HISTORY OF MEDICAL PHYSICS E-LEARNING INTRODUCTION AND FIRST ACTIVITIES -IOMP HISTORY OF MEDICAL PHYSICS

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Content

Medical Physics was one of the first professions to develop and introduce e-learning. This was underpinned by the need of extensive imaging material and specific explanations for the professional education and training. The process was additionally supported by the excellent computer skills of the majority of medical physicists.

The introduction of e-learning in Medical Physics happened before the existing of the term. Initially (in 1994) the e-learning materials were named "electronic teaching materials" and "multimedia". The term "e-learning" emerged in 1998 through the paper of A Morri in Connected Planet (Nov 1997) "*A bright future for distance learning: One Touch/Hughes alliance promotes interactive 'e-learning' service'* ".

The global development of e-Learning started some 20 years ago, hence most of the results and processes are quite recent. These also develop with high speed and often the full development is difficult to be followed. Judging by the large number of e-learning projects in medical physics, one can be sure that this field will have significant development in future and will play an important role in the global professional growth.

1. The Introduction of e-Learning in Medical Physics

The development of e-learning in medical physics has been a pioneering process, triggered by the very dynamic nature of the profession. The existing before the 1990s paper print was slow and not able to answer the very fast development of various medical equipment and related methods. The new Desk-top Publishing (DTP) methods offered an answer to this problem. This is how a sequence of 4 international projects introduced e-learning in medical physics (EMERALD, EMERALD II, EMIT and EMITEL), these projects were interlinked with 3 other international educational projects, thus forming a sequence continuing 20 years, which encouraged many other e-learning projects in the profession. Detailed description of these projects is available in the free e-book "The Pioneering of e-Learning in Medical Physics" [1]. The very innovative work on e-learning in medical physics, and its global impactresulted in the inaugural award for education of the European Union – the Leonardo Da Vinci Award (2004), what was important for the visibility of the profession.

1.1 Pilot Project EMERALD and its Image Database (IDB) - the second IDB in the world with ISBN

The concept of a project related to electronic teaching materials (later to become the pilot project EMERALD) was introduced in 1989, but the actual project was developed by S Tabakov during 1994 and was later submitted for support to the European Union (EU) programme Leonardo. This pilot project was orientated towards development of electronic materials for medical physics training (the term 'e-learning' did not yet exist).

The partners in the project were a Consortium of Universities and Hospitals from UK, Sweden, Italy and Portugal: King's College London - School of Medicine and Dentistry, University of Lund, University of Florence, King's College Hospital, Lund University Hospital, Florence University Hospital, The Portuguese Oncological Institute in Lisbon, the High School of Medical Technology Lisbon and the International Centre for Theoretical Physics (ICTP) in Trieste, Italy. Project Contractor was Prof V C Roberts, Coordinator was Dr S Tabakov and representatives of the Partners were: Prof S-E Strand, Prof J Gomes da Silva, Prof F Milano, Dr C A Lewis, Dr I-L Lamm, Dr A Campagnucci and Dr A Benini.

The project was managed and co-ordinated by King's College London and was supported by the European Federation of Organisations for Medical Physics (EFOMP), the European Association of Radiology (ESR), the International Atomic Energy Agency (IAEA) and the Medical Physics Societies of the partner countries.

The objectives of EMERALD (acronym of: European Medical Radiation Learning Development) were: "Development of common vocational training modules in medical radiation physics, which will incorporate materials for distance learning on CD and multimedia". The initially planned 3 modules were: Physics of X-ray Diagnostic Radiology, Physics of Nuclear Medicine, Physics of Radiotherapy.An additional module was also planned (Physics of Medical Imaging), but it was decided that it will be developed in future as a separate project (what later became the basis of project EMIT). The approved length of the project was 3 years.

The main tasks in the project were:
- Structuring the Syllabi of the training modules (i.e. Training Timetables)
- Preparation of the Training Workbook concept
- Preparation of Students' Manuals (Workbooks with Training tasks) for each module
- Preparation of Teachers' Guide
- Preparation of CD Image Database (IDB)
- Evaluation of the modules
- Introduction of the modules with manuals, guides, CD image database.

The EMERALD training tasks were based on the concept "learning through examples" and were similar in structure to University 'Lab Manuals'. The description of the Training tasks was made in tables and it was decided that the main competencies (achieved after completing of certain tasks) will be based on the earlier published IPEM competencies (IPEM – the UK Institute of Physics and Engineering in Medicine). The indicative time (days) for acquiring a certain competency was to be based on practical performance of the tasks and further time for adding a written description of these - i.e. preparing part of the Training portfolio (Fig.1).

Each of the three Training Modules incorporated:List of Competencies, in accord with the UK Institute of Physics and Engineering in Medicine (IPEM) Training scheme at the time; Structured Timetable (Syllabus with the approximate time necessary for each task); Student Workbook with Training tasks (performance of each task leads to certain competency); CD-ROM with Image Database (to facilitate the teaching process) [2].

Typical structure of an EMERALD Training task has the following sub-sections:
-Task name and aim
-Competencies addressed
-Equipment and materials
-Procedures and Measurements
-Results (Calculations, Diagrams, etc)
-Observations, Interpretations, Questions, Conclusions
-Reference documents
-Verification (the completion of each task requires verification by the Teacher/Trainer).

No.	Sub-module and Subject	Necessary materilas/arrangements	Competencies acquired	Days	Comments
5.x	**X-ray tube and generator**		**Understand/measur / compare separate X-ray tube/gen. parameters *(2,3,4,5,14,15,22)**	7	
5.1	X-ray tube Components. X-ray tube Characteristics. Loading diagram of a X-ray tube. Some typical X-ray tube characteristics. Special X-ray tube types.	X-ray tube diagrams; Different company brochures; Several types tube inserts	Understand/compare X-ray tube paramet.	2	
5.2	Tube housing - construction. X-ray beam filtration. Light beam diaphragm. HVL measurement. Estimating the total filtration from the HVL. Shielding, leakage radiation.	Tube housing; X-ray radigr. room; Dosemeter; Al plates HVL/Filt. diagrams; ~6 X-ray film/cassettes	Understand/measure X-ray tube filtration	1	Repeated in No.7 as part of a whole QC test
5.3	X-ray tube output parameters (consistency, output variation, linearity). Typical parameters. Factors affecting tube output. X-ray tube output spectrum and distribution. Measuring of the focal spot . Assessing the beam alignment. Seasoning of a new X-ray tube . X-ray tube failure.	X-ray radiogr. room; Dosemeter; calculator, Foc. spot meas. tool; LBD align. tool	Understand/measure /calculate tube output param., focal spot size and LBD. Learn to season the tube	2	same

Fig. 1 EMERALD Training Timetables (Training Curriculum) – sample from Diagnostic Radiology module – submodule with Training tasks related to X-ray tube assessment.

To support the teaching/training process EMERALD Consortium developed an electronic Image Database (IDB) [3] (first on CD-ROM, and later on web site, as part of another project - Emerald II).

The main types of images in the Image Database were:

-Equipment and its components; Block diagrams and graphs; QC procedures and measuring equipment; Test objects and image quality examples; Typical clinical images and artefacts, etc.

The organization of images in folders followed the organization of the Training tasks. The volume of the three IDB was about 1400 images.

Each IDB (for each module) was engraved on a CD-ROM. A PC type image browser (*ThumbsPlus*by *Cerious Software*) was used for quick and easy search through the IDB on the CD-ROM. The browser presents each image as a slide, which can be further viewed in its original JPEG size. Each image is visualised with a corresponding caption, on which basis a Keyword search can be performed (Fig. 3).

At that time CD-ROMs were not assigned ISBN (International Standard Book Number). Even the important paper book "Electronic Publishing on CD-ROM" by S Cunningham and J Rosebush (O'Reilly & Associates Inc, ISBN 1-56592-209-3, published in 1996) had an ISBN for its paper version, but not for its accompanying digital copy on CD-ROM – an excellent early PDF e-book. The popular at the time Microsoft ENCARTA Encyclopaedia was also without an ISBN.

The very small number of electronic books issued on CD-ROM at the beginning of the 1990s used ASIN numbers (Amazon Standard Identification Number - a 10-characters identifier of Amazon) after 1994, instead of ISBN numbers. After 2000 all e-books and other digital materials use unique ISBNs. Even an e-book with different formats (for different e-book Readers) is required to have different ISBNs for each format.

The new electronic media carriers (e.g. CD-ROM) contained the same information as print media (paper books), surpassing them in potential volume, image quality and cost-effectiveness. Due to this reason it seemed logical to the EMERALD Consortium that these carriers have the same identification, ISBN, as printed books. This way during 1997 the Consortium decided to publish the first ready Image Database with its unique ISBN. By that time one of the three volumes of the Image Database was fully completed - the X-ray Diagnostic Radiology (for this task special help was received by the colleague A Litchev from the parallel educational project ERM in Plovdiv).This way the IDB X-Ray Diagnostic Radiology was published on 19 February 1998 - EMERALD Image Database version a.01, 1998 , ISBN 1 870722 03 5 (Fig.2). Later the two other IDB (on Nuclear Medicine and Radiotherapy) were also published with unique ISBNs.

IDB related to X-Ray Diagnostic Radiology is one of the first 3 IDB on CD-ROM with ISBN in the world:

-Atlas of Pathology: Urological Pathology CD-ROM, 30 Dec 1997, Springer-Verlag, ISBN 3540146571

-EMERALD Image Database, Training Courses in Medical Radiation Physics CD-ROM, 19 February 1998, King's College London, ISBN 1870722035

-Developmental Psychology Image Database CD-ROM, 30 April 1998, McGraw-Hill, ISBN 0072896914

To our knowledge these are the world's first ISBN-numbered electronic Image Databases (on CD-ROM) as well as one of the first ISBN-numbered e-learning materials. The profession can be proud that EMERALD was one of the first such products in the world.

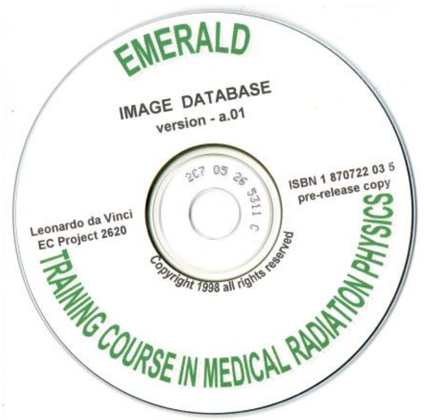


Fig. 2 The first CD with EMERALD Image Database

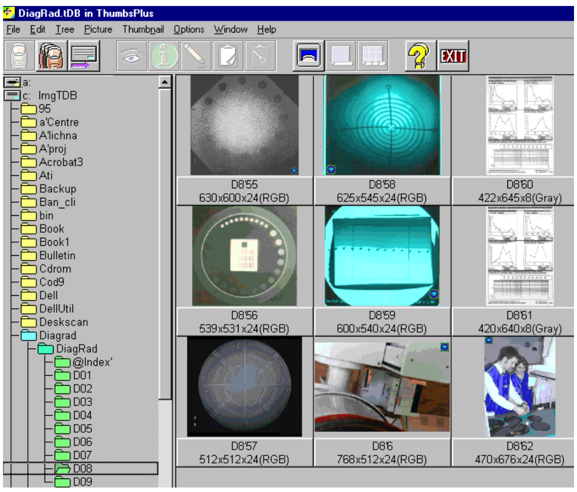


Fig. 3 The Interface of the Image Database with thumbs (slides) foreasy finding of each image. The Folders with images correspond to the Workbook chapters - a sample from the hard drive source

These materials and the IDB were new and no experience existed on their practical use. Due to this reason a Teacher's Guide was developed. The Content of the Course Guide included:

-Introduction to EMERALD project
-Trainees and Training scheme
-Training Agenda
-Mutual Intent
-Continuous Assessment
-Feedback on Placement and Manuals
-Training Timetables (full Training Syllabus)
-Principles of Radiation Protection and Risk Assessment
-EURATOM 96/29 and 97/43 Directives implementation
-EMERALD Forms (Training agenda, Statement of Mutual Intent; Safety; Continuous assessment; Feedback)
-APPENDICES (Training Portfolio; End point viva; Cheating and plagiarism).

To assess these first e-learning materials a special Conference was organised at ICTP Trieste. The EMERALD Conference (24-26 September 1998) was organised under the banner "The First International Conference on Medical Physics Training". It included experts from 26 countries, as well as EFOMP Officers. Each delegate received a copy of the Training materials and the CD with the Image Database. The three EMERALD modules were assessed and reported in separate Workgroups of experts. One important element of the Conference was the presence of young colleagues (students and trainees) who had tested the materials. They were included in each of the three training module groups. The Conference delegates strongly supported the practical implementation of the EMERALD e-learning materials [4].

The whole assessment process was initiated well before the Conference and included several levels:

-First level – the Training tasks (developed by various specialists) were exchanged and discussed internally inside the Project Workgroups;

-Second level – each Group of tasks was evaluated as an entity by the Workgroup (additionally young colleagues, who had just completed their training, were asked to check their cohesion).

-Third level – the Groups of tasks were exchanged between the different international Workgroups

-Fourth level – External Assessors were appointed to provide independent review of the products

-Fifth level - full Training module (all tasks) was tested by un-trained graduates

-Sixth level – an International Conference of experts was organised to comment on the tasks from the point of view of their use in various European countries (this being an EC project)

-Seventh level – based on the feedback above the materials were edited by the Workgroups and the final product was again seen as a totality by the Consortium and the External Assessors.

Following this Conference the EMERALD materials and their respective CD-ROMs were released as the first e-learning in the profession. These entered quickly the training activities in many countries and are now used in nearly 100 countries, covering almost all low-and-middle-income (LMI) countries. The tasks of the modules were developed in a way to be used also as stand alone materials, this way the tasks which were outdated dropped out of use, while others continue to be used for more than 20 years. The development of the first e-learning materials was so intense and dynamic, that most of the detailed publications about them were made after the completion of the projects [5,6]

In 1999 most of the materials from the EMERALD project were transferred into the first educational web site in the profession www.emerald2.net (currently www.emerald2.eu), what will be described further down. The international use of these materials and their impact for the profession will be described later in this chapter.

The content of all 3 modules and its tasks can be seen at the EMERALD and EMIT web site [7].

Module 1 - "X-ray Diagnostic Radiology Physics" was developed mainly by the UK partners. In included 49 Training tasks in the Diagnostic Radiology (DR) Physics Workbook, grouped in 10 chapters (in 2002 a new chapter with tasks related to Digital Radiology was added).

Module 2 - "Nuclear Medicine Physics" was developed mainly by the Swedish partners. It included 46 Training tasks in the Nuclear Medicine (NM) Physics Workbook, grouped in 15 chapters.

Module 3 – "Radiotherapy Physics" was developed mainly by the Italian and Portuguese partners (with input from Swedish partners specifically for Brachytherapy). It included 48 Training tasks in the Radiotherapy Physics (RT) Workbook, grouped in 21 chapters.

The following ISBN numbers were assigned to the EMERALD materials:

PRINTED

1. Workbook on Physics of X-ray Diagnostic Radiology : ISBN 1 870722 04 3
2. Workbook on Physics of Nuclear Medicine : ISBN 1 870722 05 1
3. Workbook on Physics of Radiotherapy: ISBN 1 870722 06 X
4. Course Guide: ISBN 1 870722 07 8

ELECTRONIC (CD-ROM)

5. Image Database vol.1 - Physics of X-ray Diagnostic Radiology: ISBN 1 870722 03 5
6. Image Database vol.2 - Physics of Nuclear Medicine: ISBN 1 870722 08 6
7. Image Database vol.3 - Physics of Radiotherapy: ISBN 1 870722 09 4

The EMERALD Consortium developed three Training modules, each including specific Workbook with Training tasks and Image Database. The completion of each module requires 4 months (80 days). During this time the trainee is expected to acquire most necessary professional skills. This part of the training was called "condensed" and can be performed in most countries, where training conditions exist. Further the trainees can spend several months in their country/state where they can additionally study local Regulations and professional requirements.

Each of the three modules is based on Training tasks. Each task was given a notional completion time (in days). To achieve completion of all three modules in a period of 1 year would require very intensive work. However the design of the EMERALD scheme would allow the individual modules to be taken separately with intervals between each. The overall volume of the printed materials (tasks and guide) was c.720 pages, the overall number of images associated with the electronic teaching materials was 1400.The initial distribution of these materials on CD was later replaced with e-learning materials on the Internet [7] from 1999 (please see further down).

1.2 Project EMIT and the first Conference on e-Learning in Medical Physics

In 2001 the EMERALD Consortium expanded and developed a new project – EMIT (acronym of: European Medical Imaging Technology Training). The project EMIT was developed as a continuation of project EMERALD. Its main aim, as per the EC application was to use the original e-learning platform of EMERALD for adding two new Training modules related to Medical Imaging - Magnetic Resonance (MRI) and Ultrasound Imaging (US).

The Consortium included as partners: King's College London - School of Medicine and Dentistry; King's College Hospital Healthcare Trust; University of Lund; Lund University Hospital; University of Florence; Florence University Hospital; Hospital Albert Michallon, Grenoble; the European Federation of Organisations for Medical Physics (EFOMP). This was the first EC project for EFOMP, which paved the way for future European projects for the Federation. Later the project was joined by two more partners: the International Centre for Theoretical Physics (ICTP), Trieste, Italy and the Tempus ERM Medical Radiation Physics Centre in Plovdiv, Bulgaria (part of Medical University Plovdiv).

The new expert colleagues, who joined the project Consortium were: Dr A Simmons, Dr S Keevil, Dr C Dean, Dr D Goss, Dr V Aitken, Dr R Wirestam, Prof. F Stahlberg, Dr M Almqvist, Dr T Jansson, Dr J-Y Giraud. As in the EMERALD, Project Manager was Prof C Roberts, and project Coordinator was Dr S Tabakov. The approved length of the project was two years and a half (it was later extended to 33 months).

The EMIT project followed the same methodology, structure of training tasks and IDB as project EMERALD. It included additionally some simulation and interactive training tasks.

The materials of EMIT were also assessed, using similar methodology as for EMERALD [8]. A special EMIT Conference was organised under the banner "The First International Conference on e-Learning in Medical Physics" (Fig.4). The Conference included project partners and representatives from IOMP and IFMBE (the International Federation on Medical and Biomedical Engineering). The venue of the Conference was in ICTP, Trieste (9-11 October 2003). At the Conference all delegates signed a Declaration where they expressed their intent to collaborate in the future development of education/training and e-learning materials (Fig.5).

The project EMIT developed two training modules (on MRI and Ultrasound Medical Imaging) each with a common length of 4 months (80 days) – as in project EMERALD. During this time the trainee would have to acquire most necessary professional skills - this is the "condensed" part of the training which can be performed in most countries where training conditions are set up. Further the trainees can spend up to 2 months in their own country/state where they can additionally study the local Regulations and professional requirements.

The content of the two modules and its tasks can be seen at the EMERALD and EMIT web site [7].

Most of the modules were developed by the UK and Swedish partners, with input from the other partners.

The Module "Diagnostic Ultrasound Imaging Module" included 54 Training tasks (327 pages), grouped in 21 chapters. This module also included tasks for sonographers.

The Module “Magnetic Resonance Imaging” included 50 Training tasks (185 pages), grouped in 19 chapters. This module also included simulations and spreadsheets with imaging data to support the training.

The following ISBN numbers were assigned to the EMIT materials:
EMIT Training Course Guide (incl.Curricula) ISBN 1 870 722 15 9
EMIT Training Workbook (e-book) on Ultrasound Imaging ISBN 1 870 722 19 1
EMIT Training Workbook (e-book) on MRI Imaging ISBN 1 870 722 18 3
CD-ROM EMIT Image database on Ultrasound Imaging ISBN 1 870 722 17 5
CD-ROM EMIT Image database on MRI Imaging ISBN 1 870 722 16 7

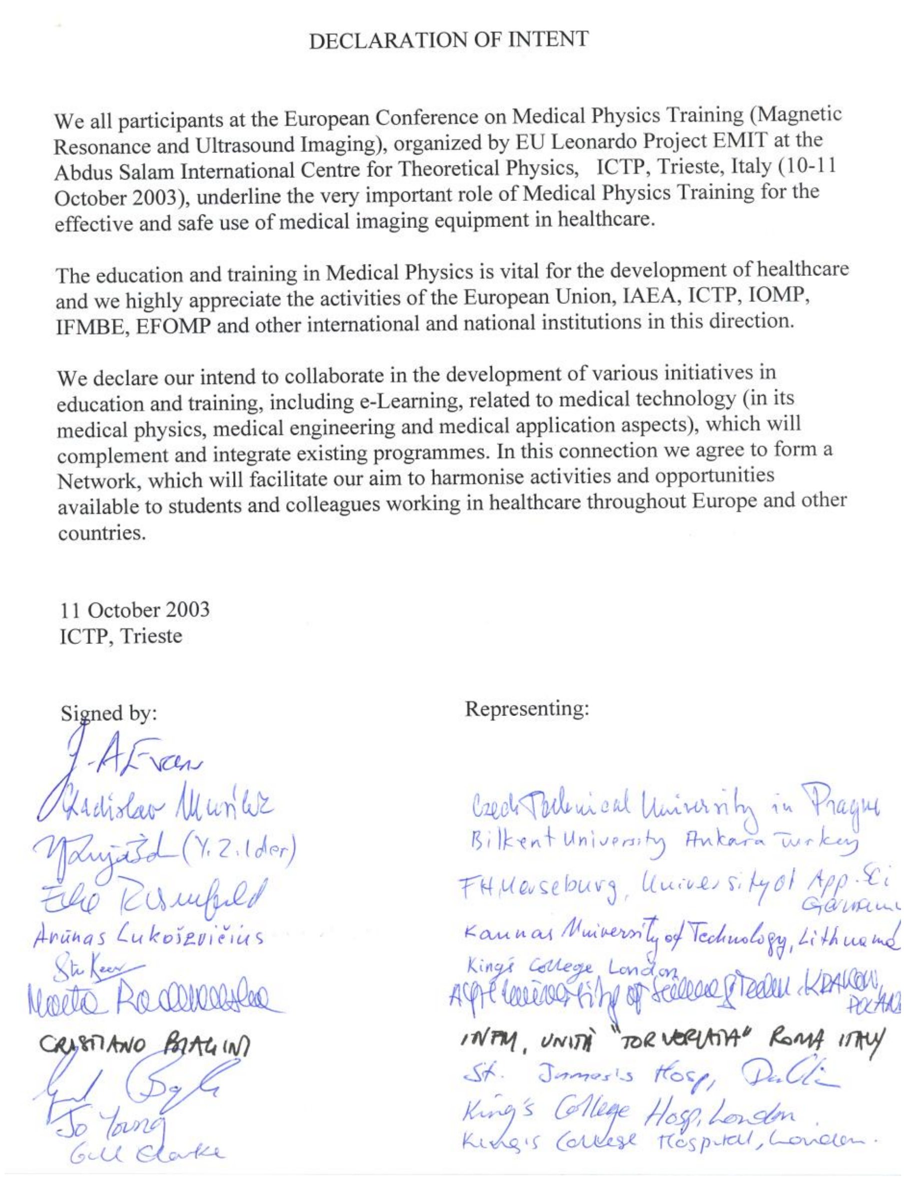
Additionally the above Training modules were published as web-based e-books and engraved together with the Image database on two CD-ROMs (one for each module).
The MRI e-book and IDB CD-ROM structure includes about 4600 files.
The Ultrasound e-book and IDB CD-ROM structure includes about 8900 files.
CD-ROM EMIT – Ultrasound Imaging (Guide, e-book, IDB) ISBN 1 870 722 14 0
CD-ROM EMIT – MRI (Guide, e-book, IDB) ISBN 1 870 722 13 2

Both combined CDs were published on 13/8/2004. The EMERALD materials were re-produced in a similar way. The final CDs and the structure of one CD are shown on Fig.8.

Fig. 4 Delegates at the EMIT International Conference on e-Learning in Medical Physics, ICTP, Trieste, 2003
Conference Participants: Prof.R Stollberger, Dr M Stoeva. Dr R, Dr P Kaplanis, Prof. L Musilek, Dr A Paats, Prof. V Poutanen, Dr S Naudy, Dr C Étard, Dr E Perrin, Dr A Briguet, Prof E Rosenfeld, Dr G Helms, Prof J Nagel, Dr T Sioundas, Dr P Zarand, Prof M Bracale, Dr C Bigini, Dr F Fidecaro, Prof. L Bertocchi, Dr G Boyle, Mr L Torres, Prof. A Lukoshevicius, Mrs V Gersanovska, Dr C vaan Pul, Prof. M Radwanska, Dr N Teixeira, Dr K Nagyova, Dr A Millan, Dr I Hernando, Prof Y Ider, Dr A Krisanachinda, Prof P Sprawls, Dr S Keevil, Dr C Oates, Dr A Evans, Dr N Fernando, Prof. C Roberts, Dr S Tabakov, Dr C Lewis, Dr V Aitken, Dr C Deane, Dr D Goss, Ms G Clarke, Dr A Simmons, Dr I-L Lamm, Dr R Wirestam, Prof F Stahlberg, Dr M Almqvist, Dr T Jansson, Prof. F Milano, Dr J-Y Giraud, Prof. P Smith, Dr M Buchgeister, Mr A Cvetkov, Ms J Young, Ms M Boutros, MsT Wehrle, Ms S Riches

The pioneering work and the impact of these two projects gained the first EU Leonardo da Vinci Award for Education. The Award was presented to the Consortium at the high level EU Conference “Strengthening European Co-operation in Vocational Education and Training”, held in Maastricht, The Netherlands, on 14-16th December 2004 (part of the summit of all European Ministers of Education). This was an excellent opportunity for high visibility of the profession – Fig 7.

Fig.7 The Leonardo da Vinci Award Certificate



DECLARATION OF INTENT

We all participants at the European Conference on Medical Physics Training (Magnetic Resonance and Ultrasound Imaging), organized by EU Leonardo Project EMIT at the Abdus Salam International Centre for Theoretical Physics, ICTP, Trieste, Italy (10-11 October 2003), underline the very important role of Medical Physics Training for the effective and safe use of medical imaging equipment in healthcare.

The education and training in Medical Physics is vital for the development of healthcare and we highly appreciate the activities of the European Union, IAEA, ICTP, IOMP, IFMBE, EFOMP and other international and national institutions in this direction.

We declare our intend to collaborate in the development of various initiatives in education and training, including e-Learning, related to medical technology (in its medical physics, medical engineering and medical application aspects), which will complement and integrate existing programmes. In this connection we agree to form a Network, which will facilitate our aim to harmonise activities and opportunities available to students and colleagues working in healthcare throughout Europe and other countries.

11 October 2003
ICTP, Trieste

Signed by:	Representing:
Ladislav Musil	Czech Technical University in Prague
(Y. Ziylder)	Bilkent University Ankara Turkey
	FH Merseburg, University of App. Sci Germany
Arūnas Lukoševičius	Kaunas University of Technology, Lithuania
	King's College London
	AGH University of Science & Technology Krakow, Poland
CRISTIANO BIAGINI	INFM, UNITÀ "TOR VERGATA" ROMA ITALY
	St. James's Hosp, Dublin
Jo Young	King's College Hosp, London.
Gill Clarke	King's College Hospital, London.

Fig. 6 Main (first) page of the Declaration of EMIT Conference on e-Learning in Medical Physics.

Fig. 8 EMERALD and EMIT CD-ROMs with sample CD jewel boxes (and CD covers). The content of one CD (DR) is shown on the left, including the IDB (folder DiagRad) and the Web site with e-books (folder Emerald2)

Additionally to the e-learning materials project EMIT developed the first Medical Physics Thesaurus and Dictionary of Terms, which gave the basis of the later project EMITEL, which developed the first Medical Physics e-Encyclopaedia and Multilingual Dictionary (translated by 2017 to 29 languages). These will be described further down.

The initial e-learning materials (Training Tasks and IDB) developed by project EMERALD, and the following project EMIT,were transformed into new 5 CD-ROMs including web-based e-books with Training tasks, hyperlinked to the images from the Image Databases. The overall volume of these 5 e-learning modules was 247 Training tasks, supported by 3100 specific educational images[1,3,9]. Each of the new CDs also included the first Medical Physics e-Dictionary of Terms (in 7 languages at the time).About 5,000 of the CDs with these materials were produced and distributed to colleagues in Europe and around the world.

This transformation of the initial EMERALD e-Learning materials into web-based materials was made through the project EMERALD II (described further down). All these e-learning materials were uploaded to a specially made educational website. The e-learning materials of EMIT were also developed as web-based materials and published at this special web site. All these e-learning materials are now available for free use at http://emerald2.eu/cd/Emerald2/.The global use of these e-learning materials, expanded with their online use, will be described further down as part of EMERALD II project.

2. Internet based e-Learning materials and other e-Learning Projects

2.1 Emerald – Internet Issue, the first dedicated education/training web site in the profession

Immediately after the end of the EMERALD project in 1998 its Consortium launched another project aiming to transfer to Internet the Training Tasks and the images from the Image Databases. The project also aimed to disseminate the use of these e-learning materials in Europe and worldwide. The name of the new project was EMERALD – Internet Issue (aka EMERALD II, or E2) For this task the initial Consortium was expanded with new partners from France, Czech Republic, Ireland, Northern Ireland – it included: King's College School of Medicine and Dentistry; King's Healthcare Trust; University of Lund; Lund University Hospital; Portuguese Institute of Oncology, Lisbon; University of Florence; Florence University Hospital; Centre Alexis Vautrin - Nancy; Czech Technical University in Prague; Northern Ireland Regional Medical Physics Agency - Belfast; St James's Hospital, Dublin. Later the Medical Physics Centre ERM from Plovdiv, Bulgaria also joined the project. The new expert colleagues, who joined us were: Dr A Noel, Prof. L Musilek, Dr P Smith, Dr N Sheahan, Dr S Bowring, Dr Stoeva and Dr Cvetkov. As in EMERALD, Project Manager was Prof. C Roberts, and project Coordinator Dr S Tabakov. The approved length of the project was two years (expanded to 2.5 years).

The main drivers for the development of the EMERALD web site were B-A Jonsson and M Ljungberg from Lund [9]. Their University was already firmly on the path of e-learning and they had their own platform for distance learning through Internet – the e-learning management system LUVIT. The new web site was specially coded (www.emerald2.net) [10]. The decision to have a tailor-made web site (i.e. not to use third-party software for development of web-sites) proved to be very important – this web site has now worked for nearly 20 years without any interruption or problem (during 2007 M Stoeva and A Cvetkov re-programmed the web site, keeping its concept, and it now works at www.emerald2.eu).The new web site was made with an uncomplicated user-friendly platform, handling PDF documents and images. This also allowed easy future upgrades of materials – something very important for a dynamic profession as medical physics.

The internal structure of the web site was following the structure of the three EMERALD Training modules. New folders were also added for further video or other materials, which could be included in future to the web site. The web site has about 4000 files organised in 30 folders. These were the new Internet-based e-books of EMERALD. In 2003 the EMITInternet-based e-books were also added to the main web site. The internal structure of one of these e-books can be seen on Fig.8.

The use of these e-books (e-learning training materials) is still the same - it requires simultaneous work with two browser windows (main window and image window). The main window includes a large Text Frame for the PDF file; a Contents Frame for navigation through the training tasks; and an "Image-slide" Frame for browsing the images in each chapter. The additional image window contains the respective image (hyperlinked to the text) and image caption. The images are in JPG format, embedded in separate HTML frames (the image window). When an image is called this window appears (pop-up) over the main window and has its own minimise/close buttons. All functionality of Adobe Acrobat Reader is preserved, allowing saving and printing of each part of the e-learning materials. Also, each image could be saved separately as JPG file. This simplicity allows the users to learn directly -using their own computers with their Internet browser and Adobe Acrobat Reader (without the necessity to install additional software). The Graphical Interface of the e-books is shown on Fig.9.

In order to help distribution of the medical physics e-learning materials into the education/training in the LMI countries (where at the time the Internet was still very slow), the Consortium decided to engrave the whole web site on a CD. This was a very novel idea (invented by the Consortium), but due to the extremely rapid development of the project (alongside all other clinical duties of the project members) this was not published at the time. Later this method (web-site on CD) was widely used in all IT-related developments. These new CDs (one for each module) were described in the previous paragraph.

The new EMERALD II web site was launched at the end of 1999 – this being the first dedicated education/training and e-learning web site in medical physics. The web site continues to be used worldwide with at least 2000 hits per month. The web server official statistic for March 2018 shows total visits 4033 (c.1400 in Europe; c.1400 in Asia; c.700 in North America; c. 250 in South America; c.250 in Africa).

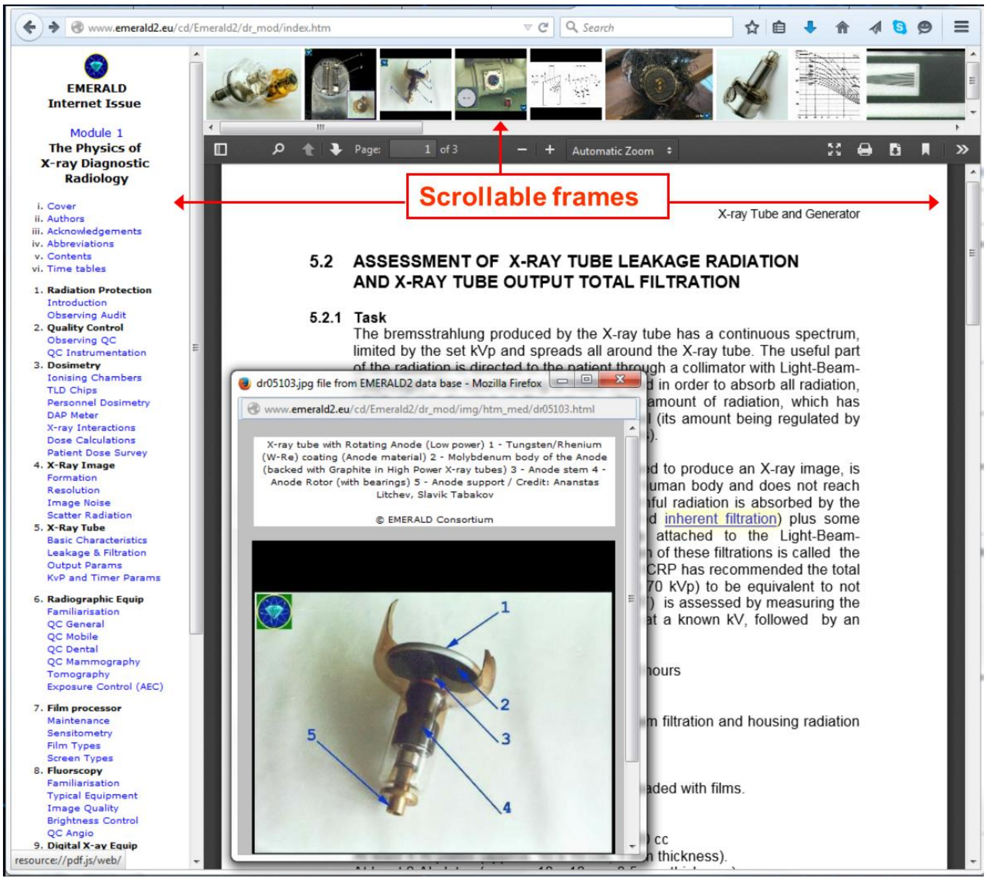


Fig. 9 Screen captures of the EMERALD II e-book (showing the two windows – for text and pop-up image), also showing the 3 HTML frames of the web site.

2.2 The Sprawls Resources

The Sprawls Resources is a very important web-based Medical Physics educational project launched almost simultaneously with EMERALD II and is available on the web at www.sprawls.org/resources. The Resources Project is provided by the Sprawls Educational Foundation, www.sprawls.org. Professor Perry Sprawls was a clinical medical physicist and educator on the faculty of Emory University in Atlanta, Georgia USA. His major emphasis was on developing educational programs and materials to support the effective and safe application of the various imaging modalities, especially Mammography, Computed Tomography and Magnetic Resonance Imaging. It provides a variety of learning opportunities for practicing medical physicists and students in addition to materials to be used by medical physics educators. These include many of Professor Sprawls' lectures, text books (as e-books), materials with medical images, high-quality visuals and additional learning guides including mind maps [11].

The materials are based on Professor Sprawls' approach to learning and teaching which involves helping learners/students develop highly-effective mental structures and representations of medical physics realities and concepts that can then be applied in medical physics activities. This is achieved by providing materials in an organized and structured content with extensive visuals. He promotes teaching as a collaborative process between the provider of resources, especially visuals and textbooks, to be used in classroom activities, and the local teachers who then conduct discussions using the resources and add their knowledge and experience.

Examples are shown in Figures 10 and 11.

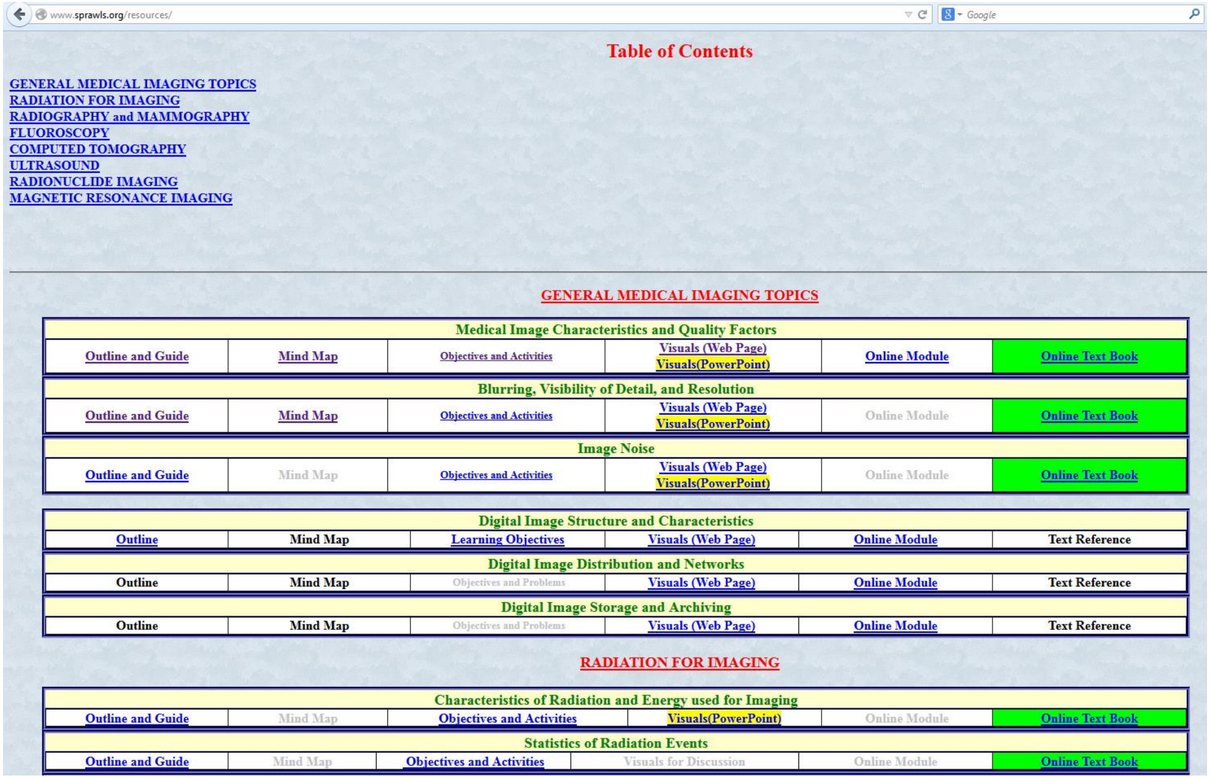


Fig. 10 Sample Graphic interface of P Sprawls's web site (from 2014)

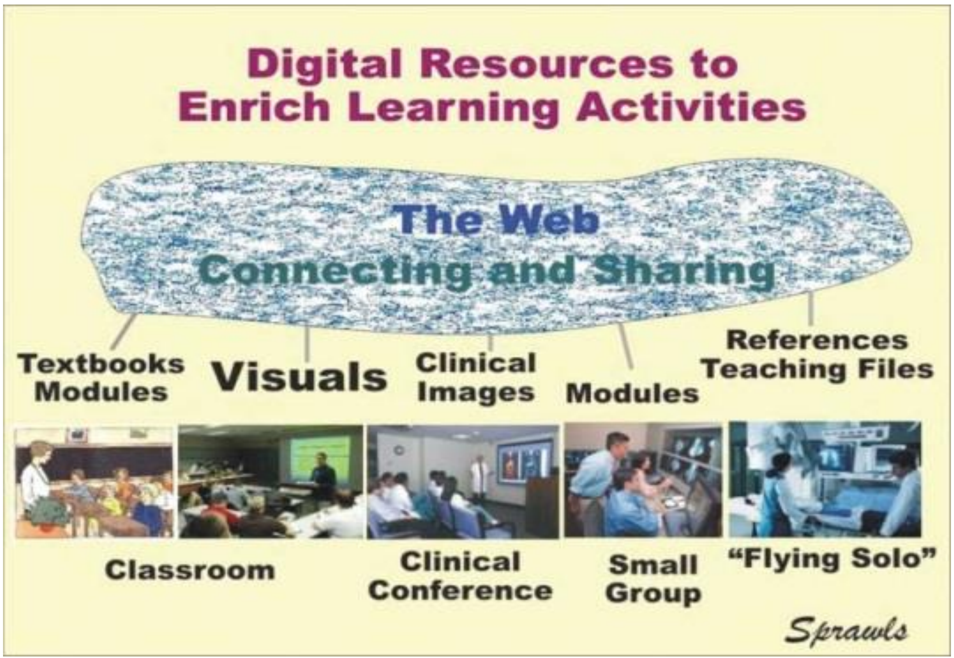


Fig. 11 The many applications of web-based resources to support medical physics education.

This way the learner is easily and effectively guided through the learning process. Sprawls's use of the method for organizing and remembering the material (Mind Maps) is unique for Medical Physics. This web-based resource quickly became one of the most visited educational websites in the profession and is used in virtually every country of the world where there is medical physics activity (Fig.12).

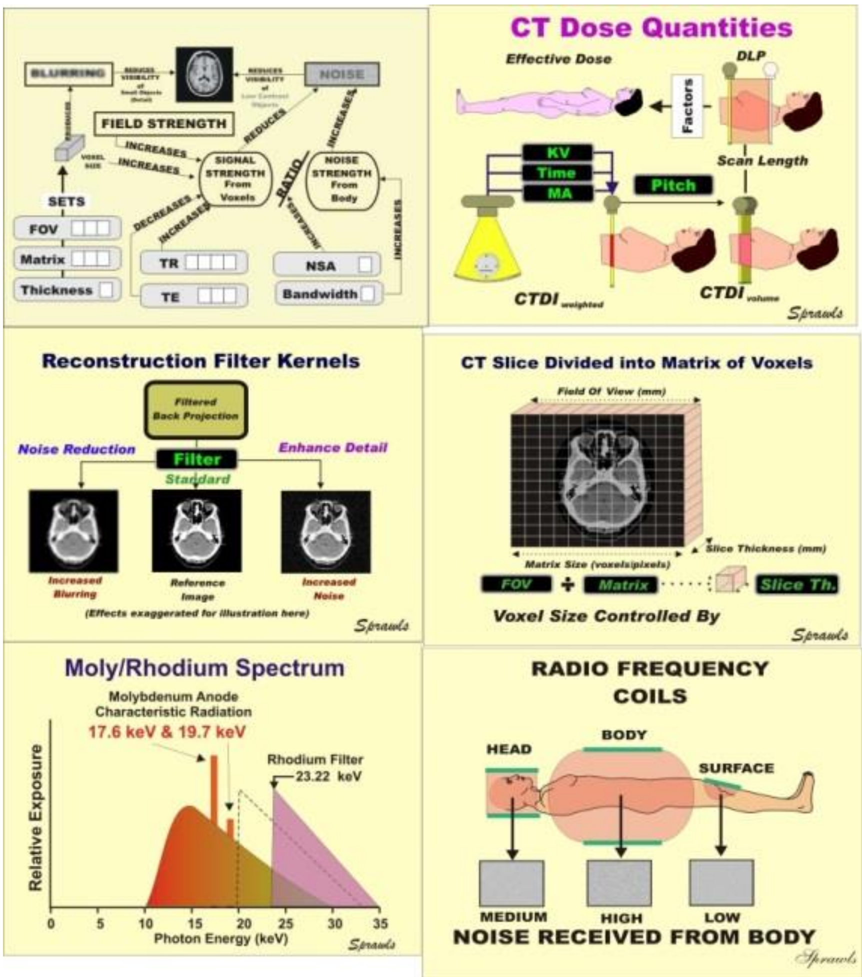


Fig. 12 Example content provided within the Sprawls Resources.

The websites, www.sprawls.org/resources and www.emerald2.eu complemented each other very well – one providing the academic and classroom education activities, the other – the practical tasks (i.e. the training). Both websites (developed fully independently) shared a common vision – simple and effective web shell, whose main function is to deliver the necessary knowledge. Both web sites were intentionally distanced from the most hyped web technologies and placed emphasis on the educational content. Both websites use dedicated programming without any third-party templates. Both websites are run by experts, enthusiastically supporting the development of Medical Physics. Both websites have continued to run for almost 20 years with thousands of visitors. It was only natural to collaborate and indeed Sprawls became one of the main contributors to the later project, EMITEL Encyclopaedia, which incorporated many of the EMERALD&EMIT images and Sprawls' visuals.

One of the most successful global disseminations of e-learning in medical physics was through the ICTP International College on Medical Physics, whose objective is to provide condensed education on medical physics (imaging) to colleagues from low-and-middle-income (LMI) countries. Since 2002 each attendee to this unique summer College receives free all e-learning materials from the web sites sprawls.org and emerald2.eu

The first ICTP College on Medical Physics took place in 1988 - a 4 week activity with nearly 100 participants from the developing (LMI) countries. The regular series of such Colleges started in 1992 and continues to run on a regular basis (usually bi-annually) with similar number of participants. Until now the ICTP has educated more than 1000 young medical physicists - mainly from developing countries (LMI countries). A specific re-organisation of these e-learning materials was made for the College participants – all e-learning was compiled on a single CD (with the hyperlinked images from the IDB). So far participants from more than 80 developing countries have attended the College in ICTP, Trieste. They have triggered tens of Medical Physics activities and courses in their countries using the materials from the College [12]. This way hundreds of colleagues from developing (and other) countries have received help in the practical implementation of the profession. The ICTP College will be described in another chapter.

Beginning in 2004 Prof. Perry Sprawls developed a comprehensive tele-teaching process using a combination of methods, including web-based visuals and Skype, to teach from one country to another. It was the first extensive use of tele-teaching in the profession. One of the first MSc Medical Physics programmes using this to offer e-learning plus tele-teaching was at the University of Malaya, an activity led by Kwan H Ng and supported by the Sprawls Foundation. This was before the development of commercial teleconferencing (tele-teaching) programs that have expanded this form of education.

2.3 Various Directions of e-Learning after 2000

After 2000 e-learning entered in most professions. A useful book was published in 2003 by Springer "The Internet for Radiology Practice", A Mehta (ISBN 0-387-95172-5). The book promoted Teleradiology and included an extensive list of web sites with e-learning materials related to radiology, but also useful for medical physics.

Around the end of 2002 another set of CDs with teaching materials appeared – issued by the International Atomic Energy Agency (IAEA). As EMERALD, these three CDs (focussed on Radiation Protection) were covering 3 main fields of Medical Physics – Diagnostic Radiology, Nuclear Medicine and Radiotherapy. They included ready lecturing materials as Power Point slides. These 3 CDs were also distributed free and were of great help to the medical physics community. Some of their slides included images from the EMERALD Image Database. The easy inclusion of images to the digital teaching materials was now almost a standard for medical physics. These excellent materials also included Manual for Trainers and Multiple Choice Questions [1,13,14].

The increased use of e-learning in Medical Physics led to the invitation from the Editorial Board, led by R Allen, of the Journal of Medical Engineering and Physics in 2004 to run a special issue on e-learning. The Special Issue on e-Learning in *Medical Engineering and Physics* was published in 2005 (vol. 27, No.7, September 2005, Guest Editor S Tabakov). It soon triggered significant interest and some of its papers were among the most frequent downloads of the Journal. This high professional interest in e-learning was very promising for the profession. This way in 2008 another Journal - *Biomedical Imaging and Intervention* published its Special Issue on e-Learning (Guest Editor Kwan Ng).

e-Learning was gaining popularity in Medical Physics and Engineering and a number of new projects and activities were initiated. This was only natural as, apart from the specific professional knowledge, our colleagues had excellent computer and software skills. These projects could be grouped in three main directions of e-learning development:

a. Development of e-learning modules

These were projects such as EMERALD, EMIT and Sprawls.org, other examples of such courses were the project *Demystifying Biomedical Signals* (a signal-processing educational project led by University of Southampton, R Allen, A De Stefano, D Simpson, M Lutman) [15] and *A web-based course on Medical Physics for School Teachers* (led by University of Lund, B-A Jonsson) [16], etc. Such e-learning modules continue to be developed and to be welcome by colleagues – for example the *i.TREATSAFELY* tool of Pawlicki et al [17]; *the Personal Dosimetry module* of Koutalonis et al [18], etc.

A common feature of such projects is that they are very informative (with many images and diagrams) and are easy to update. However these modules required inventiveness in the development and organisation of teaching materials. One important element for such modules was the added facility to print the material on paper – i.e. these are excellent for hybrid/blended learning (classical and e-learning). Usually such modules have long life (depending on the use of software tools).

A variation of this trend is the Virtual Library of the American Association of Physicists in Medicine (AAPM), launched around 2006. This is an excellent educational tool, based on the videos of many open lectures presented at the AAPM meetings [19]. The web site is with free access for medical physicists from the developing countries (http://www.aapm.org/education/VL). This library is now open for free to all colleagues from LMI countries.

Specific e-learning module on Radiation Protection was developed during 2010. This was due to the fact that developing a common international Radiation Protection training was quite difficult due to the significant difference between the respective legislation in various countries (around 2010 this was harmonised in the European Union and such programmes were developed with the active involvement of ESR and EFOMP) [20, 21]. The first such project*MEDRAPET*(Medical Radiation Protection Education and Training) was coordinated by J Damilakis. The project will be described in a separate chapter, together with other EU projects with EFOMP involvement. The 2015 CRC book (IOMP&IRPA-commissioned) *Radiation Protection in Medical Imaging and Radiation Oncology* (Editors R Vetter and M Stoeva) also discusses issues related to the international approach to Medical Radiation Protection education/training.

b. Development of e-learning Computer simulations

These are projects simulating the functions of medical equipment. Some very useful simulations were developed in University of Patras, Greece (for medical image processing, including X-ray equipment simulator, a project led by N Pallikarakis) [22], University of Cagliari, Italy (an X-ray equipment simulator, a project led by V Fanti) [23], etc. Such e-learning simulations continue to be developed– for example the Radiotherapy simulators of Hartmann et al [24] and Kirby et al [25]; the simulation of Linear Accelerator of Carlone et al [26], etc.

The common feature for such projects is that they are very effective teaching tools, but are difficult to develop. Most importantly - they are software dependent and usually have short life cycle (some of the simulations above stopped working after several years). Some other simulations (e.g. in the field of Radiotherapy, as the project Prism, led by B Hartmann and J Meyer, used in University of Canterbury, New Zealand) have prolonged life, but still the use of specific software makes their practical implementation more difficult (especially in developing countries) [24].

Very useful teaching resources are interactive GIF images. Although not a simulation, these provide an easy way to understand complex processes. An example of such resources is the collection of the Colorado University [27]. This web site included also software link helping the users to create their own interactive GIF images. Others also promoted various software tools [28], although a number of commercial tools already existed.

In fact Computer simulations in Medical Physics existed from the beginning of the 1990s. For example an Image Backprojection Reconstruction simulation on a floppy disk was prepared by a colleague from India and distributed through the IAEA. The 1990 decade, and the first decade of the 2000, saw a number of very good simulations in the field of Imaging and Radiotherapy. However this trend lost speed during the second decade of the 2000, as a number of simulations stopped working with the introduction of new 64-bit PC Operating systems, which discouraged some teams.

AAPM is most active of medical physics societies in keeping the profession informed about various online simulations, modules and other resources [29,30] (the Education activities of AAPM will be included as a separate chapter of the History project). Similarly IOMP opened a new online Journal (Medical Physics International) oriented toward education/training and professional issues, including e-Learning (to be described further down).

c. Development of Course-management systems

Development of tailor-made Course-management systems is the most difficult one and rarely used. Such a programme was developed in the Medical Physics Centre in Plovdiv, Bulgaria by M Stoeva and A Cvetkov [31], but was difficult to maintain. Most educational programmes these days use one of the standard Course-management e-learning platforms (Virtual Learning Environment, VLE, or LMS – Learning Management System) - e.g. Moodle, Web CT, Blackboard, etc. These are in fact programmes managing the delivery of the material and the teaching process. These platforms facilitate the process of learning by allowing easy access to lecture notes, as well as providing the management of the educational programmes. Examples of such use of these e-learning platforms in MSc programmes can be seen at [32,33,34].

A very useful educational web site was launched in September 2006 - the IAEA Radiation Protection for Patients (RPOP) web site (rpop.iaea.org) – a very big project led by the IAEA (initially coordinated by M Rehani) [35]. This project was a combination of modular, structured programme and information hub (Fig. 13).

This free website is orientated towards a very large audience – medical physicists, radiologists, radiographers and various medical staff applying radiation, but most importantly - patients. The web site provides free download of training materials as Power Point slides and posters on radiation protection. This was one of the first professional web sites to allow download of large files with Power Point presentations and other materials. Soon the web site was at the top of the “Radiation Protection” lists of all Search engines. This was helpful for many patients undergoing radiation procedures in medicine and currently this is the most visited web site in the profession with hundreds of thousands visits per year (c. 286,000 in 2012).

This large web site is supported by a team in IAEA and has regular updates. Most of the materials are translated into Spanish and Russian. This web site is also used as a portal to various Radiation Protection IAEA projects – e.g. SAFRON (an integrated voluntary reporting registry of radiation oncology incidents and near misses). The significant contribution of IAEA for the education, training and e-learning in medical physics will be described in a separate chapter.

Fig. 13 The Home page of the IAEA RPOP Web site and first slide of one of the Power Point presentations (from 2015).

2.4 Medical Physics International Journal

The interest in education and training, and the need of a stable forum to discuss the e-learning development led to the launch of an IOMP Journal on the subject "Medical Physics International" (MPI). The new ISSN 2306-4609 for it was obtained at the end of 2012 and the first issue produced in April 2013, as a free on-line Journal (published twice a year). Its web domain was registered as www.mpijournal.org [36] . The Co-Editors in Chief were approved as P Sprawls and S Tabakov and the first Editorial Board included also: KY Cheung, M Rehani, W Hendee, T Suk Suh, V Tsapaki, S Kodlulovich Renha, A Krisanachinda, T Ige, M Stoeva, A Cvetkov, J Damilakis, R Wu, V Tabakova. Since its beginning the MPI Journal gained steady popularity, having at the beginning c. 4000 visits per month. As per the official server statistics, during 2018 the visits to the MPI Journal during March 2018 are c.11,100 (about 60% being from LMI countries). A number of e-learning and other educational and professional projects were published in the MPI Journal. This will be further described in other chapters.

The large number of on-line resources in medical physics require the development of a catalogue of these e-learning materials, which to be regularly updated and available to all colleagues. The free online IOMP Journal "Medical Physics International" is well suited to host and update such a catalogue.

3. Medical Physics e-Encyclopaedia and Multilingual e-Dictionary of Terms

The quick international dissemination of the e-learning materials (in English) of projects EMERALD and EMIT led to the need of a Multilingual Dictionary of Medical Physics [37]. The first Thesaurus of this Dictionary was made as part of project EMIT, supported by all EMIT Consortium members (listed in the respective paragraph).

3.1 Medical Physics e-Dictionary of Terms

The development of the Dictionary followed original methodology described in the free e-book "The Pioneering of e-Learning". In brief - an Identification number (ID) was assigned to each term from the Thesaurus and all translations were based on the IDs of the English terms. The ID number was the main identificator of each term. These were arranged in a Master Table (in MS Excel), where the rows with IDs were fixed. New columns however could be added to the Master table – a column for each language. The first column of the Master table was the ID, and the second column – the English language terms (arranged alphabetically, according to the Thesaurus compiled by the Consortium) – these two columns were also fixed. All additional columns were added by the translation groups – one per language (Fig. 14) .

Groups of translators were formed in each language, usually including specialists in the main fields of the professions (Physics of: X-ray Diagnostic Radiology, Nuclear Medicine, Radiotherapy, Ultrasound Imaging, Magnetic Resonance Imaging, Radiation Safety). General terms were covered by all translators (mainly terms related to relevant frequently-used terminology from physics, mathematics, medicine, etc). Each Language Group received the Master Table and inserted their translated terms in their dedicated Language-column (one term in a cell, as per the ID).

	A	B	C	D	E	F
1	ID	English (master file) Final update	BULGARIAN	Lithuanian	CHINESE corrct	Arabic
11	10	3D (three dimensional)	тримерен (3D)	3D (trimatis)	三维	ثلاثي الابعاد
12	11	3D display	тримерен дисплей	3D vaizduoklis	三维显示	عرض ثلاثي الابعاد
13	12	3D imaging	тримерно изобразяване	3D vaizdavimas	三维成像	تصويرثلاثي الابعاد
14	13	3D spatial abilities	възможност за тримерно изобразяване	3D erdvinė geba	三维空间能力	قدرات (امكانات)فضائية ثلاثية الابعاد
15	14	3D visualization	тримерна визуализация	trimatis (3D) vaizdinimas	三维可视化	تصور ثلاثي الابعاد
16	15	Helium	Хелий (He)	Helis	氦	هيليوم
17	16	A number	атомен номер	Numeris, skaičius	A 模式	A العدد الذري
18	17	A mode	A режим (в ехографията)	A-moda, būdas, režimas	原子序数	A نمط (طريقة)
19	18	Abdominal imaging	изобразяване на абдомена	Pilvo (abdominalinės) srities vaizdinimas	腹部成像	تصويربطني (جوفي)
20	19	Absolute risk	абсолютен риск	Absoliuti rizika	绝对风险	مخاطرة (مجازفة) مطلقة
21	20	Absolute scale of merit test	абсолютна скала (за изпитване) на качеството	Absoliutinės kokybės vertinimo skalės testas	绝对标准刻度测试	المقياس المطلق لاختبارالاستحقاق
22	21	Absorbed dose	погълната доза (доза)	Sugertoji dozė	吸收剂量	الجرعة الممتصة

Fig. 14 Dictionary Master Table with translations, showing also colour coded queries during the Terms translations

Each Translation Group had its own Language Coordinator, who was responsible for collecting and verifying the translations from the Group members (usually colleagues with different specialisms). The Language Coordinators were in contact with the Main Dictionary Coordinator (the EMIT Coordinator, later EMITEL Coordinator), where all important partial results were sent, and where the Master Table was kept (with all languages). Translations in need of further discussion were highlighted in colour. If a specific term did not exist in a certain language, the English term was included in the corresponding cell in the Language column.

During the process of this development the Thesaurus was gradually updated with new terms coming from the specialists involved in the project. This was mainly due to the quick evolution of the profession in the past decade and the related inclusion of new terms. To handle this, the IDs of the existing terms were left 'as is', and a new continuation of the main English Master Table was made (again in alphabetical order). The additions to the Thesaurus were made in three stages, each new inclusion of a batch of terms starting after the next round number (in 500 increments) – i.e. ID 4000, ID 4500, etc (e.g the second batch is from 4001 to 4320; after time the third batch is from 4501 to 4817; the next one would start with ID 5001, etc). A total of 756 new terms were added this way after ID 4000.

The first e-Dictionary was developed early in 2003 (using Visual Basic) and was engraved on a Mini CD, together with demos of the e-learning materials EMERALD and EMIT. The software developers for this CD-Dictionary were A. Cvetkov and M Stoeva (AM Studio). The Mini CD included an executive file of the Dictionary and required its installation on the PC of the user. The interface required selection of the two languages for the translation (From .. To…) and included the necessary fonts. This user-friendly design allowed very easy use of the Dictionary (Fig. 15). There were three Dictionary windows: the Left Search window (From), where the user types the term; the Left Display window, which presents a limited list of the respective Language table from the database (from the Input Language); a Right (To) window presenting the translation of the selected text from the Output language.

Close to two thousands of these Mini CDs with the first in the profession Multilingual e-Dictionary were distributed free during the World Congress on Medical Physics and Biomedical Engineering in Sydney, Australia (August 2003). This dissemination of the Dictionary and the Thesaurus of Medical Physics Terms triggered the development of some future Dictionaries in specific languages (transferred later into EMITEL).

The inclusion of new languages in the Dictionary presented new challenges because of the different alphabets, which were difficult to be handled by the existing software used for the mini CD. However at that time the current web technologies advanced enough to allow transferring the Dictionary on the Internet. A new domain was registered and a new web-design was created by A. Cvetkov and M Stoeva from AM Studio (www.emitdictionary.co.uk). The design was using directly the synchronised tables of the Dictionary.

This new phase of the e-Dictionary (the Web Dictionary) was dependent on the settings of the Internet browser, which allowed various alphabets to be used. This led to rapid expansion of the number of languages in the Web Dictionary. However at that time the search was still based on the beginning of the first word of the term. This was not convenient for complex terms (e.g. the term Dose did not call related complex terms starting with other letter – as Absorbed dose or Effective dose). This was later improved in the final EMITEL Web Dictionary.

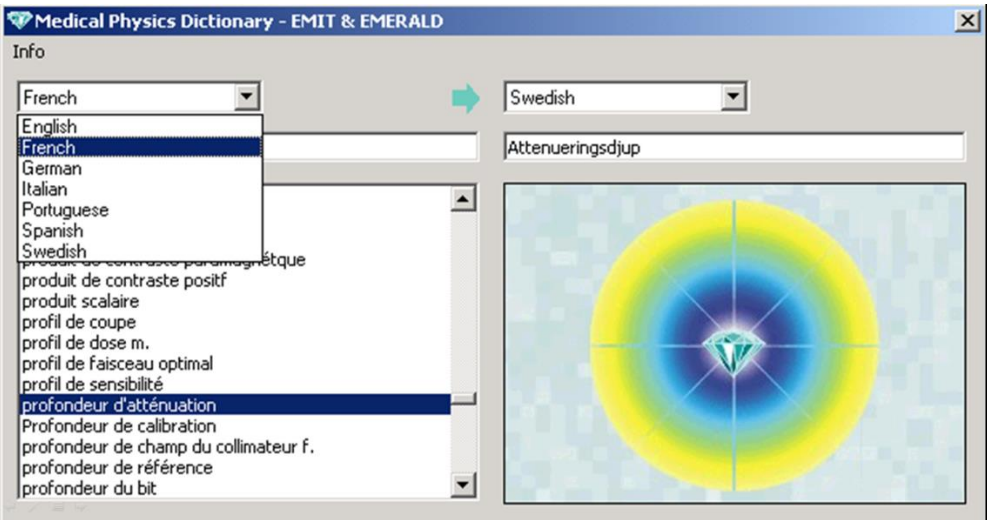


Fig. 15 Graphic interface of the first CD-based Medical Physics Dictionary (2003-2005) distributed free on mini CD, and also with the EMERALD and EMIT CDs

The Web Dictionary design included again a user-friendly interface with Windows for Input and Output Languages and a small Search window for the term to be translated. The results were displayed as two parallel tables of corresponding terms (scrollable).The new Web Dictionary was launched in 2005 and for several months attracted thousands of users (it is still in use at www.emitdictionary.co.uk, in parallel with the e-Dictionary web-version included as part of the e-Encyclopaedia web site).

The Dictionary of terms with explanations was further developed in the project EMITEL, which aimed at developing explanatory articles for each term, thus transforming it to an Encyclopaedia. This project was approved for funding by the EC during 2006 and will be described further in this chapter.

A new web site was developed for EMITEL (www.emitel2.eu, opened for free use in 2009), handling both the Dictionary and the Encyclopaedia. The new web-design was introduced again by A. Cvetkov and M Stoeva from AM Studio, which then became full partners to the project. It included a new Web database, but still used the initial parallel language tables, which proved very useful. Two Search Engines were designed – one of those being Multilingual (handling the Dictionary), the other one – in English, only for the Encyclopaedic entries [38].

The EMITEL Dictionary Search engine allowed direct search for terms, or part of terms. Hence a search for the term Dose is now returning all complex terms including Dose - Absorbed dose, Effective dose, Mean absorbed dose to air, etc. This also reduced eventual problems with misspelling.

Currently the Dictionary exists in 29 languages (in 8 alphabets), translated by colleagues listed at the end of this chapter. Thus the original 7 languages were supplemented by new 22 languages and the final Dictionary included: Arabic, Bengal, Bulgarian, Chinese, Croatian, Czech, English, Estonian, Finnish, French, German, Greek, Hungarian, Italian, Japanese, Korean, Latvian, Lithuanian, Malaysian, Persian, Polish, Portuguese, Romanian, Russian, Slovenian, Spanish, Swedish, Thai and Turkish. Most recently a new language is being prepared for inclusion (in Georgian language), the translation being coordinated by G Archuadze. Currently the Dictionary and the Encyclopaedia EMITEL are updated with new terms (a new project to be completed in 2020). Thousands of colleagues use these e-learning materials each month.

3.2 Medical Physicse-Encyclopaedia

The Medical Physics Thesaurus and Dictionary were used for the development of the firste-Encyclopaedia of Medical Physics. This was realised by the project EMITEL (2006-2009), which included also the IOMP and concluded as a huge project including about 300 specialists from 36 countries.

The project EMITEL (acronym of European Medical Imaging Technology e-Encyclopaedia for Lifelong Learning) was prepared with objectives: to develop an original e-learning tool, to be used for lifelong/continuing learning of a wide range of specialists in Medical Physics and Medical Imaging Technology. The tool was planned to be linked to the existing EMERALD and EMIT materials and to include (additionally to Medical Imaging) Radiation Protection&Hospital Safety and Radiotherapy topics, thus forming a one-stop knowledge database (or rather a Web portal) for colleagues who want to acquire a specific competence, as well as for those who want to refresh their knowledge and to keep up with the new developments in medical physics.

The project Consortium included as partners: King’s College London - School of Medicine and Dentistry; King’s Healthcare Trust; University of Lund; Lund University Hospital; University of Florence; AM Studio, Plovdiv, Bulgaria; the International Organization for Medical Physics (IOMP). Project Manager and Coordinator was S Tabakov. The results of the project were also aimed at increasing the academic information supporting the e-learning tasks, developed by EMERALD and EMIT.

One specific feature of this project was that it required parallel work of 7 Work Groups. The Groups were organised as per the internal topical division of the profession:
-Diagnostic Radiology (X-ray) physics
-Magnetic Resonance Imaging physics
-Nuclear Medicine physics
-Radiotherapy physics
-Radiation Protection in Medicine
-Ultrasound Imaging physics
-General topics

EMITEL was a very large project – not only the largest in the profession, but also with extremely complex coordination. Finally, EMITEL with its pre-project and post-project phases took about 5 years, plus another year for paper-print preparation.

The Encyclopaedia contains a large number of entries (articles) – one per each term in the Thesaurus. The size of the entries varies, most of these being between 150 and 500 words). Special Guide was made for all project contributors. The Encyclopaedia was written in English, what required additional work from the UK team to edit some of the entries coming from the international teams.The development of the Encyclopaedia followed original methodology described in the free e-book “The Pioneering of e-Learning in Medical Physics” [1].

The Refereeing of the Encyclopaedia was going in parallel with the writing of articles, to fit with the limited project time. After the refereeing the entries were also used by MSc students from King’s College London, who commented on the clarity of explanations of terms. A system of specific file organisation was developed at the Coordination office, allowing to specify the phase of development of each entry and its readiness to be released (Fig. 16). A master Database was also developed at the Coordination office to allow monitoring the overall progress of the project.

A special web portal for the Encyclopaedia was developed by the project partners M Stoeva and A Cvetkov from AM Studio – www.emitel2.eu [38, 39]. It includes 3 parts:
-a web Database containing all Encyclopaedic entries, as well as the Dictionary and its translations
-a Content Management System (CMS) with various levels of access, which was used for the update of the database and control of the parts of data to be visualized;
-a web site for access to the information (www.emitel2.eu), which has two search engines – one multilingual for the Dictionary and one in English to perform search inside the text of the entries.

Each Encyclopaedic entry file went through several stages of Development/Refereeing/Editing:
-Internal refereeing (in the Workgroup)
-First Editing by the author, based on remarks from Internal refereeing
-Sending to project Coordinator for upload to the web site for internal viewing only: preview.emitel2.eu
-Feedback from the other Workgroups
-Possible Second Editing by the author in case of need
-Sending the file to an External Referee by the project Coordinator
-Feedback from External Referee discussed by the author and the Workgroup
-Final (Third) Editing by the author
-Final sending to project Coordinator for upload to the web site (www.emitel2.eu - open for all)

From the beginning it was agreed that the Encyclopaediawould consist of a large number of small articles, thus allowing easier search. The academic level of the Encyclopaedia entries (articles)was agreed to be at Master level (MSc, or equivalent) and above. This way it was not necessary to use very simple explanations, and at the same time was a way of allowing medical physics MSc students to use EMITEL as an educational resource [40].

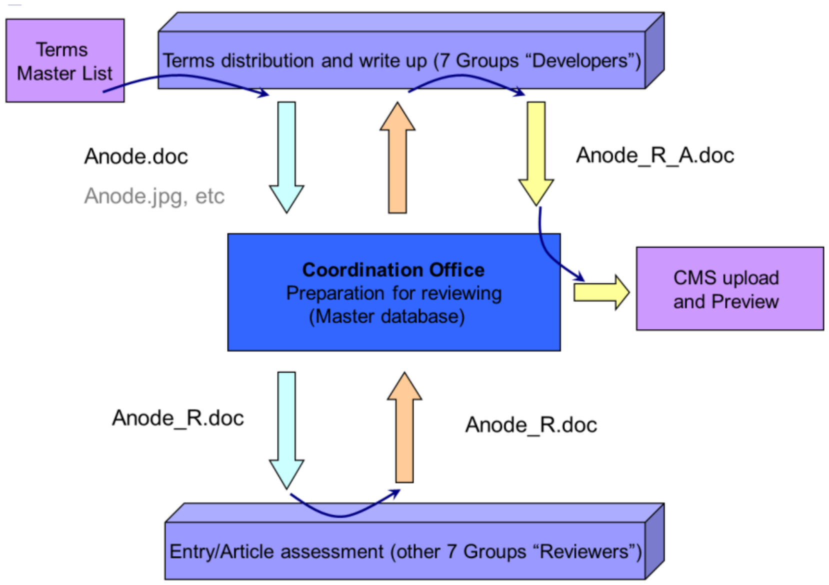


Fig. 16 EMITEL project main workflow (example of an entry “Anode” with its files and changing of file names during the process of Preparation > Refereeing/Reviewing > CMS Upload). This was performed in parallel in all 7 Groups of Developers and Reviewers. The distribution was at the Coordination office with 4 parallel large folders of the Encyclopaedia (depending on Entry the development stage) – Initial Entry; Reviewed Entry; Approved Entry; Upload

There were three main types of Encyclopaedic articles/entries – short, medium and large (the latter going to about 500 words). Specific Guides were made for the different types of articles/entries. The use of font sizes, images, tables, diagrams, captions, References, etc was standardised in order to help the significant number of authors to prepare entries with unified look.

The web site handling both the Encyclopaedia and the Dictionary provided all necessary links between them. The interface allowed both - to use separately the two elements and to use these simultaneously. To serve both functions two separate Search Engines were added to the Web site. The first Search Engine serves the Multilingual Dictionary (it can work with various alphabets, as per the Internet browser settings of the user). The second Search Engine serves the Encyclopaedic articles (entries in English), this way allowing search for synonyms, acronyms and other words inside the text of the articles. This Search Engine can also search within articles specific to one of the areas of the Encyclopaedia (X-ray Diagnostic Radiology, Nuclear Medicine; Radiotherapy, Ultrasound Imaging, MR Imaging; Radiation Protection). Each entry displayed at the web site has an additional Area indicator (e.g. the entry Anode is available in two areas/fields – General and Diagnostic Radiology) (Fig.17). Selecting the area field displays the relevant Entry. The web site was developed with a special “hidden” part – Content Management System, which allows updates of the material online.

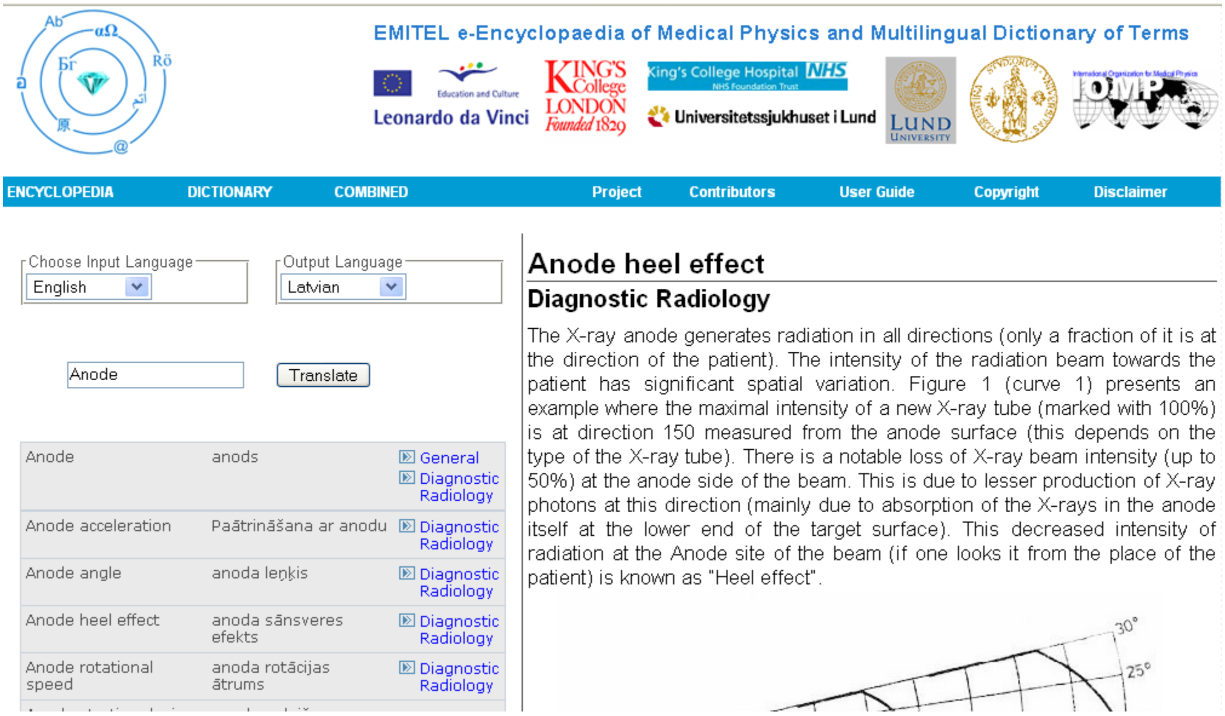


Fig. 17 Sample Print-screen of the Encyclopaedia web site – Combined Dictionary and Encyclopaedia

The large assessment conference (EMITEL Conference) was held at the premises of our long-standing project partner - ICTP, Trieste (23-26 October 2008) – Fig.18. Its main objective was the assessment of the e-Encyclopaedia materials, their further development, dissemination and use. The Conference included project members, also a group of students, who used the e-Encyclopaedia for several months and gathered very useful feedback, and also medical engineering professionals, thus widening the scope of EMITEL. The Conference was by invitation only, gathering about 70 specialists - leading experts in Medical Physics. These included 21 present and past Presidents of Medical Physics Societies, Federations and Organisations (including a number of IOMP Officers). All assessors (and later all users) found the Encyclopaedia a very useful e-learning resource

The number of articles on the e-Encyclopaedia web site is about 3200. Their volume (Word files and JPG images) is more than 1GB. The images, diagrams, etc are approx. 2500. The final printed volume, in alphabetically arranged A4 pages, depends on the typeset - when the default Times New Roman 12 was used, it reached 2100 pages.The e-Encyclopaedia EMITEL was launched at the World Congress WC2009 in Munich and from the very beginning until this day it has a steady flow of about 50,000 searches per month. The Encyclopaedia of Medical Physics was also printed on paper by CRC Press [41].

The further paper-pint of the Encyclopaedia by CRC Press reduced the number of pages. Currently the Encyclopaedia is being updated – a project to be completed by 2020 (and print as Second Edition by CRC Press). EMITEL e-Encyclopaedia of Medical Physics and its Multilingual Dictionary of Terms has thousands of users from around the world. For information – the web server official statistic for 3 months (from January to March 2018) shows total visits 30,775 (c.10,000 in Europe; c.13,000 in Asia; c.4,000 in North America; c. 2,000 in South America; c.2,000 in Africa).

Fig. 18 EMITEL Conference, ICTP, Trieste, Italy, 2008 (part of participants): from L>R front row sitting: E Morris, E Chaloner, J Calvert, G Clarke, J Chick, A Krisanachinda, I-L Lamm, M Radwanska, B Allen, M Lewis, R McLauchlan, I Horakova, M Almqvist, V Tabakova, S Tabakov, A Benini; front row standing: C Oates, K Olsen, G Mawko, M Petersson, B-A Jonsson, R Magjarevic, M Secca, E Moser, J Boyle, P Bregant, N Pallikarakis, S Christofides, D Bradley, F Schlindwein, S Keevil, R Wirestam, F Milano, E Podgorsak, D Frey, A Cvetkov, K Keppler, D Goss; second row standing: M DeDenaro, C Deehan, M Buchgeister, G Taylor, A Simmons, T Schaeffter, J Thurston, D Platten, H Terrio, M Leach, T Jansson, C Deane, P Zarand, A Evans, M Grattan, P Smith, C Lewis

4. Conclusion

The projects and results described in the chapter about e-Learning in Medical Physics showed the dedication of many medical physicists to e-learning, as well as their innovative thinking. The profession has now truly embraced e-learning, this being now an intrinsic part of its education and training. Obviously this will continue and further new e-learning materials, simulations and other innovations will enhance the global professional development of medical physics.

The double growth of medical physicists during the decade 1995-2005 (compared with the previous 3 decades) coincides with the introduction of e-learning in the profession. Further the double growth of the medical physicists globally in the following decade 2005-2015, coincides with the extensive use of e-learning (Fig.19). This data show that e-learning, as part of the overall emphasis on education and training in the profession, is an important element of the global growth of the profession [42].

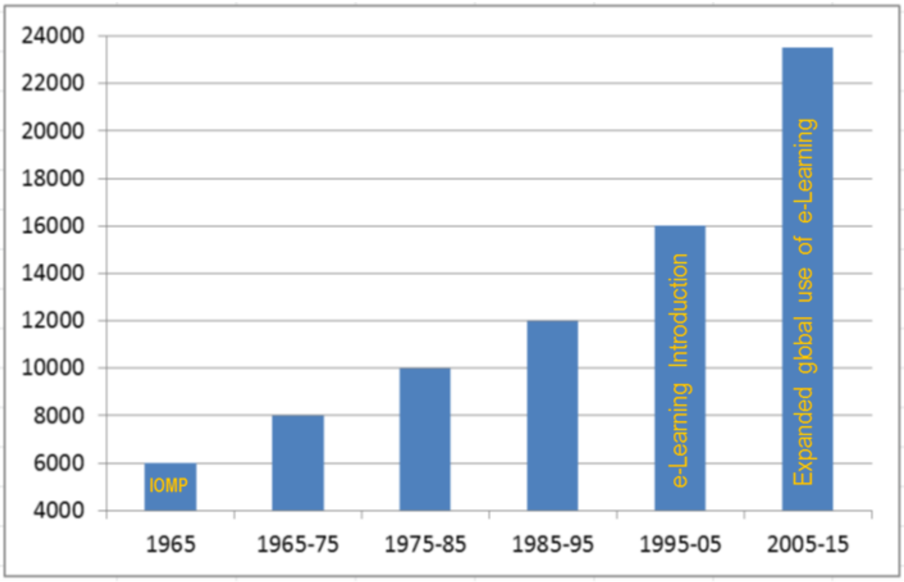


Fig. 19 Global growth of medical physicists in the world in the period 1965-2015

Most of the pioneering projects, which laid the foundation of e-learning in medical physics were developed on voluntary basis by hundreds of colleagues from many countries. The main players of this process were mentioned in the text of the chapter. Here below we list also all contributors to the extremely large projects on the Multilingual e-Dictionary of Terms and the e-Encyclopaedia of Medical Physics.

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