A NOVEL CURRICULAR MODEL FOR MEDICAL PHYSICS AND RADIATION PROTECTION EDUCATION – AN ALTERNATIVE POSSIBLE WAY FORWARD FOR AFRICA?

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***Abstract*— In Malta, the Medical Physics and Radiation Protection professions have, in recent past, faced an acute shortage of entrants owing to the low popularity of two-year Masters programmes (including the one in Medical Physics) and the very low number of undergraduate physics graduates. A formula needed to be found to: (a) address the paradox of having to reduce the Masters programme to a single year at a time when the knowledge-skills-competences required for modern medical physics and radiation protection practice are expanding rapidly, (b) ensure that the potential stock of entrants to the Masters would be independent of erratic student numbers in undergraduate physics. We also wanted to address what we believe are shortcomings of the present curricular model of medical physics education, particularly the low level or even non-existence of medical science, soft skills, professional issues and hospital experience. An extensive literature review of current issues impacting the medical physics and radiation protection curriculum was carried out. We also surveyed medical physics programme curricula worldwide; best practices were identified and used as further inputs to the model. Very importantly, the programme also needed to be cost-effective and attractive to the young people of today. We have opted for a four-year undergraduate inter-faculty programme that combines physics, medical physics, and radiation protection followed by a single year Masters in medical physics. This innovative curricular experiment has been a great success and has attracted many students. The inter-faculty nature of the programme (where students share lectures with both physics students from the Faculty of Science and healthcare students of the Faculty of Health Sciences) together with the element of clinical practice have been found to be the most appealing features. We have succeeded to develop a state-of-the-art programme at minimal cost.**

Keywords— **medical physics, radiation protection, curriculum development, professional issues.**

I. INTRODUCTION

The impetus for this curriculum development project started off from two very pragmatic issues: (a) Traditionally the qualifications framework for Medical Physicists consisted of an undergraduate degree in physics, followed by a Masters in medical physics. However, the number of students taking undergraduate physics has plummeted in many countries. How can one ensure sufficient applicants to the Masters in medical physics hence guaranteeing the development of the profession and the necessary human resources for the development of healthcare services? How can we ensure that the number of entrants to the Masters in medical physics be independent of what happens in physics? (b) Owing to the wide range of content that needed to be covered, Masters programmes in medical physics have in the past been of a two-year duration. However, two-year Masters programmes have lost their popularity over the last years as for economic reasons students are unwilling to forgo two years salary and prefer single year Masters programmes. In addition, though undergraduate programmes are often free, the same often does not hold for post-graduate programmes which often carry tuition fees again making uptake even less attractive. However, reducing the Masters in medical physics programme to a single year is problematic as it is found to be nigh impossible to compress the two-year content of a regular Masters programme into a single year particularly at a time when the number and complexity of medical devices and the use of physical agents in healthcare is expanding rapidly. Medical Physicists today need to not only deal with ionising radiation and all three associated specialties of medical physics (D&IR, RO and NM) but also ultrasound, MRI, advanced image processing software, artificial intelligence (including pattern recognition and machine learning), advanced mathematical techniques such as Monte Carlo and computational methods (e.g., iterative image reconstruction). In addition, given the many developments on the professional front, certain obvious lacunas that have lowered the quality and appeal of our programmes needed to be addressed - in particular the low anatomy/physiology/pathology content (how can we be taken seriously as a healthcare profession without a strong component of these in our curricula?), the quasi-total absence of hospital experience and the low attention to legislation, soft skills (communication, inter-professional skills, management) and strategic leadership skills which are so critical for our students to be able to survive in the complex environments in hospitals today. Finally, the curriculum needed to be attractive to physics students and very importantly its cost had to be minimal.

II. MATERIALS AND METHODS

We aimed for a state-of-the-art curriculum which would be valid not only in the present but also for the next future. We therefore carried out an extensive literature review to identify the issues impacting the present and envisaged future development of the medical physics profession. These issues are listed in Table 1. We also surveyed medical physics undergraduate and Masters programmes via the internet; best practices were identified and used as further inputs to the curriculum development process and the outcome curriculum model.

Table 1: Issues impacting the development of the medical physics profession and curriculum.

Area	Issues
Technological and Scientific	The rapid expansion in the number and complexity of medical devices The rise of artificial intelligence (including pattern-recognition, machine-learning) [1] Need for increased scientific / mathematical/ statistical /programming skills.
Professional	EFOMP Policy Statement on Education and Training 12.1 [2], Malaga Declaration [3] and Medical Physics 3.0 [4]: the role of the medical physicist should be expanded to *all* medical devices and *all* physical agents and include a high level of involvement in service development and patient care. Need for high scientific leadership skills. Need for a higher level of medical sciences. Need for higher level of soft skills [5]
Economic	Low university budgets The threat of commoditization [6] Inter-professional competition [6] Need for strategic leadership skills [6]
Social and Legal	Political pressure for higher standards of patient service and safety and associated legislation Political pressure for higher standards in occupational and public safety with respect to *all* physical agents (not only ionising radiation) and associated legislation

III. Results

In order to maximise the appeal of the programme to pre-university students and increase their future employment opportunities we opted for an undergraduate degree which involves *all three of physics, medical physics and radiation protection (BSc (Hons) Physics, Medical Physics and Radiation Protection)*. Hence graduands of the programme can go on to further studies or seek future employment in all three areas. It also has the advantage of ensuring strong physics and mathematics foundations whilst including sufficient medical physics and radiation protection content to permit us to reduce the duration of the Masters in medical physics programme from two years to one. The Bachelor programme is a four-year programme to ensure comprehensive robust cover of the necessary content. Since the programme is a Bachelor programme it does not carry a tuition fee.

A. Structure of the Bachelor programme

The overall structure of the programme can be found in Table 2 (number of asterisks indicates weighting). A description of the programme and full curriculum can be found here https://www.um.edu.mt/courses/overview/UBSCHPMRFT-2022-3-O and here https://www.um.edu.mt/courses/programme/UBSCHPMRFT-2022-3-O.

The programme consists of five parallel strands.

The first strand includes all the essential physics and mathematics-for-physics study units normally found in any regular Bachelor physics programme. Our students attend the same Physics classes as the regular physics students of the Faculty of Science. This ensures a solid foundation in physical science, mathematics, statistics and computational methods, and very importantly the strong problem solving and analytical skills so critical for higher level medical physics and radiation protection competences. It also ensures that our students maintain close ties to their physics roots; a link which would be very useful in their future careers in medical physics and radiation protection. It also keeps open the possibility for them to continue for higher studies in physics as opposed to medical physics or radiation protection should they wish to. The physics staff are pleased with the higher number of students taking their classes. Very importantly, since our students are joining the regular physics groups, the cost of these study units for our programme is zero.

Table 2: Structure of the undergraduate curriculum

Year	Physics Mathematics Statistics Programming	Anatomy Physiology Pathology	Medical Physics Radiation Protection	Hospital Clinical Practice	Research Ethics Legislation Professional Issues
4	**		*****	112 h	***
3	***	*	****	112 h	*
2	****	**	**	112 h	*
1	****	****	*		*

The second strand consists of an anatomy /physiology/pathology strand. A good grounding in the medical sciences is required of all healthcare professionals and Medical Physicists are no exception. X-ray physics and medical devices as well as ultrasound and MRI are of little value unless we link them with a good knowledge of anatomy so that we can liaise with Radiologists and Radiographers. Radionuclide physics and gamma sensors are meaningless unless they are linked with physiology and pharmacology so that we can work as a team with Nuclear Medicine Physicians and Nuclear Medicine Radiographers. Monte Carlo techniques are worthless if not tagged to anatomy and radiobiology-based treatment planning. Medical Physicists have in the past been criticized for not involving themselves at a deep level in the everyday challenges of clinical departments; *this needs to stop. We must accept this criticism with humility, avoid excessive professional pride and do* *something about it.* In these study units our students join shared common units taken by Radiographers, Physiotherapists and other healthcare professions. This has the major advantage that they learn to appreciate and work with other healthcare professions and other healthcare professionals in turn learn about our own profession. Again, since our students join already established study units, the cost for the programme is zero.

The third strand involves medical physics and radiation protection study units. These study units lay the foundations for and serve as an introduction to the various specialties of medical physics which are then studied at a higher level during the Masters. They also lay the foundations of occupational and public radiation protection, not only for medical uses but also for industrial and environmental protection. This has the advantage of expanding the employment opportunities of our graduates beyond the medical arena should they wish to do so. The lectures are delivered by both academic and hospital Medical Physicists ensuring strong theoretical and clinical foundations. These study units obviously carry a cost for the programme as they are specifically for medical physics and radiation protection students. Their cost is provided mostly by money that would have been allocated to the budget of the previous two-year Masters in medical physics which has been since reduced to one academic year. There is therefore minimal increase in overall costs.

The fourth strand involves clinical hospital practicals. At the moment we divide each cohort into smaller groups which rotate around the departments associated with the three main specialties of medical physics. We leave the organization of the practicals in the hands of the clinical Medical Physicists so that they may adjust the programme according to their actual clinical duties and to any opportunities arising such as the introduction of new equipment. In future, we plan to expand these practicals to other clinical areas such as physiological measurement and also to industrial locations. It is important that in parallel with the hospital practicals, students are supported by discussion sessions so that they be helped to understand that it is normal to note differences between what they experience directly in the real world of clinical practice and the future desired higher vision for medical physics and radiation protection services for the country - a vision which they themselves are being invited to help build.

The final strand involves research, legislative, ethical, soft and professional skills. Many of these study units (e.g., healthcare ethics, principles of healthcare research, healthcare management, academic English, communication) are shared units and again carry no cost. The same holds for physics research-oriented practicals as students join the regular physics students. Some areas such as professional issues are specific for medical physics students and carry a cost. In terms of research project, we have at the moment included a short 10ECTS dissertation in medical physics/radiation protection, however we would also like to add a second short 10ECTS dissertation in physics.

B. Content of the Masters programme

The content of the Masters programme can be found in Table 3. One should notice that all three specialties of medical physics are given a high weighting to ensure that students can apply for any post-Masters traineeships available and in any specialty of their choice. In addition, advanced signal and image processing and artificial intelligence (pattern recognition and machine learning) feature strongly.

Table 3: Content of the Masters programme

Study Unit	ECTS
Medical physics and radiation protection in radiation oncology	10
Medical physics and radiation protection in nuclear medicine and radioisotope cyclotron facilities	10
Medical physics and radiation protection in diagnostic and interventional radiology and dentistry – *Ionising* imaging modalities	10
Medical Physics and Radiation Protection in Diagnostic and Interventional Radiology and Dentistry - *Non-Ionising* imaging modalities	10
Advanced signal and image processing for physiological measurement and medical imaging	10
Machine learning and pattern recognition	10
Research dissertation	30

IV. Discussion

We will now discuss the major issues that needed to be addressed and the way they were tackled.

A. Cost of the programme

One of the determining issues in today's world is that of cost. If the cost of a curricular programme is high the proposal will be rejected by the university authorities. This is particularly relevant in the case of professions such as medical physics which notwithstanding their importance to society have little political clout. The cost of the programme was reduced to a minimal level in several ways. If we consider the undergraduate programme, the physics/ math/ statistics/ programming strand, the anatomy/ physiology/ pathology strand and a sizeable chunk of the research/ ethics/ legislation/ professional strand come *at zero cost as our students simply join established classes*. *The good news is that these three strands constitute a major chunk of the Bachelor programme*. The only costs are essentially the medical physics and radiation protection study units, the hospital practicals and the research projects.

During the clinical practicals, students join whatever is happening in the various departments at the time and shadow the clinical physicists. We do not insist that specific practicals are set up for the students as this would create too high a burden on our clinical colleagues and increase the cost of the programme. At the undergraduate level it is sufficient that students get a feel of the real hospital world by shadowing Medical Physicists in action. After all, in most countries in the world, Medical Physicists have their officially recognized training programme following the Masters. During these clinical practicals, the students can experience not only the many medical devices but also the various types of radiation detectors and radiation monitors hence obviating the need for us to set up and maintain our own radiation laboratory. The costs of setting up a specialized radiation laboratory and its maintenance and technician costs would be sufficiently high as to destabilize the initial and running cost budgets of the programme. Updating the equipment on an ongoing manner would also be a significant cost.

The medical physics / radiation protection research projects (undergraduate and Masters projects) are specific to us and do carry a cost. However, we have an agreement with clinical hospital directors such that our students do clinical service development-oriented projects. This is a symbiotic relationship - our students help develop the service with their projects and in turn we can use hospital equipment without cost. This arrangement has the advantage that our students work with modern equipment which is in actual service. When funds are low it is best to invest the available funding on improving the program for the students such as by inviting international experts to give lectures on state-of-the-art topics where the expertise is not locally available. Practicing Medical Physicists can be invited to these presentations hence providing CPD opportunities to the profession.

B. Summer school in human biology

During market research discussions with potential students from pre-university colleges, it was becoming clear that although such students found the Bachelors programme appealing there was an issue of major concern. This was related to the fact that pre-university physics/mathematics students do not have a background in biology a would find it difficult were they to join students from other healthcare professions during anatomy, physiology and pathology since students of these professions often had a background in pre-university biology. We solved this problem by having a pre-course summer school in human biology (I have my first daughter to thank for this idea!). Applicants for the programme are offered a free online set of lectures in human biology over the two summer months preceding the start of the course programme. Since many students work during the summer it was found impossible to find a common time for synchronous online sessions. Therefore, lectures were recorded and could be followed by the students asynchronously on any day and at any time of their choosing. Students were encouraged to submit any difficulties via email during both the summer school and during the first year of the programme. We are pleased to report that the summer school has been a success and students have not had any major difficulties in their medical sciences classes. However, students who opt not to attend the summer school find that they would need to work much harder during the first few months of the programme to make up.

C. Interfaculty problems for students

Our course programme is an inter-faculty programme in which our students have the opportunity to use the resources of both the Faculty of Science and the Faculty of Health Sciences. This has of course major advantages, but it also sometimes creates problems for the students as they have to deal with two groups of academic staff members with two entirely different ethoses. Physicists who have spent their lives in the physics milieu tend to be more theoretical and scholarly in their approach whilst academic and clinical Medical Physicists get their inspiration more from the real world of hospital practice. We have ongoing discussions with the students about this and we explain to them that one important role of the medical physicist is to help bridge this dichotomy between the theoretical world of physics and real-world practical milieu of healthcare. Another difficulty for the students is that they have to deal with two sets of administrators. We have solved this problem by having an inter-faculty board of studies with members of staff (both academic and administrative) from both faculties and with strong student representation.

D. Marketing the programmes

The major selling point of the undergraduate programme is that since it includes physics, medical physics and radiation protection, that is, both pure and applied physics – this means that the range of employment opportunities for graduands is very wide. Table 4 lists some opportunities. We have found that physics and mathematics pre-university students have an appetite for knowing about the human body and health issues - areas of knowledge which those taking the physical sciences lack – and this is highly motivating for them. Many physics students find the applications of physics in medicine interesting and challenging. *It is important to emphasize the summer school in your marketing campaign as this allays their concern regarding human biology*. The single year Masters has a lot of applicants and the issue with low numbers has been resolved. The students of the Bachelors programme having just completed a four-year programme view the single year Masters as an easily doable option and as a natural extension to their undergraduate studies.

D. Students coming to the Masters from physics.

Students who enter the programme from physics and not through our Bachelor programme do not have a background in medical physics and radiation protection. These students are again offered attendance to the summer school in human biology. They are also encouraged to voluntarily attend undergraduate units concerning medical sciences, ethics, healthcare research methods, legislation and professional issues. Such students have the option of choosing either clinically oriented research projects or more technically oriented projects should they wish to do so.

V. CONCLUSIONS

A visionary yet pragmatic approach to medical physics and radiation protection education has been presented and discussed. The curricular programme addresses all the requirements for a modern and forward-looking programme yet at a minimal cost. In Malta, we are at the moment in the fourth year of the undergraduate programme, and we will have our first graduands from the Bachelor programme. We will also have a first intake for our redesigned Masters curriculum. The undergraduate programme has been a resounding success and we have many students. Most of these have already shown a wish to continue on to the Masters programme. The existence of the programme has been critical in boosting the number of students not only for medical physics and radiation protection but also for physics itself. It has been a win-win situation.

Table 4 Employment and further study opportunities for graduands of the programme

Area	Opportunities
Physics	Further studies and research institutions in all areas of Physics All employment areas which require a Physics degree Physics teacher: secondary, pre-university, university Industry Radiation laboratories Software development and data science industry National statistics office
Medical Physics	Further studies and research in all areas of Medical Physics Clinical Medical Physicist in public/private hospitals Dental clinics Medical/biomedical research institutions Public/private hospitals Radiopharmaceutical production (e.g., cyclotron facilities) Medical device vending: company representative, marketing, consultancy, application specialist, system installation, critical examinations. Health authorities: consultant re medical devices and software, health technology assessment, international, regional and national legislation and guidelines Medical device manufacture Radionuclide / radiopharmaceutical production Medical device regulatory authorities
Radiation Protection	Further studies and research in all areas of radiation protection Industrial uses of radiation (e.g., airports, shipbuilding, industrial radiography, food industry, customs) Environmental (e.g., national radiological preparedness and emergencies, radiation monitoring of the environment, environmental contamination Officer with the national radiation regulatory authority As an expert consultant on policy and review of local implementation of legislation, drafting of national guideline and documentation. Radiation Protection Expert Nuclear energy industry
Others	Researcher: local/overseas industries/universities, International, regional and national projects, research and development in industry As an auditor / inspector to ensure hospitals, industries, research laboratories conform to legislation. Member of examination board to assess and certify radiation professionals. Employment with European/International institutions: IAEA, IEC etc

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