 3.34) and year 7 (large and medium effect sizes). The perceptions about the curriculum component radiology cases decreases; but this significant decrease is limited (small effect size).

4. Discussion

At Gent University, the innovative radiology curriculum was implemented step by step from 1999 on, in the context of a large scale curriculum reform. The overall efficacy of the curriculum reform has been underpinned in an earlier study [35]. But, in the post 1999 period, a next step was made in the particular innovation of the radiology curriculum by the adoption of a new E-learning system and the implementation of E-testing. The latter was in particular geared to radiology teaching due to the adoption of special software (touch screen). Additional innovations extended the curriculum with of case-based radiology learning. This approach builds

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on small groups discussion of radiology cases to develop an appropriate case solution by using internet based supervised electronic forums.

In this study, we centered on student perceptions about the key curriculum components in the innovation: Radiology syllabus, E-learning, E-teaching, Radiology clerkships, Radiology cases and Radiology research are integrated in education approach of undergraduate radiology. As stated in Section 1, the importance of the affective learning domain cannot be underestimated in relation to the clinical competences and performance [28]. Affective attitudes

Table 4
Post hoc analysis (Thamhane post hoc test) of differences in student attitude towards components of the Radiology curriculum according to training year.

<table>
<thead>
<tr>
<th>Curricula component</th>
<th>Years of training</th>
<th>Mean difference</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiology teaching</td>
<td>7+2</td>
<td>0.71*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>7+3</td>
<td>0.37*</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>6+2</td>
<td>0.84*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>5+2</td>
<td>0.50*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>5+3</td>
<td>0.87*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>5+4</td>
<td>0.33*</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>4+2</td>
<td>0.64*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>4+3</td>
<td>0.30*</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>3+2</td>
<td>0.34*</td>
<td>L</td>
</tr>
<tr>
<td>Radiology syllabus</td>
<td>7+2</td>
<td>0.51*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>7+3</td>
<td>0.74*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>6+2</td>
<td>0.54*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>5+2</td>
<td>0.57*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>4+2</td>
<td>0.55*</td>
<td>L</td>
</tr>
<tr>
<td>E-learning</td>
<td>7+2</td>
<td>0.96*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>7+3</td>
<td>0.28*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>7+4</td>
<td>0.36*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>6+2</td>
<td>0.95*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>6+3</td>
<td>0.26*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>6+4</td>
<td>0.33*</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>5+2</td>
<td>0.84*</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>5+4</td>
<td>0.24*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>3+2</td>
<td>0.60*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>3+2</td>
<td>0.69*</td>
<td>L</td>
</tr>
<tr>
<td>E-testing</td>
<td>3+2</td>
<td>0.14*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>3+4</td>
<td>0.19*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>3+5</td>
<td>0.21*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>6+2</td>
<td>0.19*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>6+4</td>
<td>0.24*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>6+5</td>
<td>0.25*</td>
<td>S</td>
</tr>
<tr>
<td>Radiology clerkship</td>
<td>7+5</td>
<td>0.44*</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>7+6</td>
<td>0.23*</td>
<td>M</td>
</tr>
<tr>
<td>Radiology cases</td>
<td>5+6</td>
<td>0.25*</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>5+7</td>
<td>0.20*</td>
<td>S</td>
</tr>
<tr>
<td>Radiology research</td>
<td>No significant differences</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Effect size based on Cohen's d: small effect (>0.20); medium effect (>0.50); and large effect (>0.80).

* Items were scored from “totally disagree” (1) to “totally agree” (5).

* p < .05.

Fig. 2. Changes in student’s perceptions about the different components of the radiology curriculum. Significant differences are observed in the components: radiology teaching, syllabus, E-learning, E-testing, and radiology clerkship (p < .05).
PART 2: Chapter 2.1 The perceived long-term impact of the radiological curriculum innovations in the MD training at Ghent University

reflecting emotional responses and personal experiences are sensitive to personal feelings and the context [38]. The innovations in learning and teaching environment are only beneficial and result in higher learning performance when they are perceived as such by the students [29,30]. This brings us to the central research question about the curriculum innovation. In addition, we were interested in the way student perceptions evolved during consecutive training years.

The results shown an overall positive perception about the different radiology curriculum components. This is in line with the results of previous studies that pointed at the positive impact of a “blended learning” approach: combinations of E-learning and face-to-face methods such as traditional lectures and the adoption of printed materials [9,17]. Next to favorable attitudes towards learning, these studies also refer to the positive impact on knowledge acquisition. In the present study, student perceptions about all curriculum components are positive and receive a higher appreciation throughout the training years. This can partly be explained by the increased experience with the valid components of the curriculum. This helps students to understand sufficiently the place of radiology in the overall medical curriculum in the pre-clinical and clinical training years.

The positive perception of the traditional printed radiology syllabus is especially important in the third training year, with a slight jump between year 5 and 6. The latter change in perceptions can be linked to the introduction of the concurrent new curriculum component radiology clerkships. The syllabus might have become at that stage a relevant resource to carry out the specific tasks during the clinical clerkship. In addition, the need to repeat basic radiology knowledge is also pressed by the planning of an interdisciplinary exam at the end of year 6 that implies mastery of integrated radiology knowledge and skills. The latter interpretation points at the relevance of traditional knowledge resources to guarantee continuity in the curriculum [20].

The E-learning component becomes and is an indispensable tool in state-of-the-art radiology education [8,10–16]. This can be linked to the advantages related to instant accessibility, availability of exercises of different difficulty level, documented with high quality images. At Gent University, a dedicated E-learning and E-testing system have been in use since 2003. This means that students can build on seventy years of experience in using these curriculum components. More than 7000 did already use this provision. In the context of this study, the positive and increase in positive perceptions of the E-learning component cannot be doubted. Up to the seventh training year, the perception remains positive and is the highest perception score when comparing different curriculum. We hypothesize that the positive curriculum perception can be linked to the collaborative learning environment, the flexibility in time and place, adaptation to the learning pace of the student, the E learning provision. This implicates that the E-learning environment is perceived as a perfect medium for individualized, class-room independent, self-regulated learning that encourages the exploration of detailed knowledge and helps in the developing of the interpretation skills in radiology across all years of medical training.

In this context, the curriculum component E-testing is well perceived that support the previous research [13,37] on computer based method of evaluating students in radiology. Although, in the ICMC curriculum radiology is no longer considered a separate discipline, radiology is still assessed separately via the E testing environment and this in almost every training year (except year 6). The focus on this separate exam is considered to be of importance. It consistently makes radiology visible in the curriculum and avoids students skipping radiology.

The radiology clerkships are reported in the literature as a vital part of a radiology curriculum [39–41]. In the present study, students reflect an increasingly positive perception of the radiology clerkships. We explain this by referring to the opportunities offered during these clerkships to attend radiological investigations, to learn working with radiological tools (PACS, web PACS and radiological CDIs). The subarea items also stress good communication and supervision of staff, the opportunity to participate in multidisciplinary meetings and the possibility to experience the daily working of a department. The differences between perceptions of students in year 5 and 6 (7) can be related to the duration of the clerkship (half day for year 5 end 1 week or longer for years 6 and 7) and the nature of the tasks to perform during the clerkship (observational tasks for year 5 and active tasks for years 6 and 7). A very high and positive perception was observed in relation to radiology research during the clinical training years. The lack of an increase in these perceptions can be due to a ceiling effect, or can be linked to the small percentage of selected students that continue to carry out scientific work in the radiology field. The findings that students nevertheless express a highly positive perception about scientific work in the radiology field are important because it might foster their future professional career choice for radiology.

Contemporary multidisciplinary medical education in which radiology plays an integral part, introduces case-based learning as a key curriculum component. Case-based radiology teaching is interlinked with the clinical radiological clerkships. During clinical radiological clerkships, students are asked to work with cases on PACS or web-PACS system (in year 5 and 6) or to develop cases making use of the PACS system (in year 7). Recently (since 2008–2009), “Radiology web-based cases” have been introduced in year 5 and 7 as part of interactive ex-cathedra lessons. The lecture setting can explain the less positive perception of radiology cases at this stage of the training. Previous research stresses that the case-based method is effective when linked to inter-professional learning and small-group collaborative learning. Only in those settings, increases in student satisfaction were observed [42]. Additionally, the fact that the “Radiology web-based cases” have only recently been introduced also explain the lower perception levels of students. Perhaps is too early to come to clear-cut conclusions about this component. Future research could focus on the specific position of the cases and this in relation to the other curriculum components, such as radiological clerkships and radiology research.

4.1 Limitations

A number of limitations have to be mentioned in relation to this study. First, though a response rate of 87.5% is acceptable, the small non-response can have introduced some bias. A second limitation is linked to the newly develop Evaluation Radiology Teaching Concept Scale (ERTeCS). Future research should underpin the completeness of the curriculum components covered by the instrument. In addition, further validation research is needed considering the nature of some of the goodness-of-fit indices. A third issue is related to the cross-sectional nature of the study. This allows to study the perceptions of students in different training years, but remains limited when it comes to the study of the longitudinal nature of the perceptions of the curriculum components. Lastly, our study centered on student perceptions about the radiology curriculum. Future research could center on a qualitative study approach, next to studying the link with actual student performance.

5. Conclusions

To conclude, the present research results point at a favorable perception of the innovative radiology curriculum components. The study points – both during pre-clinical and clinical years – at the appreciation for curriculum components that combine traditional curriculum components (ex-cathedra lessons with syllabus) with
distance learning components such as E-learning and E-testing. In clinical years – as expected – students switch to the application of knowledge and skills and therefore heavily appreciate practice linked curriculum components.

References

Chapter 2.2: Radiological clerkships as a critical curriculum component in radiology education

Elena V. Kourdioukova\textsuperscript{a}, Koenraad L. Verstraete\textsuperscript{a}, Martin Valcke\textsuperscript{b}

\textsuperscript{a} Department of Radiology, Ghent University Hospital (UZG), MR/1K12, De Pintelaan 185, B-9000 Ghent-Belgium
\textsuperscript{b} Department of Educational Studies, Ghent University, H. Dunantlaan 2, B-9000 Ghent-Belgium

Radiological clerkships as a critical curriculum component in radiology education

Elena V. Kourdioukova\textsuperscript{a,}\textsuperscript{*}, Koenraad L. Verstraete\textsuperscript{a}, Martin Valcke\textsuperscript{b}

\textsuperscript{a} Department of Radiology, Ghent University Hospital (UGZ), MR1-1K12, De Pintelaan 185, B-9000 Ghent, Belgium
\textsuperscript{b} Department of Educational Studies, Ghent University, H. Dunantlaan 2, B-9000 Ghent, Belgium

\begin{abstract}
Objective: The aim of this research was to explore the perceived value of clinical clerkships in the radiology curriculum as well as the impact of radiology clerkship on students’ beliefs about the profession of radiology as a whole and as a career.

Methods: This study is a sequel to a previous survey in which student perceptions about radiology curriculum components were investigated. The present study focuses on a further analysis of a subsection in this study, based on 14 statements about radiology clerkship and two statements about radiology as a career.

Results: Perceived usefulness of the aspects of radiology clerkship as “radiology examination”, “skills development” and “diagnosis focus” were awarded the highest scores. The predict value of the subscale “radiology examination” on the level of performance was very high (adjusted $R^2 = 0.19, p < 0.001$).

Conclusion: Students expressed highly favorable evaluation of clerkship as a learning environment to learn to order and to interpret imaging studies as well as an unique possibility to attend various radiological examinations and to access to specific radiology software systems, as well as to get a better view on radiology and to improve image interpretation skills. This positive attitude towards clerkship is closely tied to students’ beliefs about the profession of radiology as a whole. These aspects of dedicated radiology clerkship are crucial for effective and high-quality education as well as for the choice of radiology as a career.

\end{abstract}

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1. Introduction

In an earlier study, a detailed picture was developed about the perceived impact of components of an innovative radiology curriculum at Ghent University (e.g., e-learning, radiology case based learning, radiology online assessment). Research consistently emphasizes that the way students experience and perceive an educational innovation mediates the attainment of learning outcomes that result from their innovative learning environment [1–4]. In the context of clerkships, such student perceptions seem to be particularly important. It has e.g., been found that satisfaction with the residency experience was associated with factors that enhance learning [5]. In addition, positive experiences with clerkship can influence future career decisions [6]. More recently, the potential impact of radiology clerkships in view of future radiology careers has been studied. Available evidence states that students consider their clerkship of importance to develop as a radiologist and in view of their future career choice [7–9].

\* Corresponding author. Tel.: +32 09 332 1069; fax: +32 09 332 4969.
\textit{E-mail address: elena.kourdioukova@ugent.be} (E.V. Kourdioukova).

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In this study we investigate the perceived educational impact of radiology clerkship during a clinical training period on student knowledge and skills acquisition and development of attitudes towards radiology and the radiology career.

2. Description of the required clinical radiology clerkship at Ghent University

The structure of radiology curriculum and the way the radiology is taught at Ghent University was described in detail in a previous study. Fig. 1 reflects the place of radiology clerkships throughout the curriculum, with a focus on the clinical training years.

In the present study we center on the perceived impact of the compulsory radiology clerkship for 6th year students. These students stay at a radiology department for 1 week and have to carry out specific tasks during this period. The related learning objectives and the internship schedule are clearly defined and information about it is available via the educational e-learning platform of the university. During the first internship day, students are given practical information and are introduced to the learning objectives that have to be attained. Next, students have to fill out an online prior knowledge test. This test – consisting of 42 items – covers the mastery of radiology anatomy, different radiology techniques, radiology of diseases and radioprotection. A variety of question formats are implemented: multiple choice questions, drop down menu questions and “click on the structure” questions. Students receive automated immediate feedback to identify their knowledge gaps. The tests build on the radiology curriculum that was part of the 2nd to 5th year curriculum (radiology anatomy, pathology, interpretation, radiation protection and appropriate use of radiological techniques). The prior knowledge test highlights the need to refresh the radiology knowledge base. As to the latter, students have access to syllabi and reference books, and e-learning exercises. The latter vary in difficulty and are an efficient means to upgrade their knowledge base.

During the next days of their internship, students carry out a selected number and type of radiological examinations (radiographic examinations, computed tomography (CT), magnetic resonance imaging (MRI), positron-emission tomography (PET-CT), ultrasound, etc.). They participate in routine clinical practice. They attend clinical radiology conferences and multidisciplinary team meetings. They apply recommendations about appropriate use of radiology equipment. Other learning objectives urge the interns to improve their interpretation skills of radiological images, to work with web-based PACS (Picture Archiving and Communication System) and to work with CDs containing image data from different hospitals resulting from different software packages to manage radiology images (AGFA, KODAK, E-FILM, ETIAM, TELEMS). At the end of the clerkship all students submit an evaluation form that helps them to reflect on the radiology tests, their experiences, and what they have learned during the clerkship. Students also fill out an online final radiology test, consisting of 54 questions.

3. Research objectives

In view of this study, the following research objectives have been stated:

1. To describe – according to the students – the perceived value of the radiology clerkship during clinical training years.
2. To determine the perceived impact of the dedicated radiology clerkship experience on radiology knowledge acquisition.
3. To explore the perceived impact of radiology clerkship on students ideas about radiology as a profession and radiology as a future career choice.
4. Research design

4.1. Participants

Students, enrolled for the MD training in 2008 (years 2–7) at Ghent University, were asked to complete a questionnaire about their perceptions in relation to the undergraduate radiology curriculum components. The design, content and structure of the Evaluation Radiology Teaching Concept Scale (EERTeCS) were extensively discussed in a previous article. The EERTeCS was filled out anonymously, and after obtaining informed consent. The questionnaire was accompanied by a letter giving background information about the objectives of the study. Participation was voluntary and students were informed that neither participation nor non-participation would affect their grades. Ethical approval was granted by the Human Investigation Ethical Committee of the Ghent University Hospital. In the present study, only the data from 6th and 7th year students are used, and only part of the EERTeCS research instrument, as will be explained below. Since we focus on radiology clerkships, we also center on the group of students who have experienced the 6th year radiology clerkship. At the time of the EERTeCS administration only 90 students (all 7th year students, and only part of 6th year students) did already participate in this clerkship.

5. Research instruments

5.1. Validity and reliability of the Radiology Teaching Concept Scale (EERTeCS)

Since we focus in the present study on radiology clerkship, only a subpart of the EERTeCS is used in the context of this research report. The original subscale about the radiology internship consisted of 18 items. Data from the research sample were split up in an exploratory subsample and a confirmatory subsample. An initial exploratory factor analysis – building on the exploratory subsample data – was helpful to eliminate items with weak factor loading. This resulted in a final 14-item scale, consisting of five subscales (Table 1). Standardized sum scores were calculated for each subscale related to a particular latent internship related variable (minimum 1–maximum 5). In the next step, a confirmatory factor analysis was carried out, based on the factor structure develop on the base of the data from the confirmatory subsample. The analysis resulted in satisfactory goodness-of-fit indices: $\chi^2 = 97.017, p < .001$; CMIN/DF = 1.76 ($>5$ indicates adequate fit); CFI = .957; GFI = .915 ($>0.90$ indicates adequate fit); RMSEA = .073 ($<0.08$ indicates an adequate fit). Lastly, reliability coefficients were calculated (Table 1). The Cronbach’s $\alpha$ values range from 0.68 to 0.96, indicating acceptable to very good reliability levels, reflecting an acceptable to strong internal consistency.

The five subscales reflect five foci upon the nature and value of the radiology internship experience: (1) radiology diagnosis focus, (2) skills development focus, (3) interdisciplinary focus, (4) radiology examination focus, and (5) clerkship setting focus. The related items in Table 1 illustrate concretely the particular core to each subscale.

5.2. Radiology as a profession and radiology as a career option

Two specific EERTeCS items focused on profession/career related issues. Statements such as “I think that radiology has a future as a profession” and “I am interested in radiology as a career choice” were additionally analyzed to explore the orientation towards
PART 2: Chapter 2.2 Radiological clerkships as a critical curriculum component in radiology education

Radiology Clinical Clerkships at Ghent University

<table>
<thead>
<tr>
<th>Year</th>
<th>5</th>
<th>6</th>
<th>Elective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Required structured-guided</td>
<td>Required</td>
<td>Elective</td>
</tr>
<tr>
<td>Duration</td>
<td>half day</td>
<td>5 days (one week)</td>
<td>12 weeks for the potential Radiology Residency candidates</td>
</tr>
</tbody>
</table>

Tasks
- Observational tasks
- Active tasks
- Active tasks

Objectives
1. To demonstrate the working of radiology department (the equipment, patient flow, image flow, reporting, administrative and logistic work)
2. To learn to work with radiological CD’s from different hospitals containing imaging studies
3. To learn to work with web-based PACS and solve radiological cases
4. To solve electronic teaching files/cases

1. To follow a selected number and type of radiological examinations (conventional radiography, CT, MRI, ultrasound, etc.)
2. To improve the interpretations skills of radiological images
3. To learn to work with web-based PACS (case-based learning) and on CD’s
4. To participate in routine clinical practice in the department
5. To learn "what to order and when" (recommendations for appropriate use of radiology)
6. To attend clinico-radiological conferences and multidisciplinary team meetings

1. To obtain a high level of radiology images interpretation
2. To learn to make a prescription according to Guidelines for appropriate use of radiology
3. To make different radiology cases

Fig. 1. Clinical radiology clerkships at Ghent University.

Table 1
Statements representing attitude towards clinical radiology clerkship.

<table>
<thead>
<tr>
<th>Statements</th>
<th>$\alpha^2$</th>
<th>Mean</th>
<th>SD</th>
<th>t-Test</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiology clerkship (14 items, N=90)</td>
<td>0.88</td>
<td>3.23</td>
<td>0.91</td>
<td>**</td>
<td>0.59</td>
</tr>
<tr>
<td><strong>Subscale: diagnosis focus</strong></td>
<td>0.85</td>
<td>3.52</td>
<td>0.86</td>
<td>**</td>
<td>0.72</td>
</tr>
<tr>
<td>1 I improved my knowledge of radiology during the clerkship</td>
<td>3.36</td>
<td>1.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 My skills for interpretation of radiological images improved during the clerkship</td>
<td>3.20</td>
<td>1.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subscale: skills development focus</strong></td>
<td>0.81</td>
<td>3.61</td>
<td>0.83</td>
<td>**</td>
<td>0.27</td>
</tr>
<tr>
<td>3 During the clerkship I learned to work with radiological CD’s with imaging studies from the various hospitals</td>
<td>3.61</td>
<td>1.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 I am able to work independently with radiological CD’s with imaging studies from the various hospitals</td>
<td>3.39</td>
<td>1.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 During the clerkship I learned to work with web-based PACS system</td>
<td>3.46</td>
<td>1.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 I am able to work independently with web-based PACS system</td>
<td>3.44</td>
<td>1.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subscale: interdisciplinary focus</strong></td>
<td>0.96</td>
<td>3.25</td>
<td>0.97</td>
<td>***</td>
<td>1.19</td>
</tr>
<tr>
<td>7 I believe taking part in multidisciplinary staff meetings during the radiology clerkship offers added value to the clerkship</td>
<td>3.96</td>
<td>1.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 I found my participation in multidisciplinary staff meetings during the radiology clerkship informative and fascinating</td>
<td>4.03</td>
<td>1.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subscale: radiology examination focus</strong></td>
<td>0.79</td>
<td>3.89</td>
<td>0.54</td>
<td>**</td>
<td>0.25</td>
</tr>
<tr>
<td>9 During the radiology clerkship I was able to attend various radiological examinations</td>
<td>3.97</td>
<td>1.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 I am able to solve the clinical questions posed during radiological examinations</td>
<td>3.43</td>
<td>1.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 During the clerkship I learned to correctly prescribe a radiological examination</td>
<td>3.16</td>
<td>1.29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 I am able to correctly prescribe a radiological examination independently</td>
<td>3.54</td>
<td>1.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subscale: clerkship setting focus</strong></td>
<td>0.68</td>
<td>3.23</td>
<td>0.91</td>
<td>**</td>
<td>0.25</td>
</tr>
<tr>
<td>13 There is sufficient variation in the tasks the student have to perform during the clerkship</td>
<td>3.51</td>
<td>1.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 I believe the supervision by docent and radiologists was optimal during clerkship</td>
<td>3.05</td>
<td>1.27</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparing the benchmark score ($\pm$3): "effect size based on Cohen's d: small effect (>0.20); medium effect (>0.50); large effect (>0.80); **p < .001; ***p < .05.

The items are scored from "totally disagree" (1) to "totally agree" (5).

N= number of respondents, SD= standard deviation, $\alpha= $Cronbach’s alpha.
the radiology profession and radiology as a career choice. Students scored these items on a five point Likert-scale ranging from "strongly disagree" to "strongly agree".

5.3. Radiology knowledge test scores

A particular part of the ERTeCS consisted of ten knowledge questions regarding to general radiology knowledge.

6. Procedure

As stated above, only the ERTeCS data from 6th and 7th year students—enrolled for the MD curriculum—were used in the present study (n = 194). Students enrolled in the 6th year and the 7th year of medical training were included in a secondary analysis (Fig. 2). The ERTeCS data subset included the scores for the general radiology prior knowledge test, and the items in relation to student ideas about radiology as a profession and radiology as a career option.

To obtain a performance measure related to radiology, scores from the ERTeCS prior knowledge state test were used.

7. Statistical analyses

Statistical analyses were carried with AMOS (structural equation modeling software—version 6.0) and SPSS (version 15, Statistical Package for the Social Sciences, SPSS; Chicago, II, USA). The quantitative analysis initially builds on descriptive statistics, after checking for accuracy of data entry, missing values and outliers. Inferential statistics were applied to compare group means: one-sample t-test was used to compare student perception scores with a benchmark score and an independent samples t-test was used to compare students performance on prior knowledge test for groups students that were involved or not involved in a radiology clerkship. Analysis of variance (ANOVA) and regression analysis were used to study the predictive power of the perception measures on student performance, and their ideas about radiology as a professions and radiology as a career choice.

8. Results

8.1. Response rate

As can be derived from Fig. 2, the number of students (year 6 and 7) filling in the ERTeCS questionnaire was 194. At that specific moment, only about half of the students (n = 99) had already been involved in a radiology clerkship and could react to items in relation to the radiology clerkship. But, all students (n = 194) solved the ERTeCS general radiology prior knowledge test, and replied to the items in relation to the radiology profession and radiology as a career option.

8.2. Perceived value of the clerkship

The standardized scores for each subscale are presented in Table 1. When we adopt a benchmark score of >3, we can conclude that the average subscale scores reflect a positive perceived value in relation to the five foci of the radiology clerkship. Fig. 3 shows in a more graphical way how the appreciation levels for the different foci in the radiology clerkship are high. When testing the mean subscale scores with the benchmark (benchmark score = 3), consistent statistical analysis results are obtained for three clerkship foci: radiological examination (mean = 3.89, SD 0.54, p < .001, high effect size: Cohen’s d = 1.19), skills development (mean = 3.61, SD 0.83, p < .001, medium effect size: Cohen’s d = 0.72) and diagnosis focus (mean = 3.52, SD 0.86, p < .001, medium effect size: Cohen’s d = 0.59. In relation to two internship foci, the analysis results are marginally significantly different: interdisciplinary focus (mean = 3.25, SD 0.86, p < .05, small effect size: Cohen’s d = 0.27) and clerkship setting (mean = 3.23, SD 0.91, p < .05, small effect size: Cohen’s d = 0.25).

8.3. The impact of the radiology clerkship on radiology knowledge acquisition

All students (n = 194) solved the ERTeCS general radiology prior knowledge test. The results of an independent samples t-test show significant differences between the score of students involved in a radiology clerkship (n = 99) and the score of students not involved in a radiology clerkship (n = 95): mean [SD], 746.5 [SD = 157.7] vs 648.5 [SD = 171.3]; p < .001.

8.4. Students perceptions about the usefulness of clerkship and learning performance

As stated in the introduction, there is empirical evidence that positive student perceptions play a mediating role in attaining higher performance levels in the context of a curriculum innovation or an innovative learning environment. To test this assumption in the context of the radiology clerkship, a stepwise multiple linear regression was carried out in which the average perception radiology clerkship score was entered to predict the general radiology knowledge test score. The overall radiology clerkship perception scores seem to explains 12% of the variance in the test score (adjusted R² = 0.12, p < .001). When we enter separately the five internship subscale perception scores in the regression analysis, the picture changes. The subscale Radiological examination seems to be single significant predictor in the equation and explains up to 19% of the variance in the radiology test score (adjusted R² = 0.19, p < .001). This can be considered as a high proportion in explained variance. The other four clerkship subscale scores do not seem to contribute in a significant way to the equation.

8.5. Students perceptions about the radiology clerkship and choosing radiology as a profession or as a career choice

The results present a clear picture about the students’ perceptions towards radiology as a profession and career. Most of our 6th and 7th year students (84.5%) believe that radiology has a future as a profession and 10.3% are interested in radiology as a future career. Previous research originating from students enrolled in US medical schools, reported average percentages of 7.4% [15] to 8% [16] of students considering radiology as a career choice.

It is important to repeat that at the time of the ERTeCS questionnaire administration—about half of the 6th year students were already involved in a radiology clerkship (99/194). This helps to compare student perceptions of students involved/not involved in a radiology clerkship. Students with radiology clerkship experience adopt a more positive orientation towards radiology as a profession (ANOVA between subjects F = 7.47, p < .01, Partial Eta squared = .008). But, this difference—though significant—is not large. This can be explained by referring to the medical curriculum structure of Ghent University. Students are exposed to radiology from years 2 to 7 of their training. This implies already early contact with radiology in preclinical years (ex-cathedra radiology lessons, radiology e-learning exercises, etc. This makes radiology a visible [17] component of the Ghent University integrated medical curriculum and explains partly the positive perceptions [18] about the radiology profession. Nevertheless, the particular radiology clerkship experience in the 6th year seems to affect students’ opinion about radiology as a profession.
A stepwise linear regression, with the five radiology clerkship subscale scores as predictors for the dependent variable student's opinion about radiology as a profession, shows interesting results. Only one clerkship subscale score seems to contribute in a significant way to the equation: The “Clerkship setting” focus explain 15% of the variance in responses to the question about radiology as a profession (adjusted $R^2 = 0.15$, $p < .001$). This high proportion can be explained by the large variation in tasks that student have to carry out during their radiology clerkship and the provision of sufficient supervision by expert radiologist during the clerkship. This is in line with the research findings that stress the importance of student exposure to role models [14]. The other clerkship subscale scores did not contribute significantly to student attitudes about radiology as a profession.

Secondly, we center on the tendency of students to opt for radiology as a future career choice. Not surprisingly, students who were already involved in a radiology clerkship showed less interest in radiology as a personal future career choice (mean score 1.4 versus 1.7, ANOVA between subjects $F = 22.28$, $p < .001$, Partial $Eta squared = .02$). It is likely that students who are enrolled in a clerkship during their 6th and nearly final year of their medical training, will already have an established idea about their future professional orientation and especially about their future specialization. This interpretation is also supported by Shepherd at al. stressing the

![Diagram](image_url)

**Fig. 2.** Student samples and participation details.

![Diagram](image_url)

**Fig. 3.** Perceived usefulness of different aspects of the radiology clerkship.
importance of radiology electives in view of opting or not opting for a specialization in radiology [9]. Ambivalent students who are yet not sure about their future career choice can benefit from the 6th year clerkship and be considered as a ‘target group’ increase the attractiveness of a radiology career choice. A stepwise linear regression with the five clerkship subscale scores as predictors shows that the subscale "Diagnosis focus" significantly explains 11% of the variance in opting for radiology as a career choice (adjusted R² = 0.11, p < .001). This is in line with other research findings. Developing an adequate level of radiology knowledge, clinical thinking, and interpretation skills of radiological images are in line with perceived needs of students [19–21] in view of a prospective career choice. Other clerkship subscales did not contribute significantly to the proportion of explained variance in the dependent variable.

9. Discussion

The present study reemphasizes the importance of affective variables – such as student perceptions about the learning environment – as mediating variables [1,3,22] to attain clinical competences and learning. Since the department of radiology at Ghent University has been responsible for the design, development of an innovative, it was a logical step to evaluate the curriculum innovation and to build on the perceived educational impact of radiology clerkship as part of the quality control cycles in relation to the implementation of the innovative.

The results of our research are consistent with previous underpinning the critical role of radiology clerkship in the clinical part of the medical undergraduate curriculum [9,11,12]. Our study shows that radiology clerkship for 6th year students (duration of medical training program in Belgium is 7 years) reinforce the learning process. Teaching and evaluation methods related to radiology clerkship have been broadly explored in the literature. The results of our study, are in line with the earlier findings about the usefulness and effectiveness of pre- and post-clerkship tests [23–25]. One of the important learning objectives of the clerkship is the improvement of the radiology knowledge base and the development of basic skills image interpretation (23,25). The results of our study indicate that students perceive the clerkship as valuable for their knowledge development and skills improvement. This is even confirmed in the regression analysis when using the perceived value as a predictor for the knowledge test scores. This is in agreement with the literature that points at the impact of attitudes on students’ performance [26]. Positive attitudes towards radiology clerkship components influence considerably knowledge test scores.

Our findings are consistent with results from previous research that students need radiology clerkships [8,11,20] to be well-prepared to multidisciplinary clinical practice and to order appropriate radiological examinations in relation to common/specific diseases. Also graduate students who do not consider a career as a radiologist are also expected to interpret radiologic images independently from the opinion and report of a radiologist’s expert [8,21]. Our results show – in line with earlier findings – how radiology clerkships attract students to consider radiology as a career [27]. In addition, the clerkships induce a more positive perception of the radiologist profession; this is again in line with earlier research results [21,28]. The students ERTeCS also indicate that our students perceived radiology clerkship as a setting to learn to order and to interpret radiology images, as well as an unique possibility to attend radiology patient examinations, and to have access to the different radiology software systems used in clinical centers throughout the country. The latter can play very important role to enhance the appeal of the radiology profession.

Such experiences may especially influence students with still a neutral or ambivalent perceptions about radiology as a personal career option.

10. Limitations

A number of limitations have to be mentioned in relation to this study. First, at the moment of the questionnaire administration, only a part of 6th year students had already been involved in a radiology clerkship. This implies that the groups compared in this study were the result of a random assignment. This depended entirely on the scheduling for radiology clerkship of the faculty administration. A second limitation is related to the predictive value of student perceptions about the radiology clerkship on radiology knowledge test results. Since only a proportion (11–15%) of the variance in test results could be linked to the clerkship perception scores, a large part of the proportion clearly depends on other variables and processes. Future research should center on a further refinement of the set of predictive variables and how the clerkship experience interacts with other predictor variables. In this context it is also of importance to stress the fact that student perceptions were entered as predictors. It looks promising to enter radiology clerkship scores as additional measures.

Lastly, we did not center on the changes in attitudes towards radiology due to the clerkship experience. Considering the fact that now a valid and reliable instrument is available to study student perceptions in relation to five clerkship foci, future studies could center on the specific impact of the clerkship experiences on changes in these affective variables.

References


Chapter 2.3: The quality and impact of Computer Supported Collaborative Learning (CSCL) in radiology case-based learning

Elena V. Kourdioukova\textsuperscript{a}, Koenraad L. Verstraete\textsuperscript{a}, Martin Valcke\textsuperscript{b}

\textsuperscript{a} Department of Radiology, Ghent University Hospital (UZG), MR/-1K12, De Pintelaan 185, B-9000 Ghent-Belgium
\textsuperscript{b} Department of Educational Studies, Ghent University, H. Dunantlaan 2, B-9000 Ghent-Belgium

The quality and impact of computer supported collaborative learning (CSCL) in radiology case-based learning

Elena V. Kourdioukova, Koenraad L. Verstraete, Martin Valcke

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ABSTRACT

Objective: The aim of this research was to explore (1) clinical years students' perceptions about radiology case-based learning within a computer supported collaborative learning (CSCL) setting, (2) an analysis of the collaborative learning process, and (3) the learning impact of collaborative work on the radiology cases.

Methods: The first part of this study focuses on a more detailed analysis of a survey study about CSCL-based case-based learning, set up in the context of a broader radiology curriculum innovation. The second part centers on a qualitative and quantitative analysis of 52 online collaborative learning discussions from 5th and 6th year and nearly graduating medical students. The collaborative work was based on 26 radiology cases regarding musculoskeletal radiology.

Results: The analysis of perceptions about collaborative learning on radiology cases reflects a rather neutral attitude that also does not differ significantly in students of different grade levels. Less advanced students are more positive about CSCL as compared to last year students. Outcome evaluation shows a significantly higher level of accuracy in identification of radiology key structures and in radiology diagnosis as well as in linking the radiological signs with available clinical information in nearly graduated students. No significant differences between different grade levels were found in accuracy of using medical terminology.

Conclusion: Students appreciate computer supported collaborative learning settings when tackling radiology case-based learning. Socratic computer supported collaborative learning groups proved to be useful for both 5th and 7th year students in view of developing components of their radiology diagnostic approaches.

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PART 2: Chapter 2.3 The quality and impact of Computer Supported Collaborative Learning (CSCIL) in radiology case-based learning

Table 1

<table>
<thead>
<tr>
<th>Statement</th>
<th>Year 5 (N=161)</th>
<th>Year 7 (N=72)</th>
<th>t-value</th>
<th>df</th>
<th>p</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>A sufficient number of cases is offered to develop problem solutions</td>
<td>3.86 (0.71)</td>
<td>3.50 (0.60)</td>
<td>3.77</td>
<td>231</td>
<td>&lt;0.001</td>
<td>Not significant</td>
</tr>
<tr>
<td>Working in small groups on a particular radiology case is interesting,</td>
<td>3.30 (1.05)</td>
<td>3.47 (0.62)</td>
<td>-1.60</td>
<td>213</td>
<td></td>
<td></td>
</tr>
<tr>
<td>because you learn from each other by discussing the problems together</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working in small groups on a particular radiology case is relevant,</td>
<td>3.21 (0.98)</td>
<td>3.04 (0.62)</td>
<td>1.56</td>
<td>201</td>
<td></td>
<td>Not significant</td>
</tr>
<tr>
<td>because the problem can be solved more quickly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working in small groups on a particular radiology case is interesting,</td>
<td>3.13 (1.07)</td>
<td>2.68 (0.73)</td>
<td>3.74</td>
<td>192</td>
<td>&lt;0.001</td>
<td>0.49</td>
</tr>
<tr>
<td>because we can work together via the university’s electronic learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>platform</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Statements were scored from “totally disagree” (1) to “totally agree” (5).
* SD = standard deviation.
* Effect size based on Cohens’s d: small effect (0.20); medium effect (0.50); large effect (0.80).

In the literature, a distinction is made between content-oriented and communication-oriented scripts [27].

A content-oriented script helps learners to select, organize, and integrate the knowledge base that is at the base of the collaborative task (such as knowledge about infections to solve a diagnostic task about tropical diseases). A typical content-oriented script e.g., invites participants to label their discussion contributions on the basis of medical procedures, or a diagnostic protocol. Other scripts present a clear-cut structure to tackle problems or cases. Lastly, scripting can be used to prepare case scenarios, hints, guidance by a staff member.

A communication-oriented script fosters the engagement of group members in the collaborative process by helping them to adopt different or specific perspectives, to consider in a conscious way the input of peers, etc. Typical examples of communication scripts build on adopting the role of a moderator, summarizer, theoretician, etc. [28]. Both scripting types are expected to invoke (1) an active cognitive processing of the declarative and/or procedural knowledge; (2) the meta-cognitive regulation of the cognitive processes during the collaborative process, since adding structure helps to trigger meaningful discourse; and/or (3) the level of interaction in the online discussion. In the context of the present study, content-oriented scripts have been adopted to foster the CSCIL work.

Case-based learning, within a scripted CSCIL setting, is relatively new at Ghent University (in use since 2008–2009). This introduced the need to evaluate this instructional approach; whether it resulted in student satisfaction and helped to develop and improve radiologic problem-solving abilities of medical students. This evaluation was set up in the context of a broader evaluation of a large-scale curriculum reform at Ghent University when an integrated contextual medical curriculum was introduced in 1999. The main features of this curriculum can be labeled as: patient-centered, student centered, community oriented, problem and evidence-based learning and teaching [29].

In this study we center on student perceptions about the CSCIL approach toward radiology case-based learning, building on data from a large-scale survey study. Further we focus on the process evaluation and outcome evaluation of the collaborative work in terms of the impact on components of diagnostic approaches in student contributions.

2. Research objectives

This study consists of 2 sub-studies.
Part 1: Survey study.
The key research question guiding this sub-study is: How do the clinical year students experience the CSCIL approach towards case-based learning?
Part 2: Qualitative and quantitative study.
In view of the second sub-study, the following research questions were put forward. The first question builds on a process evaluation of the groups discussion: To what extent do we observe differences in the components of diagnostic approaches in the discussions between nearly graduated students and fifth year students? The second question looks at the outcome evaluation: To what extent do we observe significant differences in the case solutions of fifth year students versus nearly graduating students, in terms of accuracy of visual pattern recognition, cognitive patterns and verbal justification.

3. Research design

3.1. Part 1: Survey

3.1.1. Participants

Students, enrolled for the medical doctors training in 2008 (year 2–7) at Ghent University, were asked to complete a questionnaire about their perceptions in relation to the innovative undergraduate radiology curriculum components. The design, content and structure of the Evaluation Radiology Teaching Concept Scale (ERTeCS) was extensively discussed in a previous article [30]. The ERTeCS was filled out anonymously, and after obtaining informed consent. The questionnaire was accompanied by a letter giving background information about the objectives of the study. Participation was voluntary and students were informed that neither participation nor non-participation would affect their grades. Ethical approval was granted by the Human Investigation Ethical Committee of the Ghent University Hospital. In the context of the present article, we focused on the ERTeCS—section centering on case-based learning in radiology. We build on the data gathered from 5th (early clinical year students) and 7th (last year students) year students.

3.2. Research instrument

3.2.1. The Evaluation Radiology Teaching Concept Scale (ERTeCS)

Since we focus in the present study on radiology case-based learning, only the data in relation to the specific subscale of the ERTeCS are used in this research report. This subscale consists of 4 items: tree statements center on the computer supported collaborative learning approach, one item centers on the cases to be solve during the discussions (Table 1).

3.3. Statistical analyses

The data were analyzed using SPSS (version 15, Statistical Package for the Social Sciences, SPSS, Chicago, IL, USA). The quantitative analysis focused on a screening of the descriptive statistics, after checking for accuracy of data entry, missing values and outliers. An independent samples t-test was applied to compare group means for 5th and 7th year students regarding their perceptions about radiology case-based learning.
3.4. Part 2: Qualitative and quantitative study

3.4.1. Participants and procedure

Data gathered during the CSCL sessions from classes 2008 were used for this study. This qualitative and quantitative study builds on an innovative approach to tackle radiology cases in a computer supported collaborative learning environment (threaded discussion groups). As stated earlier, scripting was provided by presenting the students a structured case solving task. In addition, prestructured guidance was developed. To standardize the teacher interventions, the guidance centered on (1) invoking reflection on what they discussed at that moment (for example: “the irregular delineation of the vertebral endplates on thoracic level: What disease causes?”) or centered on the steps in developing a case (for example: “enter a “general diagnosis” for this case”). Fig. 1 is an outline of this CSCL approach to case-based learning.

Solving cases online is an integral part of the radiology core curriculum “Radiology of Locomotor system” for all 5th year students. For nearly graduated students, an elective course “Capita Selecta in radiology for future medical specialists” is available in the radiology curriculum. This elective course comprises a specific part about musculoskeletal radiology who want to specialize in the field of radiology, rheumatology, orthopedic surgery, traumatology and/or physical therapy. In the context of the present study, the focus was
on their CSCL activities about the online cases related to musculoskeletal radiology.

The cases, to be solved via group discussions, were carefully designed following evidence-based principles of case-based learning [31] and according to the learning objectives for the courses of musculoskeletal radiology. Each case consisted of one or more radiology images (X-ray (radiographic examinations), MRI (Magnetic Resonance Imaging), or CT (Computed Tomography images) downloaded from a PACS system), and a related brief patient history (see Fig. 2). Cases covered a variety of difficulty levels, depending on the nature of the pathology and the medical imaging. The students were asked – in all 26 cases – (1) to identify the radiological key structures, (2) to list a series of differential diagnoses and (3) to formulate a final diagnosis. In 19 cases, students were asked to (4) to identify and mark anatomical structures and in 13 cases they had (5) to make a link with other available clinical data or pathology. In 6 cases, they had (6) additionally top chose the appropriate imaging technique to further solve the specific clinical problem.

The case had to be solved by group of students separately; groups did not have access to each other CSCL workspace. The cases were assigned randomly to students. Each 5th year student had to solve 4 out 26 cases and each 7th year student had to solve 15 out 26 cases. As such each student was involved in different groups to solve the assigned cases. The radiology cases were digitally available in the CSCL environment and only accessible after a personal login to their discussion group.

Fig. 3 shows a print screen of such discussion. Teacher could continuously track student participation in the discussion; who did what, when and how many times in relation to each case. Automatic log files helped to obtain objective measures in view of these variables.

In the CSCL setting, when consensus was attained in relation to a case, each group of students posted their final case solution via a special link in the electronic learning environment (drop box), in view of teacher feedback. The teacher reviewed 26 cases delivered form different group of students. The teacher based his feedback on a prestructured answer format that focused on the accuracy and the rationale presented to ground case related decisions. After the review process, the case solution with feedback was returned to the group of students in view of updating their case solution.

Within a specific amount of time, students were expected to resubmit their final version of the case solution. After a review by the teacher, this case solution was published online and available now for all students (see Fig. 4). The latter review process was necessary since these case solutions were the base of the domain knowledge to be studied in view of a final exam. For this exam the students had to study all 26 cases (also the case solutions developed by the other groups of students).

3.4.2 Qualitative/quantitative analysis of the group discussions

Two approaches were adopted. First, a process evaluation was carried out based on the nature of the discussion contributions and secondly, an outcome evaluation was set up by analyzing the content of the reviewed group case solutions.

For this study, an independent evaluator did evaluate each individual group discussion of 5th (N = 26) and 7th (N = 26) year students, and the reviewed case solutions. This analysis was directed by an analysis scheme that reflects the key concepts of diagnostic thinking approaches as established in previous studies [32, 33].

As a part of process evaluation general characteristics of the CSCL discussions were noted such as:

1. Number of meaningful contributions.
2. Number of times that students did consult a case.
3. Number of times that a teacher did intervene in a discussion.

The next part of the process evaluation of CSCL discussions was based on the identification of specific components that normally should be covered during a diagnostic thinking approach. These included:

1. Number of radiologic key structures that were missed during a group discussion.
2. Number of anatomic structures being missed during a group discussion.
3. Number of diagnoses missed during the discussion.
4. Number of differential diagnoses presented during the discussion.
5. Number of appropriate radiology imaging techniques missed during the discussion.
6. Number of adequate medical terms used during the discussion.
7. Number of lay terms used during the discussion.

The outcome evaluation based on the reviewed versions of each case solution. The accuracy and correctness of the diagnostic thinking pattern was evaluated on a scale of 1-4 with 1 = completely correct, 2 = correct but with missed key findings; 3 = correct but with not relevant findings; 4 = completely incorrect. The following components of diagnostic thinking patterns were considered:

- Approach in cognitive patterns
- Approach in radiological patterns

3.5 Statistical analyses

The quantitative analysis of the process and outcome measures was done with SPSS (version 15, Statistical Package for the Social Sciences, SPSS; Chicago, IL, USA). The analyses build on descriptive statistics, after checking for accuracy of data entry and missing values. Data about the quality of the groups discussions were analyzed with a Mann–Whitney U test (nonparametric equivalent of an independent samples t-test) to compare groups means of 5th and 7th year students. The differences in mean final exam scores were analyzed using an independent samples t-test. A significance level of p < 0.05 was put forward as a benchmark for the statistical analysis results.
PART 2: Chapter 2.3 The quality and impact of Computer Supported Collaborative Learning (CSCL) in radiology case-based learning

CASE XX

Clinical context:
A 48-year-old man with recurrent episodes of low back pain.
Medical history of low back pain since childhood.

Question:
Describe the abnormalities.
What is your preferential diagnosis?

Hint:
View photos systematically and evaluate:
A: Alignment
B: Bone
C: Cartilage-joints
S: Soft tissues

4. Results
4.1. Part 1: Results from the survey study

The number of 5th year students filling in the eRTECS questionnaire was 161/188 (85.6%), the 7th year students 72/84 (85.7%).
Table 1 summarizes student perceptions in relation to the radiology CSCL and case-based learning statements. As can be derived from the table, significant differences can be observed in relation to two topics. Students enrolled in 5th year of training seem to be more satisfied with the number of radiology cases to be solved in the CSCL setting (mean 3.86) while nearly graduated students are still positive, but slightly less satisfied about this issue (mean 3.50, p<0.001, Cohen's d 0.55, medium effect size effect). The analysis of perceptions about the potential of the CSCL approach to learn from each other when solving radiology cases, reflects a rather
neutral to positive attitude (mean > 3); with no significant differences between students of different years. Also, student seem to adopt a neutral to slightly positive perception about the potential of the CSCL setting to solve cases more quickly; again no significant differences were observed between the two student samples. The statement about the actual use of the CSCL setting to develop case solution resulted in significant differences in student perceptions. The 5th year students are significantly more positive about online groups discussions (mean 3.13) as compared to 7th year students (mean 2.68, p < 0.001, Cohen’s d 0.49, medium effect size effect).

4.2 Part 2: Results from qualitative/quantitative study

Table 2 reflects the general characteristics of the group discussions. We repeat that the time available to solve the cases differed for 5th year and 7th year students. Interventions of a teacher were not provided for the 7th year students. The latter builds on the selected nature of this advanced group of last year students, with a future interest in radiology, rheumatology, orthopedic surgery, traumatology and/or physical therapy. These students are expected to solve the cases more quickly, since they can build on their radiology clerkship experience during the 6th year of their curriculum, and the prior knowledge acquired throughout the medical curriculum. This is reflected in the lower average of meaningful contributions to solve cases (mean 4.7). In contrast, 5th year students are still developing both the radiology knowledge and skills base and attend courses about radiological anatomy, imaging techniques, and radioprotection. They have yet no clinical experiences with radiology. This results in the expectation that these students need more time to solve the cases. The average number of meaningful contributions is as a result higher and also the overall number of times students did work in the CSCL setting (N 144, SD 47).

Though not based on the systematic analysis of the data gathered while analyzing the CSCL discussions, anecdotal evidence shows some particular differences in the way students from the 5th and 7th year interact. The structure of 5th year students’ discussions has more repetitive character with checking on each other the correctness of the proposed item to solve the case. Contrary to the structure of discussion of the last year students which is more constructive. Students make their decision mostly during the first discussion session and continue to work on additional relevant issues.

Another important point during the CSCL sessions is the need of teacher to intervene during the discussions of 5th year students. The average number of teacher interventions across 26 discussion was 2.54. The reasons why these teacher interventions are necessary were mostly related to (1) a wrong direction in identifying a radiological structure or a diagnosis, (2) to stimulate the group to identify other relevant items related to their diagnosis or a validation of issues being raised.

Table 3 summarizes the differences in components of the diagnostic approaches adopted by the two different student samples during the CSCL sessions. Significant differences are visible for the number of radiological key structures being missed (mean 0.81 vs 0.10, respectively, p < 0.05) as a part of the visual pattern recog-
PART 2: Chapter 2.3 The quality and impact of Computer Supported Collaborative Learning (CSCl) in radiology case-based learning

Table 2
General characteristics of the CSCl discussions.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of cases to solve</th>
<th>Number of meaningful contributions across 26 discussions (mean; SD)</th>
<th>Number of times that students did consult a case across 26 discussions (mean; SD)</th>
<th>Number of times that teacher did intervene during the discussion across 26 discussions (mean; SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th year students</td>
<td>26 cases</td>
<td>9.23[3.76]</td>
<td>144[47]</td>
<td>2.54[0.99]</td>
</tr>
<tr>
<td>7th year students</td>
<td>26 cases</td>
<td>4 cases</td>
<td>1 weeks</td>
<td>32[11]</td>
</tr>
</tbody>
</table>

*SD = standard deviation.

Table 3
The components of the diagnostic approaches during the CSCl activities (process evaluation).

<table>
<thead>
<tr>
<th>Component</th>
<th>N cases</th>
<th>Year 5 (Mean; SD)</th>
<th>Year 7 (Mean; SD)</th>
<th>Z</th>
</tr>
</thead>
</table>
| Visual pattern recognition                     | 26      | 0.81[1.1]         | 0.15[0.4]         | -2.66 *
| Number of radiological key structures that were missed during a group discussion | 19      | 0.53[1.2]         | 0.05[0.2]         | -1.49 *
| Number of anatomical structures being missed during a group discussion | 26      | 1.1[1.1]          | 0.1[0.4]          | -3.86 *
| Cognitive patterns                             | 26      | 1.1[1.1]          | 1.3[1.3]          | -1.00 *
| Number of diagnoses missed during the discussion | 26      | 0.2[0.4]          | 0.0[0.4]          | -1.00 *
| Number of differential diagnoses presented during the discussion | 26      | 0.2[0.4]          | 0.0[0.4]          | -1.00 *
| Number of appropriate radiology imaging techniques missed during the discussion | 6       | 0.2[0.4]          | 0.0[0.4]          | -1.00 *
| Verbal justifications                          | 26      | 6.2[3.1]          | 5.6[3.1]          | -0.62 *
| Number of adequate medical terms used during the discussion | 26      | 1.7[1.8]          | 0.5[0.8]          | -2.26 *

* p<0.05

5. Discussion

At Ghent University, "Web-based radiology cases" has been implemented as a part of the large innovative project in radiology teaching since 2008-2009 and were introduced in year 5 and 7 in the context of a computer-supported collaborative learning setting. The present study presents a first evaluation of this innovative instructional concept in terms of students' experiences and in terms of a qualitative and quantitative analysis of the collaborative process and outcomes.

Previous research already emphasized the potential of developing an interactive and multimedia learning environment, focusing on radiology case-based learning [11]. The findings of the present study confirm that a scripted CSCl approach is favorable for both early clinical year students and students at the end of their medical education career. It is known that collaborative learning enhances students' satisfaction [14,15,36]. The students in the present research reported a neutral to positive attitude towards collaborative learning, thus conforming partly the social constructive benefits from working in small groups [4]. Students report to learn from each other, learn to collaborate and tend to solve clinical radiological problems more quickly.

The fact that 7th year students were somewhat less in favor of the CSCl setting can be related to the very different nature in the study profile of 7th year students. They already have a clear and
personal orientation in view of a future specialization (radiology, rheumatology, orthopedic surgery, traumatology and/or physical therapy). Students in these high-stake performing settings are known to be less oriented towards collaborative learning settings. These students have a strong personal commitment to solve the radiology cases [11].

The process and outcome analysis results of the CSCS discussions showed significant differences in the mastery of 5th and 7th year students. This illustrates that case-based "problem-solving is content specific" [37]. The results also suggest that the design of the cases was relevant, and did cover the adequate learning objectives of the curriculum [38].

In the introduction, we emphasized the importance of content scripting in the context of CSCS. The current research findings help us to refine this approach in the context of solving radiology cases. We first review the main findings. From our research, it is clear that the last year students have already attained a systematic approach in their radiology problem solving. Fifth year students still need to improve this kind of abilities: to recognize the key radiology structures, to define a diagnosis and to relate radiological signs to available clinical information. But clinical radiology in the Ghent University is only being from the 4th curriculum year. As a result, 5th year students hardly have attained radiological clinical experience. Though we can conclude that the CSCS case-based learning approach has fostered their knowledge and skills, we think that a more thorough – clinical thinking – scripting approach could be adopted. This script could be more explicitly imprinted on the case solution approach. In the literature, we can build on available experiences [39]. For instance, Miller and Andrew [40] proposed a structured radiologic problem-solving system, based on six steps: problem sensing, problem hypothesizing, problem searching and definition, problem identification, resolution, verification. Available evidence suggests that following this solution pattern approach helps to come to more thorough decision [32]. This type of script could be imposed at an early stage. Research indicates that – after an initial phase of rigid application of these scripts in diagnostic thinking, the degree of flexibility in thinking and the level of knowledge structuring in memory largely increases [33]. It is expected that a more explicit scripting approach will stimulate the development of integrated radiology thinking approaches.

We observed – in 5th year students – the need for teacher interventions to direct the case solution process. Again, we can link this to the scripting approach discussed above. These scripts could also serve as guides for the teacher to give hints, cues, recommendations, and invite reflection in the students during the group discussions. We expected that teacher interventions would maximize the results of the group decision in terms of diagnostic interpretation of the patient case as a whole. The latter is important to prevent students to proceed on a symptom-by-symptom basis [33]. Research shows that students perceive experts’ interventions during collaborative sessions as useful and important [15]. Moreover, studies also point at the modeling and motivating impact that result from the active engagement of teaching staff when managing CSCS settings, and revising draft group solutions [36].

From previous research about expertise in medical imaging diagnosis, it is known that in parallel to expertise, also the ability to verbalize the thinking process clearly improves [41]. We found no differences in accuracy of usage of medical terms between 5th and 7th year students, but significant differences were found in the usage of lay terms during the CSCS discussions. This points at the critical position of these and related courses in the curriculum to develop reporting skills that force students to actively apply their medical vocabulary. It is suggested that CSCS settings might be beneficial in this context.

In the setting of CSCS, the robust electronic learning platform is vital to support this way of teaching: to ensure the possibility of online discussions and data communication and storage as well as an access to the system. Availability of personal computers or PCs at school that can be used by students during the learning is also an important element of this system.

5.1. Limitations

A number of limitations have to be mentioned in relation to the present study. First, the study was based on a local implementation of an instructional system at Ghent university. Secondly, though we compared 5th and 7th year students, it was not our intention to judge the differential impact of CSCS case-based learning in both student samples. The approach of the present study was not experimental in nature, but rather evaluative and explorative. It helped nevertheless to point at a positive shift in competences in 7th year students. Additionally, we have to acknowledge that “problem-solving is content specific” [37]. The present study only focused on cases about musculoskeletal radiology, which is only a part of the broader radiology curriculum. Future research could center on radiological cases at the thoracic level (radiology of heart, lungs) or abdominal level (radiology of digestive tract or radiology of the uro-genital system). Next, tough we emphasized the need to adopt a content scripting approach, future research should be more explicit about the nature and structure of the scripting, the way teachers intervene and how learners adopt these scripts. It is important to note that a CSCS approach towards case-based learning is labor intensive in terms of faculty time. Future studies could explore peer tutoring approaches that have been proven to be successful in other domains [42]. Lastly, our study design focused on the nature and quality of group discussions and products. This neglects within-group differences. Also, since then difficulty level of the cases was clearly different, again differences within and between groups could have occurred that are now neglected in the

Table 4

Accuracy and correctness of discussion contributions related to the radiology diagnostic thinking patterns (outcome evaluation).

<table>
<thead>
<tr>
<th>Diagnostic thinking approach</th>
<th>N cases</th>
<th>Year 5 Mean [SD]</th>
<th>Year 7 Mean [SD]</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual pattern recognition</td>
<td>26</td>
<td>1.65 [0.8]</td>
<td>1.25 [0.4]</td>
<td>-2.26^*</td>
</tr>
<tr>
<td>Accuracy of identification of radiological key structures</td>
<td>19</td>
<td>1.63 [0.5]</td>
<td>1.26 [0.4]</td>
<td>-2.64</td>
</tr>
<tr>
<td>Cognitive patterns</td>
<td>19</td>
<td>1.53 [0.6]</td>
<td>1.26 [0.4]</td>
<td>-1.40</td>
</tr>
<tr>
<td>Accuracy of radiological diagnosis</td>
<td>26</td>
<td>1.92 [0.7]</td>
<td>1.50 [0.6]</td>
<td>-2.10</td>
</tr>
<tr>
<td>Accuracy of linking the radiological signs to available clinical information</td>
<td>13</td>
<td>2.08 [0.5]</td>
<td>1.46 [0.5]</td>
<td>-2.14</td>
</tr>
<tr>
<td>Accuracy of choosing appropriate radiological imaging techniques</td>
<td>6</td>
<td>2.17 [1.2]</td>
<td>1.33 [0.5]</td>
<td>-1.87</td>
</tr>
<tr>
<td>Verbal justifications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy of using medical terminology</td>
<td>26</td>
<td>1.38 [0.6]</td>
<td>1.15 [0.5]</td>
<td></td>
</tr>
</tbody>
</table>

* Items are scored: 1 = completely correct; 2 = correct but with missed key findings; 3 = correct but with relevant findings; 4 = completely incorrect. 

^* p < 0.05.
PART 2: Chapter 2.3 The quality and impact of Computer Supported Collaborative Learning (CSCL) in radiology case-based learning

present analysis approach. Future research could center on multi-level analysis techniques that respect the nested nature of students in groups; studying different cases.

5.2. Direction for future research

Future studies could also focus on a discourse analysis to study the particular patterns of the CSCL interactions. This would be helpful to analyze in what way students build on each other's contributions, share information and how they attain a consensus on a case solution.

6. Conclusions

To conclude, the result of the present research indicate that students appreciate CSCL case-based learning. Scripted computer supported collaborative learning groups proved to be useful for both 5th and 7th year students in view of developing components of their diagnostic approaches.

References

help to structure collaborative learning activities. Content-oriented script helps learners to select, organize and integrate the knowledge base that is at the base of the collaborative task (such as knowledge about infections to solve a discussion task about tropic diseases). Communication-oriented script fosters the engagement of group members in the collaborative process by helping them to adopt different or specific perspectives, to consider in a conscious way the input of peers, etc. (Scheltema T, Van keer H, De Wever B, Valcke M. Scripting by assigning roles: does it improve knowledge construction in asynchronous discussion groups? Int J Comput Supported Collaborative Learn 2007;2:225–46).

Scripts-based clinical reasoning: a script activation is automatic and almost unconscious. Activated scripts are used in a conscious and strategic way to confirm or refute corresponding hypotheses, and activated scripts serve to guide information selection, memorization and interpretation (Charlin BD, Tardif J, Bouchatel HPA. Scripts and medical diagnostic knowledge: theory and applications for clinical reasoning instruction and research. Acad Med 2000;75(7):182–90).
GENERAL DISCUSSION

Research focus of this dissertation

Overview of the research objectives and the related results

General discussion and conclusions

Strength and limitations of the different studies

Implications of the research findings for educational practice

Directions for future research

References
GENERAL DISCUSSION

In this general discussion, we summarize the research findings from the studies presented in this dissertation. The chapter builds on the research objectives as discussed in the introductory chapter. In addition, we present the strengths and limitations of our research, the implications for educational practice and directions for future research.

Research focus of this dissertation

The first central research problem of this dissertation was centered around the international benchmarking of radiology curriculum approaches in Europe. It is known from the literature, that medical school educational programs and undergraduate training of radiology in particular are hardly standardized throughout Europe and the United States (U.S.). The place of undergraduate radiology training in these educational programs is barely clearly defined, and a great variation in the approaches in undergraduate teaching of radiology is observed. Although the critical nature of a mandatory radiology curriculum and the need for a formal, clearly structured radiology curriculum are widely discussed in the medical literature, finding an established formal radiology curriculum is rare. Nevertheless, plenty of recommendations for innovative frameworks are available, but comprehensive information about the current state-of-the-art as to radiology teaching and learning approaches - particularly in Europe - is lacking. This also introduces questions about the extent to which radiology qualifications are transferrable within Europe.

The second main research problem of this dissertation was to evaluate the innovative radiology curriculum, implemented at Ghent University. The evaluation focused the specific educational formats being adopted as well as the perceived impact of the curriculum components.

During recent years, many medical schools have undergone curricular reforms and have implemented innovations regarding the instructional design of the teaching and learning experience. A main goal of curriculum innovations was to enhance the efficiency and efficacy of teaching approaches, resulting in better learning performance. However, the redesign of a learning environment will not automatically
influence its efficiency and efficacy and/or result in better learning performance. Research consistently emphasizes that the way students experience and perceive their learning environment, mediates the efficiency and efficacy of an innovative instructional design \(^{24-25}\). In addition, these student perceptions differ depending on the specific learning needs of students in the preclinical or clinical phase of medical training \(^{26}\). The emphasis on student experiences and perceptions introduces the relevance of studying student attitudes in relation to curriculum innovations. At Ghent University, a large scale innovation of radiology teaching has been implemented since a number of years. But, a systematic evaluation of the impact of the new curriculum was – until now - not set up.

**Overview of the research objectives and the related research results**

In view of studying the two central research problems, a number of research instruments have been developed, and particular research approaches have been adopted.

In view of benchmarking radiology undergraduate education from an international perspective, an online survey was developed: “Questionnaire on undergraduate radiology teaching”. This instrument was distributed via the European Society of Radiology (ESR) to the National Delegates of the ESR Education Committee.

To evaluate the Ghent University radiology curriculum innovation, a questionnaire “Evaluation Radiology Teaching Concept Scale” (ERTeCS) was developed and filled out by all students enrolled in the second to seventh year of medical training.

In addition, to investigate in particular radiology case-based learning within a computer supported collaborative learning (CSCL) setting, additionally, a qualitative and quantitative analyses of online collaborative learning discussions was carried out. This research design was implemented by involving early clinical year students and nearly graduating medical students. The CSCL activities were based on radiology cases regarding musculoskeletal radiology.

As described in the introductory chapter, **four research objectives (RO)** were formulated in view of the two research problems.
To describe how undergraduate radiology teaching is organized in Europe and to identify related characteristics of the undergraduate radiology curriculum (Chapter 1.1).

Analysis of the descriptive results of the ESR (European Society of Radiology) questionnaire, shows large differences in the organization of the undergraduate radiology curriculum in Europe:

- The differences start with the duration of undergraduate medical studies and the type of the undergraduate medical curriculum (classic, modular or hybrid type of curriculum). Subsequently, the results of the study show that the number of radiology teaching hours varies largely between European countries (countries mean 89 hours, median 76 hours, min 19 hours, max 212 hours) and depends on the radiological topic. In this study, seven radiology topics could be extracted that can be considered as critical components of a radiology curriculum: radiological anatomy, radiology techniques, radiology of diseases, interventional radiology, radiation protection, guidelines for appropriate use of radiology, and hands-on interpretation skills. It is reassuring to find that in more than half of the European countries these topics are present in the radiology curriculum.

- In addition, some data can be derived that can be considered as benchmarks for the critical components of a radiology curriculum: the topic “Radiology of diseases” receives the most teaching hours (mean 38.6 h; median 28h), followed by “Radiology techniques” (mean 19.4 h; median 10 h), and “Radiology anatomy” (mean 18.6 h; median 12). Further, it was found that the fourth year of medical training is reported to be the most important year for teaching, considering nearly all critical radiological topics are being dealt with (except radiological anatomy and radiation protection). The latter subjects dominate the third year curriculum.

- Written tests and oral examinations were the most commonly used evaluation formats. It is striking that the use of computer-based assessment PC or/and OSCE evaluation are not widespread.

- Finally, the involvement of radiologists in teaching radiology as well as the central position of radiology clerkships were a shared characteristics of radiology curricula in European countries.
To investigate how students perceive the innovative undergraduate radiology curriculum at Ghent University, and what helps to explain differences in student perception (Chapter 2.1).

The Evaluation Radiology Teaching Concept Scale (ERTeCS) was especially designed for this study. This research instrument studies student experiences and perceptions in relation to the different components of the radiology curriculum. Prior to the analysis of the results, the psychometric quality of the ERTeCS attitude scale was established.

The survey results reflect overall positive student perceptions about the different components of the innovative radiology curriculum. Significant differences in student perceptions between training years could be detected in relation to: radiology teaching, the radiology syllabus, E-learning, E-testing, the radiology clerkships and radiology case-based learning. This helps to conclude that student perceptions towards the radiology curriculum components change during the medical training.

More specifically, student perceptions about the E-learning component are already very positive in year 2 and rise consistently in nearly every consecutive training year, and up to year 7. This curriculum component reflects the highest positive student perception score and reflects a very strong and consistent increase.

The perception of the radiology syllabus is rather neutral in year 2, but perceptions slightly evolve in a positive way up to year 7. Nevertheless, it remains the least – nevertheless positive - appreciated curriculum component.

Perceptions about the E-testing component show a positive pattern across the training years, with only minor significant differences across training years.

Studying the perceptions of fifth year students and older, new curriculum components become central in the educational approach. Right from the start, radiology research is perceived as a very important curriculum component. This high appreciation does not change through the consecutive training years.

The component radiology clerkship is perceived in a rather neutral way in the fifth year, but perceptions become gradually more positive in year 6 and year 7. The perceptions about the curriculum component radiology cases decreases, but this significant decrease remains limited (small effect size).
(RO3) To explore the perceived value of clinical clerkships in the radiology curriculum as well as the impact of radiology clerkship on students’ beliefs about the profession of radiology as a whole and as a career (Chapter 2.2).

To study this particular research objective, the research focused on a subsection of the ERTeCS that centers on radiology clerkships and radiology as a career.

We could observe that the perceived usefulness of the following features of radiology clerkship were valued most: “radiology examination”, ”skills development” and “diagnosis focus”. The predictive value of the internship subscale “radiology examination” on learning performance was significant and very high.

Further, the radiology clerkship experience in the 6th year seems to shape students’ opinion about radiology. Students with radiology clerkship experience adopt a more positive orientation towards radiology as a profession. But, this difference – though significant - is not large.

The finding that students who were involved in a radiology clerkship showed less interest in radiology as a personal future career choice was not surprisingly. It is likely that students who are enrolled in a clerkship during their sixth and nearly final year of their medical training, will already have an established idea about their future professional orientation and especially about their future specialization.

(RO4) To explore whether case-based learning, set up in a computer supported collaborative learning (CSCL) setting, results in student satisfaction and helps to develop and improve radiologic problem-solving abilities of medical students (Chapter 2.3).

The analysis of perceptions about collaborative learning in relation to radiology case based learning, reflects a rather neutral attitude that does not change during following grade levels. Less advanced students are more positive about CSCL as compared to last year students.

The evaluation of data in relation to the collaborative learning process shows particular patterns. Students from the early clinical years of training need more time to solve cases. Their average number of meaningful contributions is larger, and also the overall number of instances students work in the CSCL setting. The structure of 5th year students’ discussions is more repetitive in nature due to the larger emphasis on checking the correctness of the input to solve the case. This contrasts with the more constructive nature of the discussions of last year students.
The latter students make present their ideas and decisions mostly during the first discussion session and continue next to focus on additional relevant issues. Significant differences are also observed in nature of their justifications. Junior students adopt significantly more lay terms during their discussions. Nevertheless, both student groups seem to master and apply almost an equal number of adequate medical terms. But again – in 5th-year students - the number of radiological key structures being missed as a part of the visual pattern recognition components and the number of diagnoses missed during the CSCL sessions as part of the cognitive pattern components are significantly higher. This introduces clearly the need for staff interventions during discussions when early clinical year students are involved.

No significant differences have been observed during the discussions, in relation to other elements, such as the number of anatomic structures, appropriate radiology imaging techniques, and the number of differential diagnoses presented during discussions.

Outcome evaluation shows – in last year students - a significantly higher level of accuracy in the identification of radiological key structures, radiological diagnosis, as well as linking radiological information to available clinical information. No significant differences were observed between students of different grade levels in their accuracy when using medical terminology.

**General discussion and conclusions**

**RO 1:** To describe how undergraduate radiology teaching is organized in Europe and to identify related characteristics of the undergraduate radiology curriculum.

This results of this - first - international comparative study about undergraduate radiological curricula in Europe, help to identify a large number of differences in curriculum content and teaching methods throughout Europe. This is in line with results of available research1-6. These content differences call for additional research that help to develop a deeper understanding of the critical components of the radiology curriculum. Next, the findings about differences in instructional formats are helpful to further the development of undergraduate radiology education. Subsequently, building on both the differences in content and instructional format, standards are needed to make teaching and learning qualifications transferrable throughout Europe. This first benchmarking study is helpful as a point of departure.
**RO 2:** How do students perceive the innovative undergraduate radiology curriculum at Ghent University, and what helps to explain differences in student perception.

As stated earlier, the affective learning domain to develop clinical competences and foster learning performance has been demonstrated\(^\text{27}\). Attitudes, reflecting emotional responses and personal experiences, are sensitive to characteristics of the learning environment\(^\text{28}\). Innovations of the learning environment are beneficial and result in higher learning performance, when they are perceived as such by the students\(^\text{24-25}\). The present research results point at a positive perception of the innovative radiology curriculum components by students enrolled at different grade levels in the medical curriculum. This finding is in line with the results of previous studies that point at the positive impact of a “blended learning” approach: combining E-learning and face-to-face lectures, supported with printed learning materials\(^\text{17, 29}\). In addition, the results show how these perception differ, depending on the learning needs of students in the preclinical or clinical phase of their medical training\(^\text{26}\). Both during pre-clinical and clinical years, students highly appreciate ex-cathedra lessons with a syllabus, E-learning, E-testing, etc. In clinical years - as expected – students centre on learning objectives that emphasize the application of knowledge and skills. Therefore, these students heavily appreciate practice linked curriculum components such as clinical radiology clerkships, case-based learning, and radiology research tasks.

**RO 3:** To explore the perceived value of clinical clerkships in the radiology curriculum as well as the impact of radiology clerkship on students’ beliefs about the profession of radiology as a whole and as career.

Previous research stated that student perceptions are particularly important in the context of clerkships\(^\text{24-25, 30-31}\) and that satisfaction with a residency experience is associated with enhanced learning outcomes\(^\text{32}\). Our results show that students are highly in favor of clerkship in view of learning to order clinical imaging and to interpret radiological images (ERTeCS scale “diagnosis focus”). In addition, it is clear that student perceive clerkships as a unique possibility to attend various radiological examinations and to access specific radiology software systems (ERTeCS scale “radiology examination”). They develop a better understanding of radiology and improve their image interpretation skills (ERTeCS scale "skills development"). In addition, the positive perceptions about the clerkship experiences influence future
career decisions\textsuperscript{33}. In the present research, a positive attitude towards clerkships was closely tied to students’ beliefs about the radiology profession. This is in line with available evidence stating that students consider their clerkship of importance to develop as a radiologist and in view of their future career choice\textsuperscript{34-36}. From our research, it is clear that this aspect of radiology clerkships is crucial, especially for students who currently reflect a neutral or ambivalent perception about radiology as a personal career choice.

**RO 4: To explore whether case-based learning, set up in a computer supported collaborative learning (CSCL) setting, results in student satisfaction and helps to develop and improve radiologic problem-solving abilities of medical students.**

Previous research already emphasized the potential of interactive learning environments, focusing on radiology case-based learning\textsuperscript{37}. The findings of the present study confirm that a scripted CSCL approach is favorable, both for student of early clinical years and students at the end of their medical education career. It is known that collaborative learning enhances students satisfaction\textsuperscript{38-40}. The students in the present research reported a neutral to positive attitude towards collaborative learning, thus conforming partly the social constructive benefits from working in small groups\textsuperscript{41}. Students report to learn from each other, learn to collaborate and tend to solve clinical radiological problems more quickly.

The process analysis, content analysis, and outcome analysis in relation to the CSCL discussions showed significant differences in the learning performance of students of different grade levels. The results also suggest that the design of the cases is important since they adequately covered the learning objectives of the radiology curriculum\textsuperscript{42}. The research findings reemphasize the need for adequate content scripting when solving radiology cases in a CSCL setting. It is clear that last year students did already attain a systematic approach in their radiology problem solving process. Fifth year students still need to further improve the key elements of such a systematic approach: to recognize the key radiology structures, to define a diagnosis and to relate radiological signs to available clinical information. Though we were able to conclude that the CSCL case-based learning approach did foster the mastery of radiology knowledge and skills, we think that a more thorough – clinical thinking - scripting approach should have been adopted. This script could have been more explicitly imprinted on the case solution approach. In the literature, we can build on
inspiring experiences\textsuperscript{43-44, 45}. The script could be imposed at an early stage. Research indicates that – after an initial phase of rigid application of diagnostic thinking scripts, flexibility in thinking and knowledge structuring in memory clearly increases\textsuperscript{46}. It is expected that a more explicit scripting approach will stimulate the development of such integrated radiology thinking approaches that are consequently more readily available for future problem solving. The scripting approach can also be linked to the need for teacher interventions. Scripts could support the coaching, tutoring, scaffolding, ... by the teacher during the case solution process, especially when working with students in their early clinical years. The scripts consequently serve as guides for the teacher to give hints, cues, recommendations, and to invoke reflection in students during group discussions. We expect that teacher interventions will maximize the results of the group decisions in terms of diagnostic interpretation of the patient case. The latter is important to prevent students to proceed on a symptom-by-symptom basis\textsuperscript{46}. Research shows that students perceive such expert interventions during collaborative sessions as useful and important\textsuperscript{40}. Moreover, studies also point at the modeling and motivating impact resulting from the active engagement of teaching staff when managing CSCL settings, and when revising draft group solutions\textsuperscript{39}.

From previous research about expertise in medical imaging diagnosis, it is known that in parallel to the development of expertise, also the ability to verbalize the thinking process improves\textsuperscript{47}. In the present study, we found no differences in accurate usage of medical terms between students of different grade levels. But, significant differences were found in the usage of lay terms during the CSCL discussions. This points at the critical position of related courses in the radiology curriculum to develop reporting skills that force students to actively apply their medical vocabulary. It is suggested that especially CSCL settings might be beneficial in this context\textsuperscript{48}.

**Strengths and limitations of the different studies**

The strengths of the studies presented in this dissertation can be summarized as follows: they build on a rich data set, methodological –sound research designs were applied, and the studies focus on issues that are of immediate relevance for radiology education.
The quality of the research data results from the focus on qualitative research instruments. Detailed attention was paid to establishing the reliability and validity of the research instrument. The Evaluation Radiology Teaching Concept Scale (ERTeCS) was developed to measure student perceptions about innovative radiology curriculum components, the perceived mastery of radiology knowledge and skills, and the orientation towards the radiology profession. To determine the validity and reliability of the ERTeCS, initially exploratory factor analysis was applied. In a next phase, a confirmatory factor analysis (structural equation modeling) was helped to establish the structure of underlying latent variables. Reliability of the questionnaire was established by calculating Cronbach’s alpha.

The research designs build on a the combination of research approaches: a quantitative survey-based study was conducted as well as a qualitative study. In the quantitative study, a cross-sectional as longitudinal approaches was adopted. Next to an analysis of the literature, observation of radiology teaching and learning activities, two focus group sessions were set up with students from different training years. These techniques helped to develop a picture about the way students perceive the curriculum, what they consider to be critical to learn and to be taught.

In addition, a series of descriptive statistics and the inferential statistics techniques were applied to study the research objectives. Next to types of T-tests (the independent sample t-tests, one-sample t-test), Analysis of variance (ANOVA) and Post Hoc tests were used to compare perceptions of students and to determine the differences between the groups. Prior to the analysis, statistical assumptions were test, in particular Levene’s test was applied to assess the equality of variances in different samples and adequate F-statistics were applied in the case of inequality of variances. To study the predictive power of some independent variables, stepwise multiple linear regression was carried out.

Finally, we consider that the results presented in this dissertation can help to further educational practice. The international benchmarking study of European radiology curricula can help to develop a strategy to develop standards in radiology education. The latter is critical in view of making radiology course credits transferrable at the European level and beyond. Another relevant issue that the innovating teaching approach which is evaluated in this thesis shows in some way the good practices that can be used broadly in undergraduate radiology teaching.
The limitation of this dissertation are related to different issues. First, we have to be aware of response bias, typical for survey based studies. This bias can also be partly related to a proportion of non-responding students. In the case of the international survey, we have to consider the fact that only one representative of each country filled out the survey. This can result in atypical responses from a particular country, given the existing differences within a country. This implies that also the between-country differences - resulting from country size, volume of the national health care system, and the number of medical training centers in a country - has potentially also been partly neglected.

A second limitation is linked to the newly developed Evaluation Radiology Teaching Concept Scale (ERTeCS). Future research should underpin the extent to which all the innovative curriculum components are covered by the instrument. In addition, further validation research is needed considering the nature of some of the goodness-of-fit indices.

A third issue is related to the cross-sectional nature of the studies building on student perceptions. Though the cross-sectional nature of the research design helped to study perceptions of students of different training years, this approach has some limitations since it only partly helps to map the longitudinal nature of the perceptions related to curriculum components. A true longitudinal design implies the follow-up of the same cohorts of students during a sufficiently long period of time, e.g., 4 or 5 years.

Lastly, the study about case-based learning within a scripted CSCL setting focused on group measures about the nature and quality of group discussions and resulting outcomes. This neglects within-group differences. Also, since the difficulty level of the radiology cases was clearly different, differences within and between groups could be related to these varying difficulty levels. These are neglected in the present analysis approach. Additionally, the fact that individuals work in different groups, and solve different cases, the variables are nested. The latter requires the adoption of specific analysis approaches that respect the multi-level nature of the data.
Implications of the research findings for educational practice

The results from the international benchmarking study regarding radiology educational systems is useful to set up teaching in European medical schools. The benchmarking exercise can help, to reorient the content and structure of a number of curricula in which there is an under-emphasis on the development of radiology competences. Another relevant implication regarding quantitative characteristics of didactical approaches, such as the total number of radiology teaching hours, or the number of teaching hours for a particular radiology topic. This is again helpful for individual benchmarking in institutions that want to make tactical and strategic decisions regarding their radiology curriculum at the local, regional or national level.

The evaluation results about the innovative radiology curriculum at Ghent University can be helpful to extract educational “good practices”. The evaluation studies also tells us that the adoption of evidence-based innovative approaches is beneficial as for teaching and learning. The “blended learning”- approach - in which face-to-face instruction is mixed with E-learning – seems to be applicable for the teaching and learning of radiology in both the pre-clinical and clinical phase of medical training. In addition, the following components can also adopted as relevant and effective curriculum elements: clinical radiology clerkships, radiology case-based learning, and radiology research activities. The results of the present studies suggest to adopt these components as formal and eventually compulsory parts of a radiology curriculum.

In the last study, scripted computer supported collaborative learning was investigated in a radiology curriculum setting. The results are optimistic as to the adoption of CSCL in a radiology curriculum especially in view of developing radiology thinking and problem solving approaches. This educational strategy can be used for teaching radiology with students of different grade levels.

The above results and conclusions about practical implications neglect the development t of critical and related teaching competences. The focus in the present studies was on the students and their perceptions, learning processes and learning outcome. But, the implication of an innovative learning environments also depends on the competences of the designers, developers and actual teachers in a teaching and learning context. This brings us to a discussion about specific needs and directions for future research.
Directions for future research

The results of this dissertation call for further research in a variety of fields. Firstly, future research, focusing on an in-depth analysis of international radiology curricula, could be extended with an analysis of concrete teaching interventions during face to face teaching (e.g., video analysis), the analysis of the nature of involvement of staff during internships, the reward systems used in particular European countries for internship students, … . These topics could be helpful for a better understanding of curriculum differences and institutional needs in or between particular European countries.

Second, the student perspective could be considered more carefully by adopting qualitative study approaches that enrich the survey data (data triangulation), next to studying more in detail the link with actual student performance. As stated before, this should be done in a true longitudinal research design.

Since problem-solving is partly content-specific50, our study about radiology case-based learning within a scripted CSCL setting, should enrich the case base and go beyond the topic musculoskeletal radiology. Future CSCL studies could center on radiological cases at the thoracic level (radiology of heart, lungs) or abdominal level (radiology of digestive tract or radiology of the uro-genital system).

Next, as suggested earlier, we should adopt a stronger content scripting approach. Future research should be more explicit about the nature and structure of the scripts, the way teachers intervene and how learners adopt these scripts. In addition, it is to be emphasized that a CSCL approach towards case-based learning is labor intensive in terms of faculty time. Future studies could explore peer and student tutoring approaches that already have proven to be successful in other academic knowledge domains51.

Future studies could also focus on a discourse analysis to study the discussion patterns in the CSCL interactions. This would be helpful to analyze in what way students build on each others’ contributions, share information and how they develop a consensus about a case solution.
In addition, we did not focus on the changes in attitudes towards radiology due to the clerkship experience. Considering the fact that now a valid and reliable instrument is available to study student perceptions in relation to five clerkship sub-foci, future studies could center on the specific impact of the clerkship experiences on changes in these affective variables and how this is related to changes in performance.

Lastly, future research should also center on the related teaching competences of the teaching staff that is responsible for the curriculum implementation. This would be helpful to support further adoption of these specific instructional formats on an institutional level. Only when a continuous critical evaluation perspective is adopted, we will be able to attain and maintain the potential benefits of the curriculum innovation.

References


EVALUATIE VAN HET RADIOLOGIE ONDERWIJSSYSTEEM BINNEN HET CURRICULUM GENEESKUNDE EN IN EEN INTERNATIONALE CONTEXT.

Doelstelling
De tweevoudige probleemstelling van dit proefschrift is enerzijds het uitwerken van een basis voor een internationale benchmarking van een radiologie onderwijssysteem, en anderzijds de evaluatie van het innovatieve radiologie curriculum van de Universiteit Gent (UGent).

Vier doelstellingen voor dit onderzoek (RO) werden naar voren geschoven:

RO 1: Het beschrijven van de organisatie van het radiologie -onderwijs in Europa en om zo de belangrijkste kenmerken van medische radiologiecurricula te identificeren.

RO 2: Onderzoeken hoe studenten het innovatieve UGent radiologie curriculum ervaren, en wat verschillen in percepties van studenten helpt verklaren.

RO 3: Het verkennen van de gepercipieerde waarde van klinische stages in het curriculum radiologie, evenals de impact van deze stage op de opvattingen van de studenten over het beroep van radiologie en het eventueel kiezen voor een carrière als radioloog.

RO 4: Het onderzoeken of casusgericht leren via computer samenwerkend leren (CSCL) resulteert in een hogere tevredenheid van studenten en of dit helpt bij het ontwikkelen van hun probleemoplossingvaardigheden.

Methoden
Voor dit proefschrift werden twee specifieke vragenlijsten ontwikkeld: de "ESR (European Society of Radiology) vragenlijst over radiologie onderwijs " om het radiologie onderwijssysteem in een internationale context in kaart te brengen en de "Evaluation Radiology Teaching Concept Scale"(ERTeCS) vragenlijst die helpt om het innovatieve UGent radiologie curriculum te evalueren. Een kwalitatieve en kwantitatieve analyse van online groepsdiscussies werd uitgevoerd om de invloed van casusgericht leren in de radiologie te onderzoeken.

Resultaten
De beschrijvende resultaten van de ESR vragenlijst, wijzen op grote verschillen in de organisatie van de radiologie curricula in Europa.
Uit de evaluatieresultaten met betrekking tot het UGent innovatieve radiologie curriculum blijkt dat studenten, zowel tijdens de preklinische en klinische jaren, de verschillende curriculum onderdelen positief waarderen; bijv. de ex-cathedra lessen met een syllabus, E-learning, E-testing, enz. In de klinische jaren waar studenten vooral aandacht hebben voor de toepassing van kennis en vaardigheden, waarderen ze vooral aan de praktijk gekoppelde curriculum componenten.

Onze resultaten tonen aan dat studenten de stage radiologie zeer positief beoordelen om op die manier voorschriftgedrag aan te leren en radiologische beelden te interpreteren. De stage biedt de studenten een unieke mogelijkheid om radiologische onderzoeken bij te wonen en om toegang te krijgen tot radiologie specifieke software systemen. Ze krijgen een beter zicht op radiologie en ze verbeteren hun interpretatievaardigheden tijdens de stage. Deze ervaringen beïnvloeden op een positieve manier hun mening over radiologie als beroep en een carrièreoptie.

Verder, blijkt het casusgericht leren via computergebaseerde samenwerkend leren duidelijk effectief in termen van proces en productuitkomsten. Deze aanpak blijkt gunstig voor studenten van de verschillende klinische jaren met het oog op het ontwikkeling en verbetering van de nodige klinische redeneringstrategieën.

**Conclusies**

De verschillen in de medische (radiologie) curricula in Europa, zetten aan tot nadenken over een standaardisering met het oog op de uitwisselbaarheid van credits behaald aan verschillende instellingen. Maar deze vergelijkende studie kan nog verder gaan en zich ook focussen op een analyse van instructiepraktijken, stages, beloningssystemen, enz.

Ook de positieve bevindingen m.b.t. het innovatieve radiologie curriculum van de Universiteit Gent zetten aan tot nadenken. Naast het implementeren van kwalitatieve studies over deze curriculuminnovatie en het oppikken van een longitudinaal perspectief, lijkt het ook nodig de lesgevers als onderwerp van studie te nemen in vervolgonderzoek. Enkel dankzij een continue kritische evaluatie kan een curriculum zijn innovatieve potentieel eindelijk bereiken en behouden.
SUMMARY IN RUSSIAN – РЕЗЮМЕ (RUS)

ОЦЕНКА СИСТЕМЫ ОБУЧЕНИЯ РАДИОЛОГИИ В КОНТЕКСТЕ МЕДИЦИНСКОГО ОБРАЗОВАНИЯ, А ТАК ЖЕ НА МЕЖДУНАРОДНОМ УРОВНЕ.

Цель настоящей диссертации - сравнение международных систем обучения радиологии, а также оценка инновационной учебной программы по радиологии Гентского университета. Четыре исследовательских цели (RO) были выдвинуты:

RO 1: Описать как обучение радиологии организовано в Европе, и определить важные характеристики студенческих учебных программ по радиологии. 

RO 2: Проверить как студенты воспринимают опыт работы и внесенные инновации в программу бакалавриата радиологии Университета Гента, и выяснить чем объясняются различия в восприятии студентов.

RO 3: Изучить восприятие ценности клинических практических занятий в учебной программе по радиологии, а также влияние этих практических занятий на убеждения студентов о радиологии как профессии и на выбор карьеры.

RO 4: Изучить вопрос как студенты-медики воспринимают методику решения клинических задач в системе компьютерной поддержки группового обучения (CSCL) и как эта методика помогает развивать и усовершенствовать способности клинического мышления при решении клинических радиологических задач.

Методика

Для этой диссертации были разработаны два специальных вопросника: для оценки образования радиологии в международном контексте был использован вопросник “ESR (Европейское Общество Радиологии) вопросник по бакалавриату преподавания радиологии". Для оценки инновационной учебной программы по радиологии в Университете Гента была использована "Шкала оценки концепта преподавания радиологии (ERTeCS). Для исследования концепта онлайн дискуссий по решению радиологических клинических задач в системе CSCL, был проведен качественный и количественный анализ онлайн дискуссий.
Результаты
Результаты вопросника ESR показали большие различия в организации учебных студенческих программ по радиологии в Европе. Оценка конкретной инновационной учебной программы по радиологии Гентского университета показала, что студенты как доклинического так и клинического периода обучения, предпочитают учебную программу с методологическими компонентами, которые сочетают традиционные методы обучения (например, лекции) с методами дистанционного обучения, такими как электронное обучение и тестирование на компьютере, онлайн клинические задачи и т.д.

В клиническом периоде обучения, студенты переходят к применению знаний и навыков и, следовательно, предпочитают клинически ориентированные практические занятия. Наши результаты показывают, что студенты значительно оценивают практические занятия по радиологии с целью научиться интерпретировать снимки радиологических исследований. Эти занятия так же предоставляют студентам уникальную возможность принять участие в различных радиологических исследованиях и предоставляют доступ к различным компьютерным системам для просмотра радиологических снимков. В течении этих занятий студенты получают более четкое представление о радиологии и улучшают свои навыки интерпретации радиологических снимков. Кроме того, опыт, приобретённый в течении этих занятий, положительно влияет на мнение студентов о радиологии как о будущей профессии.

Результаты также показывают что решение радиологических задач в инновационной системе компьютерной поддержки групового обучения является эффективным методом как в процесса обучения так и на уровне достигнутых результатов. Этот учебный метод оказался полезным для студентов разных лет обучения с целью развития и усовершенствования способностей клинического мышления при решении радиологических задач.

Выводы
Изучение международных различий в программах радиологии при подготовке медицинских кадров представляет возможность в перспективе сосредоточиться на стандартизации учебных планов и медицинских программ.
между странами Европы. Это сравнительное исследование может быть расширено путем сосредоточения внимания на анализе учебной практики, стажировки, систем поощрения и т.д.

Положительные выводы об инновационной учебной программы по радиологии Университета Гента призывают к дальнейшим размышлениям. Потому что не только осуществление качественных исследований инновационных учебных программ является важным при принятии определённой точки зрения, но также и сосредоточение на элементах, связанных с обучением преподавателей, которые отвечают за реализацию этих программ. Только тогда, когда непрерывная критическая перспектива при оценке экспериментальных инновационных учебных программ будет принята, мы сможем достичь и поддерживать потенциальные выгоды от этих инноваций.
ACKNOWLEDGEMENT – DANKWOORD

“Science seldom proceeds in the straightforward logical manner imagined by outsiders. Instead, its steps forward (and sometimes backward) are often very human events in which personalities and traditions play major roles.”

(James Watson)

Wat voor Watson geldt, geldt ook voor mij.

Vooraleer ik u vertel wat er is gegroeid in functie van mij wetenschappelijke ambities, wil ik u mijn achtergrond toelichten. U zal dan beter begrijpen wat het afleggen van dit traject voor me allemaal heeft betekend.

Ik ben afkomstig uit Rusland, waar ik 23 jaar woonde en het grootste deel van die tijd studeerde. Studeren was voor mij altijd een passie. Voor mijn gedegen studie tijdens mijn humaniora werd ik beloond met de Zilveren Medaille van het Ministerie van Onderwijs van Rusland. Deze overwinning gaf me toen de kans om verder gratis te kunnen studeren aan gelijk welke universiteit in dit grote land. Nog altijd heeft deze medaille een grote symbolische waarde voor me.

Zo heb ik deelgenomen aan de toelatingsexamens van de Faculteit Geneeskunde aan de Staatsuniversiteit van Petrozavodsk. Met succes, tot grote vreugde van mijn ouders en mezelf. Want van kindsbeen af wilde ik dokter worden.

Zes ongemeen boeiende studiejaren hebben me bovendien warm gemaakt voor academisch onderzoek. Vanaf mijn eerste kandidatuur was ik lid van de Wetenschappelijke Studenten Vereniging en nam ik actief deel aan onderzoek. Het zal wel liggen aan mijn zeer onrustige en nieuwsgierige geest, maar elk jaar deed ik iets anders om mijn wetenschappelijke kennis uit te breiden en te verbreden.

Het is allemaal begonnen met het onderzoek bij de vakgroep Fysiologie. Ik mocht participeren aan dierenexperimenten (op witte ratten!!!) om uit te zoeken of de koude stress een effect had op de beweeglijkheid van de spiereenheden. - Een super ervaring, niettegenstaande mijn aanvankelijke vrees voor deze dieren! Gelukkig werd ik geholpen door mijn promotor.

Na het afronden van dit project heb ik gekozen voor de vakgroep Psychologie, waar ze bezig waren met de uitvoering van de verschillende psychologische testen. Ze zochten naar het verband tussen de persoonlijke kenmerken en prestaties bij de studenten. Het was tevens een kans om mezelf beter te leren kennen vanuit
psychologisch standpunt. Ik heb niet nagelaten allerlei testen op mezelf toe te passen. Een verassende ervaring.

De volgende stap was de overstap naar de vakgroep Forensische Geneeskunde. Ik heb de mogelijkheid gehad om samen met studenten van de Faculteit Rechten een aantal secties mee te beleven in het mortuarium. Met als resultaat: een breder inzicht in de problematiek van deze materie. Vervolgens heb ik me geconcentreerd tot literatuur onderzoek over de mechanismen en types van strangulatie (ophanging). Enig inzicht in de uitzichtloze situatie wanneer de strop om de nek hangt en geen uitweg meer mogelijk is (ook door een aantal onomkeerbaar fysiologische mechanismen die het terugkeer niet meer toelaten), is mij duidelijk geworden. Het onderzoek is uitermate verhelderend geweest.

Vervolgens (tijdens de klinische periode van mijn studies) heb ik mijn interesse gericht op de gynaecologie. Samen met andere leden van het onderzoeksteam waren we op zoek naar de effecten van de stress gedurende de pre- en perinatale periode van de zwangerschap op de foetus en de pasgeborene. Ik heb veel zwangere vrouwen gezien, met veel vrouwen gesproken en veel bevallingen mogen meebeleven. De resultaten, vaak psychologisch indringend, hebben me echter niet afgeschrikt voor een eventueel later moederschap. Het belangrijkste wat deze studie heeft opgebracht is hoe om te gaan in deze problematiek met stress.


Mijn laatste halte tijdens de geneeskunde studies was de vakgroep Chirurgie. We hebben ons geconcentreerd op het implementeren van nieuwe laser technieken in de behandeling van de proctologische aandoeningen. Rond die tijd kwam ik tot het besef dat ik niet zozeer chirurg wilde worden. Maar dat staat los van het onderzoek, dat op zich zeer verhelderend was.

Naast zes jaar lang de obligate studieactiviteiten en examens, heb ik ontzettend veel in de wetenschappelijke bibliotheek gewerkt, wat als groot voordeel had dat ik dokters en wetenschappers met een grondige ervaring heb leren kennen. Het verbrede mijn wetenschappelijk kennis en reactie.
Uiteindelijk heb ik mijn titel als arts behaald met een grote onderscheiding.

Maar mijn lot was anders dan ik dacht.

Momenteel woon ik met mijn gezin al meer dan tien jaar in België. Mijn Russisch doktersdiploma is in België erkend als een diploma van Hoger Onderwijs, maar levert helaas geen beroepsmatige of volledige academische erkenning op. Mijn eerste reactie was – een drama, een professionele ramp! Toch niet – geen drama, geen ramp! Nadat ik geprobeerd had terug de draad op te pikken in de geneeskunde, ben ik me uiteindelijk bewust geworden dat ik mijn horizont nog verder wilde uitureiden. Ik heb al veel gezien, maar ik wou iets leren wat ik nog niet kende. Zo is de keuze gevallen op de Medisch-Sociale Wetenschappen aan de UGent. Het was voor mij zeer interessant om deze studie te voltooien. Wat meer is, achteraf gezien, het was een zeer nuttige studie voor mijn wetenschappelijke en huidige professionele carrière!

Ik weet niet van u zich dat kan voorstellen, hoe aangenaam en stimulerend het is om uw kennis en ervaring dagelijks te kunnen gebruiken in het opbouwen van een professioneel leven. Zo voelt het althans voor mij aan.

En nu, op dit moment van mijn afgelegd, niet rechtlijnig traject, met vallen en opstaan, heb ik een recent nieuw wetenschappelijk gebied leren kennen: de academische wereld van de radiologie. Dit is het wetenschappelijk gebied waar ik al mijn kennis, creativiteit en passie kon uitzetten, met als resultaat… dit eindwerk!

Vandaar dat ik zeer blij ben dat ik de gelegenheid krijg om een dankwoord te kunnen uiten aan mensen die me onvoorwaardelijk hebben bijgestaan voor dit onderzoek in al de tijd die het vergde.

Ik wil in het bijzonder mijn promotoren, professor K. Verstraete en professor M. Valcke, danken voor hun vastberadenheid, hun steun en hun doorzettingsvermogen in goede en kwade tijden, in de haast onvermijdelijke momenten van voorspoed en tegenslag.

Nog specifieker weet ik nu dat professor K. Verstraete niet enkel een superbegaafde radioloog is, maar ook een vasthoudend strateeg en een gedegen communicator – een unieke combinatie, in het licht van een het beoogde eindresultaat.
Professor Verstraete, ik dank u voor het vertrouwen in mij, voor de mogelijkheid om mijn eigen research keuzes te mogen maken en mijn eigen pad te volgen, om me in mijn visie te steunen en me delicaat aan te moedigen in momenten van tijfel. Ik waardeer ten zeerste uw betrokkenheid in alle onderwijsgerelateerde projecten waarmee we bezig waren.

Ik weet verder dat professor M. Valcke een uitmuntend professional-teacher is (van wie ik véél kon leren) met een ongelofelijke persoonlijkheid: bruisend met een groot enthousiasme en een massa energie. Hij gaf mijn inzet extra motivatie.

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De hulp van professor A. Derese (lid van de begeleidingscommissie) en professor H.P.A. Boshuizen (lid van de begeleidingscommissie) mag niet onvermeld blijven. Hun input tijdens het ontwerp van onze vragenlijst en hun uitgebreide expertise in het medisch onderwijs, leverden een vruchtbare resultaat op.

Alle onderzoekers van de Associatieonderzoekgroep (UGent) wil ik bedanken voor de gedreven mogelijkheid om samen na te denken over het betere onderwijs en onze ervaringen uit te wisselen. Onze gesprekken o.a. over de methodologische en praktische problemen waarmee elke onderzoeker geconfronteerd wordt, waren me zeer nuttig. Deze samenkomsten heb ik ervaren als een gelegenheid om mijn eigen denkgebied te verrijken met nieuwe ideeën en mogelijke toepassingen.

Naast het professionele dankwoord wil ik daarenboven de mensen bedanken die op persoonlijk vlak zoveel betekenen in mijn leven.

Vooreerst mijn ouders, mama, papoetje, (ook mijn papa die er al niet meer bij is). Ik ben zeer gelukkig dat ik altijd de mogelijkheid heb gehad om mijn eigen weg te zoeken en te vinden. We hebben samen veel moeilijke momenten doorgestaan en nog meer schitterende geluksmomenten gekend. Ik zou graag hebben dat onze gezamenlijke vreugde nog lang duurt. Mama, je weet hoe we samen droomden, al bijna 15 jaar, en nu, eindelijk, is gerealiseerd waar we altijd naar hebben gestreefd. We hebben het gehaald, lieve mama, mijn zielsvriendin, mijn onmisbare back-up.
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Mijn lieve zus, Viktoria, je bent net als ik - een strevertje, zoals mama zegt. Weet je dat het ongelooflijk stimulerend is om naast jezelf iemand te hebben die ondanks de tegenslag toch blijft doorzetten, tot het beoogde bereikt wordt ?! Ik dank je om er altijd voor mij te zijn.

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En, natuurlijk, mijn Marc, je bent mijn haven, waar mijn onrustige geest tot rust kan komen. Je weet dat ik in alle opzichten een ruimte nodig heb en je geeft me die ruimte ook. Waarvoor mijn dank. Ik dank je ook voor je geduld en je ongelofelijke attenties die lieten smelten wat het doel in de weg staat (en vooral mijn onrust). Ik speel opnieuw voor jou de geliefde pianostukken van Beethoven, Mozart, Chopin...een moment van genoot.

Om af te sluiten. De gekozen weg (kronkelig of rechtlijnig, doet er niet meer toe) is niet altijd even gemakkelijk en is bij momenten zelfs zeer moeilijk. Maar de hindernissen kunnen ook vruchtbaar zijn! Eigenlijk maken we de weg zelf. Dus, laten we die allen samen bewandelen! Tot meerdere eer en glorie van de wetenschap.

Ik dank u.

Elena V. Kourdioukova

Gent 2010
CURRICULUM VITAE

ELENA V. ORIS

was born as

Elena Vladimirovna Kourdioukova

on the 29th of Augustus in Alma-Ata (USSR)

Nationalities: Russian, Belgian

DEGREES:

1993 Degree of secondary school highest distinction (Russia)

1999 Degree of Doctor in Medicine (with high distinction) at the Medical University of Vladivostok (Russia)

2003 Bachelor degree in Medico-Social Science with distinction at the Ghent University (Belgium).

2005 Master degree in Medico-Social Science, Option Health promotion and improvement, with distinction at the Ghent University (Belgium).

2009 PhD student (Faculty of Medicine and Health Sciences Gent University)

EDUCATION/TRAINING TOPICS

2007: 3M Study day: Hospital Performance and Resource Management
2008: Course of Statistical Data Analysis (Ghent University)
2009: Madrid: course of management and coordination of the clinical studies

Amsterdam: Quality control in postgraduate teaching to medical specialist

LANGUAGE SKILLS:

RUSSIAN: native language
DUTCH: very good, fluency
ENGLISCH: good
FRENCH: basic knowledge
PC KNOWLEDGE:
MS-Office, Access, SPSS, SNAP

DRIVING LICENSE: B

WORK EXPERIENCE:

- Scientific Assistant at Ghent University, Pediatric Department (September 2005): PENTA-project (A Pediatric network around trauma)

- MKG (Minimal Clinical data) – doctor with specialty in the management of hospital data at O.L.V. of Lourdes Hospital, Waregem (Augustus 2006)

- Scientific Assistant-Expert, Radiology Department, Ghent University Hospital (since March 2008)

RESEARCH

1993-1999 Member of the scientific student association at the Medical University of Pertozavodsk, Vladivostok (Russia).

2005 Pediatric Department (Ghent University, Belgium): PENTA project: Trauma care and traumatic circumstances in children and young people between 0 and 18 years.

2008-...:

- Evaluation of the radiology teaching system in medical school curriculum of Ghent University, Belgium: the analysis of teaching components of the innovative undergraduate radiology curriculum at Ghent University and their the added value on radiology knowledge acquisition and attitude towards radiology.

- Case-based learning in radiology: a comparative study of educational effect of case-based learning in medicine and rehabilitation sciences and physiotherapy at Ghent University, Belgium.

- ESR on Undergraduate Radiology Teaching (European Society of Radiology): a general overview of radiology training to medical students across Europe with regard to developing of educational strategies and a general framework of undergraduate radiology teaching.

- The competences of Undergraduate Radiology Education: developing of the questionnaire.
- An electronic portfolio of radiological postgraduate teaching: an educational benchmarking analysis of work performance and learning activities of the residents radiologist at Universities of Belgium.

- Measuring of educational climate of radiology residency at Flemish Universities: analysis of DIRECT questionnaire.

**MEMBERSHIP:**

- Since 2008 Member of Association Research Group at Faculty of Medicine and Health Sciences Gent University
- Since 2008 Member of working group “Innovations in Education and Teaching ” at Gent University
- Since 2009 Associate member of European Society of Radiology

**Lectures:**

- 13.11.09 Lecture for medicine study association MSFU `Sams` Utrecht University: Radiology education at Ghent University: the modern approach of e-learning and e-testing.
- 16.11.09 Coordinator of session “Didactic arts” on Second day of Education Innovation at Gent University, Belgium
- 12.01.10 Presentation of ERO project (Evaluation of the radiology teaching system in medical school curriculum of Ghent University) at scientific meeting of Association Research Group UGent.