IOMP MODEL CURRICULUM FOR POSTGRADUATE (MSc-LEVEL) EDUCATION PROGRAMME ON MEDICAL PHYSICS

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Abstract— The IOMP project for Model Curriculum for Medical Physics Education was completed in 2012. It aims to present guidance on the organisation of post-graduate (MSc level) courses. The project presents several models for this: modular, distributed, mixed, topical and e-Learning. The advantages/disadvantages of these models are discussed from the point of view of specificity in the country. The project also suggests topics for the Curriculum and indicative percentage of these, as well as introduces criteria and method for IOMP Validation of MSc courses in Medical Physics..

Keywords— Education, MSc Curriculum in Medical Physics, Accreditation of MSc courses.

INTRODUCTION

The expansion of Medical Physics as a profession requires dedicated academic programs for the education and training of the young colleagues. At this time many countries do not have guidance on how to develop their education programmes. The experience in other countries provides the foundation for a project to produce a very useful Guide for development of new programs.

The Model Curriculum (Model Teaching programme) project was a spin off activity of the World Conference on Physics and Sustainable Development (November 2005, Durban, South Africa). It was supported both by the IUPAP (International Union of Pure and Applied Physics) and the IOMP (International Organization for Medical Physics). The project was discussed at the IOMP Education and Training Committee (ETC, 2006) and resulted in the formation of Work Group of experts (the authors of the article), which had a meeting during the EMITEL Conference in ICTP, Trieste, October 2008 and a number of Internet discussions. Being all active educators, the authors gathered expertise from countries with advanced Medical Physics education, as well as from countries which successfully developed their current education on this subject. This paper presents an overview of the main issues addressed by the Model Curriculum project. These include:

- Overall number of classroom contact and self-reading hours;
- MSc project and thesis;
- Structure of the Curriculum and Models of content delivery;
- Entry requirements and students' assessment;
- Principles of validation of courses/programs;
- Indicative content of the Curriculum.

OVERALL NUMBER OF CONTACT AND SELF-READING HOURS

Medical Physics education is usually provided at the Master level (final University year). In general, the total number of learning hours associated with a postgraduate (MSc-level) educational programme (also called University MSc course) include:

- Contact hours (lectures, seminars, tutorial, labs and practical exercises);
- Self-study hours (reading specified books an web-based resources and preparation for course works / exams);
- MSc project related hours (including the research and the writing of the MSc thesis)

The total number of contact hours (lectures, seminars and labs) in a postgraduate (MSc-level) education programme can vary according to the local University requirements and the level of self-reading requested by students. There are two educational models representing the approximate lower and upper limits of contact hours.

In case of high self-reading expectation, the overall contact hours could be of the order of 300 – 400 hours. However in this case each lecture hour has to be complemented by at least 2 hours additional self study (depending on the difficulty of the subject). This model requires the existence of a good reference list and the availability of a library with the necessary resources, either in print or online. To satisfy the simultaneous study of at least half of the student group (at a time). This model also requires good student testing during the delivery of education.

At the other extreme (when minimal self-study is expected) the overall contact hours could be of the order of 800-900 hours. This model is useful for Regions or Universities, where the libraries are not rich in resources, and most of the information is expected to be delivered during the lectures and labs. In this model the main resource which students have for preparation for exams is their lecture notes.

When distributing the contact hours, one needs to build a good proportion for labs and other practical hours. Their proportion could be estimated as ¼ of all contact hours.

It should be emphasised, that contrary to some other University courses, attendance to Medical Physics lectures should be regarded as essential, and coursework delivery as obligatory. These requirements are very important for our dynamic profession, where books and other sources become out of date quickly.

As a rough estimate, the sum of class contact and self-reading hours of an MSc programme in Medical Physics would be around 1100-1300 (including time for the examination and feedback tutorials).

MSc PROJECT AND THESIS

The MSc project (or Diploma work) and related thesis is of great importance for the assessment of students' ability to apply the acquired knowledge into practice. This research element of the education element should follow the above-described taught element. The nature of Medical Physics education allows for minimal overlap between these two elements and the MSc projects should follow after the completion of the educational modules. It would be advisable the subject of the MSc project to be linked to a real practical problem.

The volume of the MSc thesis is often given as around 15000 words, but this should not be a strict requirement, as different theses would produce results which would include elements which can not be measured this way (for example programming, drawings, etc.). However the thesis is expected to be "publication-like" – i.e. including all major elements of a typical research paper: Introduction; Literature search; Materials and Methods; Results; Discussion; Conclusion; Reference list.

The difficulty of the project should be related to the approximate time, which the student is expected to devote to it. In many Universities this time is around 500-700 hours.

This MSc project time, added to the time for contact and self-reading above, would give an indicative overall length of the postgraduate (MSc-level) education programme of approximately 1700-1900 hours. Again, variations related to local requirements could significantly change this figure. Normally this length would be delivered either within one-two academic year (full time studies) or in two-three academic years (part time studies). Some local regulations could require longer study time - e.g. 2 years for full time MSc programme. Similarly the taught element of the full-time programme could be extended over 1 whole year, and the MSc project could be developed over the second year (during which the student can have also some exposure to the real practice of the profession). Respectively such delivery of the programme could extend the Part-time delivery and completion up to 4 years.

STRUCTURE OF THE CURRICULUM AND MODEL OF TEACHING DELIVERY

The MSc programme could be delivered either as a condensed full-time academic activity (most often over one year), or as a distributed part-time academic activity (most often over two years). Its organisation should be based on a progressive structure, as many of the topics require background from other previous topics. From this point of view a very suitable model for Medical Physics Education is the modular model. One module is a finite element of the studies, with separate assessment (for example Radiation Protection Module). Its length varies, but is often 30-40 contact hours.

In this model each subject from the educational structure is delivered in a condensed period of time (over 1-2 weeks). The model is very effective in regions, where the concentration of lecturers is not sufficient. The model allows for various lecturers to be called from other Universities (or cities and countries). The disadvantage of this model is related to the fact that when students miss certain element (due to illness, or other reason) they would have great difficulty to be in pace with the group.

A variation of the modular model is distributed delivery of lectures on different subjects, while keeping the logical link between them. This model is more convenient for the students, but puts great pressure on the organisation, as a missing lecture (due to lecturer's illness or other reason) could disrupt the logical line of knowledge delivery.

Perhaps a suitable balance between these two possibilities provides a good solution, which is used in a number of Universities. This balance could be based on mainly distributed delivery of the basic topics (for which one University could find local lecturers) and fully modular delivery of the special topics (what would require invited external faculty of lecturers).

Obviously this method of delivery must be based on grouping the subjects (modules) in two main categories – general topics (which all students will study) and topical modules (from which the student will select a limited number, depending on their interest). Later an example model for a curriculum with its modules is described.

Other organizations of the delivery (by subject) are also possible - for example – Imaging group of modules, which would form a package including the physics principles, the medical application, the relevant equipment and its method of operations, various measurements and safety issues, etc. This however is very difficult to be applied in a small country, where the lecturers are often scattered in various cities and institutions. The advantage of this organisation is related to the better learning and examination of students. This method of delivery is suitable for a large (and rich) University, which can afford to organise solely an MSc programme in Medical Physics (and even such University would need a number of honorary lecturers).

In most other cases the University issuing the degree must have agreements with other Universities (where some lecturers work and/or suitable laboratories exist). These inter-university agreements are vital for the organisation of MSc courses in small countries. A model suitable for smaller countries (and Universities) is collecting a faculty of lecturers (from other cities or countries) and maintaining a local Education Centre (which in principle could be not just for one country, but for a whole region). This model can have variations.

One variation could be all students to be registered at their own University (which can be different from the University hosting the Education Centre) and attend all optional lectures at this Centre (which in this case is the meeting point of students and lecturers). In this case the Centre should have honorary contracts with the host University. It is assumed that the students could attend the basic lectures at their own University. When the students complete the taught element of the programme they could develop their MSc project in their own University, and graduate from it. This model is cost-effective, but will depend heavily on the inter-university agreements (between the hosting University and the other Universities sending students to it).

Alternatively, the students can register with the University, where the Centre is established, complete all taught element there (basic and optional modules), then develop their MSc project in the Education Centre and graduate from the host University. This education delivery requires good investment in the foundation of the Centre (for equipment, laboratories, teaching room, etc). Its advantage is that in this case all teaching and research are in the host University (assuming the countries sending students have educational agreement with the host country). A plus of this mod-el is that with time the host University will have a number of its own graduates to take part in the education process, what in future would decrease the cost for invited faculty.

ON-LINE STUDIES

The number of students following on-line courses and other e-Learning initiatives increased over the past 10 years. Most authors support blended delivery of e-Learning and classical learning [7, 8]. Contemporary web technology (e.g. Skype) allows for direct lecturing from distance, supported with specific on-line materials. Own development of bespoke e-Learning materials is very expensive, however a number of suitable and well used such materials exists on Internet [e.g. 9, 10, 11]. Their use however has to be specified in the Programme description/handbook. In such case the home University (offering e-Learning degree) has to agree on the use of these materials (blended with their own education) and has to consider inclusion of on-line teachers in the Programme Faculty of the MSc course (if appropriate). e-Learning is most suitable for remote areas, but its delivery without contact with real practising lecturers is not recommended. The best results of e-Learning are usually for further education of junior specialists, who already work in Medical Physics Departments as technicians, or similar. This way they have the necessary contact with the profession, as well as supervisors for their MSc projects.

ENTRY REQUIREMENTS

A normal entry requirement would be undergraduate degree (BSc-level) in Physics, Engineering or other relevant subject (based on minimum 3 years University education). The variation of undergraduate programmes and courses is enormous and the entry level should be decided for every single case. When this level is doubtful, an extra preparatory period (approximately one term) could be added. During this period the student will have to pass additional elements on Physics, Research methods and Human Physiology&Anatomy. If such model is used, we could expect that the Full Time delivery would extend over minimum of 2 years (e.g. 1/2 year preparatory + one year taught element + ½ year research project). Such education course could build very sound educational base and could include elements of further practical training (what otherwise would be difficult to organise as a separate activity).

Due to the variety of University undergraduate programmes, it is not possible to advice on specific entry requirements. Selecting students with an interview is always advisable, as this way the selecting panel could agree on the acceptable entry level, type of questions, etc.

STUDENTS' ASSESSMENT

As usual standard written exams (2 to 3 hours exam writing time) are required for passing the educational modules. The percentage which the exam mark takes from the overall module mark is advisable to vary between 60 and 80%. This way the remaining 40-20% are for course work to assess the progressive build-up of Medical Physics knowledge (coursework in a form of essay on a subject, small design project, a set of tasks, etc given and assessed during the semester). The dynamics of our profession and the structure of knowledge does not allow for missing coursework (or any other type of home work). This work should be structured to be answerable in approx. 8 hours (by an average student). The course work has to be assessed and feedback given to the students before the exam.

Due to the relative difficulty of the Medical Physics exams, it is advisable for these to be distributed in two exam sessions (after each substantial term). At least 3 days revision time should be given in-between exams. In case of modular delivery the exam could follow directly the end of the module. It is a good practice for the exam questions to be confidentially agreed not only by the respective lecturers, but also by an External Examiner, who is from another University (or at least is not involved in the course delivery).

The pass mark of each module is to be decided by the University, but it should not be below 40% (assuming 100% is the maximum mark) for each element of the assessment - written exam and course work. Many Universities require for the minimal sum pass mark to be 50% and the written exam to be assessed by two examiners.

Assessment of the MSc thesis (or Diploma work) includes normally an oral exam (viva voce), where the student has to defend his/her project/hypothesis and answers the questions of the examiners. The number of examiners in the panel can vary according to local requirement. Normally the pass mark for MSc thesis is 50%. This mark should include approx 70-80% from the theses assessment and 30-20% from the actual oral exam presentation. A good practice can be introducing an Interim MSc exam (approx. 1 month after the beginning of the MSc research work), where the student presents his/her idea, initial literature search, expected results and working plan. This Interim exam can be assessed with 10% from the total MSc thesis mark, but could give an early feedback to the student for the development of his/her re-search and could prepare him for the final oral examination.

SUGGESTION FOR THE MODULES OF THE PROGRAMME

The syllabi of modules of the Model Curriculum include the main components necessary for initiating practice in the profession. However due to the dynamic development and expansion of the profession these have to be regularly updated. The Model Curriculum is based on a number of publications, collected over the last 15 years at special Conferences, Workshops and Seminars [1-8].

Based on these an indicative suggestion for the main modules in a MSc-level programme in Medical Physics (plus their % of contact hours) can be presented as:

Basic modules:
Basis of Human Physiology and Anatomy ~10%
Basis of Radiation Physics ~10%
Research Methods ~10%
Radiation Protection and Hospital Safety ~10%

Topical modules:
Medical Imaging Physics and Equipment 1 ~10%
(non-ionizing radiation - MRI, Ultrasound)
Medical Imaging Physics and Equipment 2 ~10%
(ionizing radiation – X-ray, Nuclear Medicine)
Radiotherapy Physics and Equipment ~15%
Other optional modules could also be included.

MSc project work ~ 25%

INDICATIVE OUTLINE OF THE SYLLABI OF THE MODULES

Basic modules

Basis of Human Physiology and Anatomy ~10%

This module aim is to give to students background for their further studies and to help them in their future work with medical colleagues. From this point of view it is advisable for this module to be placed at the beginning of the teaching programme. It could have internal structure based on sub-modules (approx. 2 to 4 hours each), according to the main systems in the body (with emphasis on physiology). In principle it can be delivered as 5 to 8 days full time module. The lecturer(s) could use one of the many existing textbooks on the subject (suitable adapted medical physicists). For example a suitable book could be "Introduction to the Human Body" by Tortora and Grabowski.

Basis of Radiation Physics ~10%

This module aims are to provide suitable background of the basic physics of the ionising and non-ionising radiations used for medical diagnostic or therapeutic purposes. The module will need some initial reminder of the radiation concept; fields and photons; the origin of different types of ionising radiation; the interactions of radiation with living organisms. The module may follow elements of existing Physics education, but has to include laboratories on Radiation measurement and has to include more detail about:

- Photon interactions: Elastic scattering, Rayleigh scattering, Compton scattering, photo-electric absorption, pair production. Interaction cross sections, and dependence on energy and atomic number. Absorption and attenuation coefficients.
- Particle interactions : Interaction of charged particles with matter; Electron-electron collisions, delta rays, polarisation effect, radiative losses; Heavy charged particles, Bragg peak. Stopping power and dependence on energy, atomic number, density.

Elastic scattering. Range.

- Radiation measurements: Concepts of fluence, absorbed dose, exposure, kerma.

Methods of radiation detection: gas detectors, scintillation detectors, semiconductor detectors, thermoluminescence detectors, photographic film.

- Ultrasound: Acoustic propagation and interaction. Pulses and diffraction. The pulse-echo principle. Doppler effect. Acoustic properties of human tissues. Transducers.
- Electromagnetic radiation: Sources of radiation, interaction, hazards and medical applications for each: Lasers, Radiofrequency, Microwave, Infra-Red, Visible and Ultra-Violet.

Research Methods ~10%

The aim of this module is to introduce the basic principles of research methodology, related project planning and ethical issues; the practical applications of modern data processing in medicine (medical signals and image processing), including statistical techniques relevant to medical data. The module may include also study/application of relevant software (e.g. MatLab, SPSS, etc). The module may follow elements of existing Signal/Image Processing education and has to include more detail about:

- One dimensional signal processing : Sampling: Nyquist, aliasing, quantization;

Spectral analysis: DFT, FFT, Hilbert, Hartley, Hough; Correlation and Convolution;

Various Filtering methods.

- Two dimensional signal processing: Image perception and quality, Spatial frequencies; Image Enhancement and Restoration: Point operations, Pixel group processing, Global operations, etc; Image analysis: Segmentation, Morphological processing, Feature extraction, etc; Image compression; Foundation of backprojection reconstruction; Image transfer and archiving systems.
- Statistical methods: Frequency distribution and summary measures; Sampling distribution; Hypothesis testing; Analysis of variance; Basis of Time series; Regression.

Radiation Protection and Hospital Safety ~10%

This module aims to provide the theoretical background of the radiological protection requirements (ionising and non-ionising radiation), as well as fundamentals of general hospital safety. The module may follow existing national methods for Risk assessment and has to include more detail about:

- Biological effects of ionising radiation; Dose response – relationships and factors affecting dose response; Quantities used in protection: Quality Factor, Equivalent Dose, Effective Dose; Background radiation; Organisations concerned with radiation protection (e.g. ICRP, IAEA, etc); Framework for radiation protection; Development of recommendations; National legislation concerning medical use of radiation; Personnel monitoring; Dose control for patients; Strategies for patient dose reduction.
- Ultra-Violet radiation: Biological effects, Measurement, Maximum Permissible Exposure; Monitoring and protection
- Microwaves and Radiofrequency (including MRI): Classification, Biological effects, Measurement, Maximum Permissible Exposure; Monitoring and protection.
- Lasers: Types of lasers and classification of hazard, Biological effects; Measurement, Maximum Permissible Exposure, Monitoring and protection.
- Ultrasound: Classification, Biological effects, Monitoring and protection.

Topical modules:

Medical Imaging Physics and Equipment 1 ~10% (non-ionizing radiation - MRI, Ultrasound)

This module aims to educate students in the physics of medical imaging with non-ionizing radiation (MRI and Ultrasound). Due to the rapid development of these imaging modalities (especially MRI) the module is expected to adapt regularly to the progress in these fields. The main parts of this module have to include more detail about:

- Magnetic Resonance Imaging

Physics of MRI; MRI Instrumentation; K-space; Different MR imaging methods; Pulse sequences; MR Contrast and Image quality; Health and Safety; MR Spectroscopy; Flow imaging; Perfusion, Diffusion and Functional MRI; Three dimensional reconstruction; Clinical applications of MRI; Image artefacts; Inter-relationship between medical imaging techniques.

- Ultrasound Imaging

US wave motion and propagation; Acoustic properties of biological media; Acoustic radiation fields; Safety measures; Transducers; A-mode; B-scanning; Doppler Ultrasound; Image artefacts; Blood flow measurements; Measurement of acoustic power; Clinical applications of US imaging; Image artefacts; Inter-relationship between medical imaging techniques.

Medical Imaging Physics and Equipment 2 ~10% (ionizing radiation – X-ray, Nuclear Medicine)

This module aims to educate students in the physics of medical imaging with ionising radiation (X-ray and Nuclear Medicine Imaging). Due to the rapid development of these imaging modalities the module is expected to adapt regularly to the progress in these fields. The main parts of this module have to include more detail about:

- Diagnostic Radiology

X-rays production and equipment; Interaction of X-rays with matter; Radiological image quality; X-ray detectors: Film, Image Intensifier, Storage phosphor, Flat panel; Scatter radiation and filtering; X-Ray Computed Tomography; Scanner configurations; Reconstruction types; CT image display, windowing, CT numbers; X-ray patient dosimetry and protection; Optimization techniques; Clinical applications; Image artefacts; Inter-relationship between medical imaging techniques.

- Nuclear Medicine Imaging

Radionuclides and production of Radiopharmaceuticals; Disease-specific radiopharmaceuticals; Radiation protection in Nuclear Medicine; Image quality and noise; Nuclear Medicine instrumentation and quality control: Gamma camera, SPECT, PET, SPECT/PET-CT, etc; Optimization techniques; General imaging principles, cardiac imaging, multigated studies, first pass studies, renal studies, modelling; Image artefacts; Inter-relationship between medical imaging techniques.

Radiotherapy Physics and Equipment ~15%

This module aims to provides the necessary background for the support of Radiotherapy Physics activities. Due to the rapid development of this field the module is expected to adapt regularly to the Radiotherapy progress. The main parts of this module have to include more detail about:

Interaction of radiation with tissues; Radiobiology in Radiotherapy; Radiotherapy dosimetry; External beam radiation and treatment planning; Megavoltage Linear Accelerator; Radiobiology in Radiotherapy; Radiotherapy with particle beams; Brachytherpay: High dose rate (HDR) treatments; Low dose rate (LDR) permanent implants; Beam models and planning tools; Treatment room design, machine commissioning and networking; Imaging in Radiotherapy; Quality management in Radiotherapy; Principles of Clinical application.

VALIDATION OF THE PROGRAMME

Usually a small country will have no experience in setting and accrediting a suitable post-graduate programme (course) in Medical Physics. Validating the programme by an experienced body will assure the local University (or Ministry of Education) that this programme is in line with the international standards. Additionally, the fact that the MSc graduates will work in Hospital environment (indirectly involved with patient health), makes the external validation an important element of the educational process.

IOMP has significant expertise allowing the provision of validation of such post-graduate programmes in Medical Physics and has set up of a special Validation and Accreditation Panel (VAP) of experts to the ETC Committee. This Panel (or sub-committee) could not only assess and validate the programmes, but could also provide External Examiners and suggest suitable lecturers. The activities, terms and internal rules of the VAP are still in discussion. It is expected Validation activities of the IOMP to be implemented during the period 2011-2012. These will include: Validation requirements; Application Form, Validation Procedure and Validation Certificate (all to be found at the IOMP web site at implementation stage).

CONCLUSION

The project for Medical Physics Model Curriculum, was developed by leading specialists and approved by the IOMP ETC. It presents a background for initiation of new MSc courses. Part of the project has been used in the new IAEA Project Post-graduate medical physics academic programmes

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