SCIENCE EDUCATION: THE NEED FOR AN INTERDISCIPLINARY APPROACH

Loredana MARCU*

*University of Adelaide, School of Chemistry and Physics, Australia
loredana@marcu-net.com

Summary: With today's evolving science and technology, there is a desperate need for retailoring science education. Whether biology or physics, chemistry or computing, mathematics or engineering, one should seek for interaction between disciplines not only at research level but also at teaching levels. The term 'interdisciplinary' is increasingly gaining meaning for the new generation of researchers and educators as the novel approaches to all areas of science are based on multidisciplinary methods. Fields such as medical physics, biochemistry, computational biology, bioengineering, physical chemistry, just to mention some, are a valid proof of the need for interaction between sciences. Often students are confused regarding their future, as they are not aware of the applicative side of their chosen discipline. Furthermore, both undergraduate and postgraduate students encounter frequent gaps in their knowledge because of the lack of coordination and interaction between disciplines. These hiccups in the educational system could be overcome through a better organization of curriculum. An example of interdisciplinary approach in science education is medical physics. A medical physicist must have a multidisciplinary vision of physics, otherwise the goals of this developing area are not met. The aim of the present talk is to illustrate the branching science of medical physics, the need for its correlation with molecular biology, chemistry, computing, mathematics and technology, and to underline its ultimate goal: to be of service, as an adjuvant field, to the novel areas of medicine.

INTRODUCTION

Interdisciplinary education has a crucial role in science teaching, because it supplies new resources for the progress of science and technology. Fields such as medical physics, biochemistry, computational biology, bioengineering, physical chemistry, just to mention some, are a valid proof of the need for interaction between sciences. The purpose of the interdisciplinary approach is to dissolve the boundaries of various areas of study and encourage learning across the curriculum. The key factors of an interdisciplinary education are the application, association, integration and transfer of knowledge. Learning skills in isolation is not a viable approach in modern education. Through interdisciplinary teaching the students can experience the applicative part of what they are learning and also see the value of it. Together with constructive and critical thinking, effective learning is encouraged as well.

Both undergraduate and postgraduate students encounter frequent gaps in their knowledge because of the lack of coordination and interaction between disciplines. These hiccups in the educational system could be overcome through a better organization of curriculum. An interdisciplinary course syllabus should be defined and structured in conformity with the needs of the specific industry/ medical/ environmental/ academic or research field. In view of the fact that, for example, a medical physicist in his/her future career will need anatomy, cell biology and nuclear physics knowledge, the academic curriculum for medical physics must include these subjects. However, it is essential to have the subjects thought through and taught with medical physics in mind, without deviating from the set goal, which would be easy considering the very broad fields of science mentioned above. The applicative side of the subjects, in this case to medical physics, and their relevance to the field should be a key factor in developing and implementing any curriculum.

THE INTERDISCIPLINARY EDUCATION OF MEDICAL PHYSICS

An example of interdisciplinary approach in science education is medical physics. A medical physicist must have a multidisciplinary vision of physics, otherwise the goals of this developing area are not met. Medical physics is a branching science with its many roots originating from atomic and nuclear physics, cell and molecular biology, anatomy, chemistry, computing, mathematics, engineering technology, just to mention the major disciplines involved in the development of this field.

Worldwide, the universities are running courses on medical physics both at undergraduate and postgraduate levels. The academic centres have implemented this area of learning and research with interdisciplinarity in mind. There is a whole team of physicists, cell biologists, chemists, geneticians, radiation safety officers and medical doctors involved in the teaching process, illustrating the imperative need for the interdisciplinary approach (see figure 1). Clinics, hospitals, as well as industry expect to hire 'educated' medical physicists, with a comprehensive background knowledge meant to cover all the major aspects of radiobiology, health physics, radiotherapy, protection against radiation. This thoroughness can only be achieved through careful planning of the curriculum and well trained educators with broad visions and knowledge.

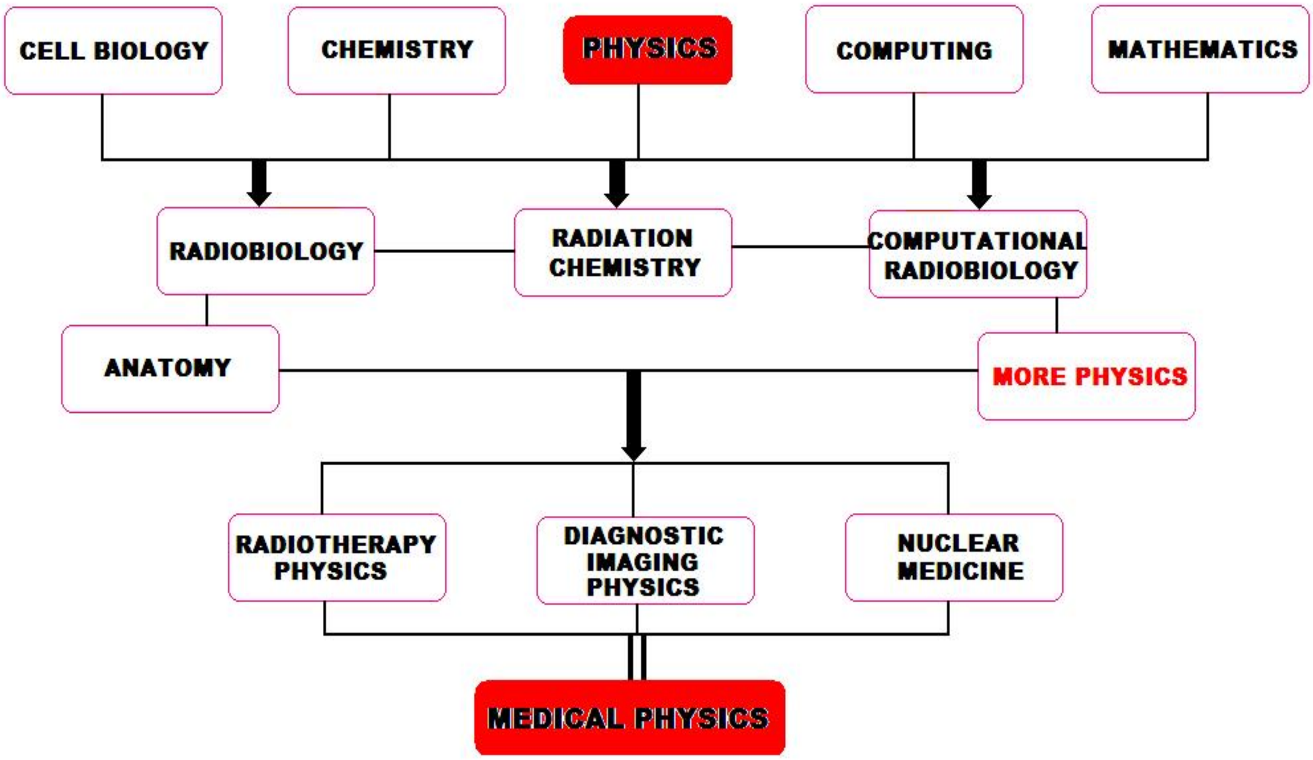

Figure 1. Graph illustrating the interdisciplinary relationship between sciences in the area of medical physics.

The question arises as to what the actual role of a medical physicist is and why is there need for such a vast interdisciplinary approach to teach this field. The short answer is that the ultimate goal of medical physics is to be of service, as an adjuvant field, to the novel areas of medicine. A clinical medical physicist can be part of either of the following fields: radiotherapy, nuclear medicine, diagnostic radiology, radiation protection (see figure 2). In more detail, the role of the medical physicist in clinics is to facilitate the production of quality diagnostic images consistent with the available technology, to optimize safety (including radiation, mechanical, and electrical) for the patient, to develop and maintain a quality assurance program for all imaging and treatment equipment, to determine doses from radiological and radiotherapeutic procedures, to develop and implement a radiation safety programme, to supervise the preparation, handling, and disposal of radionuclides, to determine the shielding requirement for radiotherapy and diagnostic equipment, to participate in treatment planning and delivery of specialized treatment techniques, to instruct radiation oncologists, dosimetrists, nurses, and radiation therapists on radiation physics and safety, to have input in the design of clinical trials, to advise doctors and medical officers upon dose limits, and many more. Beside the clinical settings, medical physics plays an important role in industry (research, product development, nuclear power plants, mining), and also environment (radiation waste management, health physics).

Interdisciplinary approach has always been part of physics. With the field of medical physics this interdisciplinarity became wider, because of its 'medical' component. Today, it remains up to the educators whether they choose to teach the various components in a multidisciplinary or interdisciplinary approach. Surveys among students have shown higher efficiency when it comes to interdisciplinary lectures which is mainly due to better understanding of the correlation and integration of subjects, in other words, a better visualisation of "the big picture".

Interdisciplinarity can be interpreted also as a link between education and research. Especially for the medical-related areas, like medical physics, it is crucial to incorporate in the course plan practical applications of the lectures. University hospitals worldwide assure a basic training for the students to introduce them into the medical environment and to allow their theoretical knowledge to get more profound.

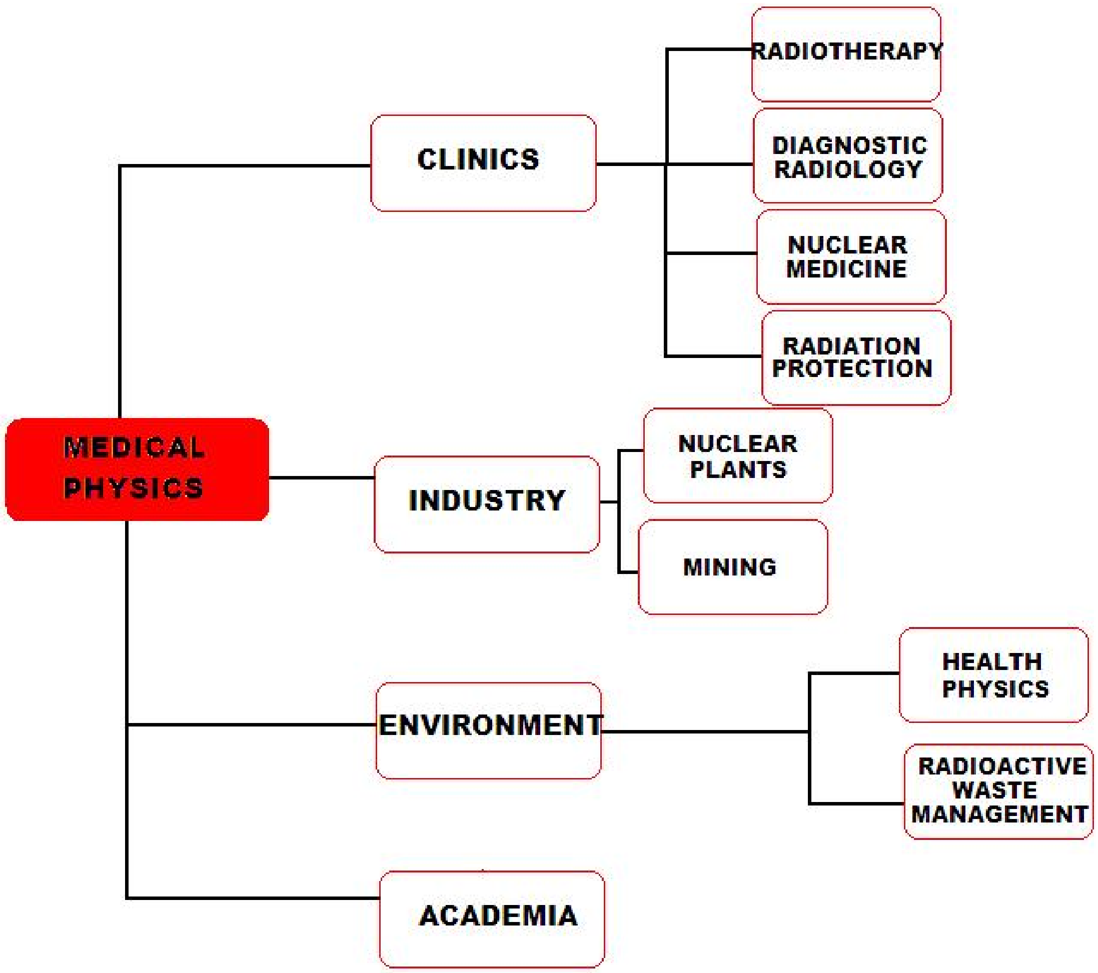

Figure 2. The integrated role of medical physics

Implementing the key courses required for medical physics training into the teaching curriculum

In order to carefully plan an interdisciplinary curriculum, the educator has to consider several factors: the ultimate aim of the course, the connection between disciplines and to what extent the student would benefit from interdisciplinary teaching, communication between teachers and the flexibility they can show when teaching applied areas of their field of knowledge. Small projects during school term and also final examination can be a valuable tool in self-assessment for the student and, for the teacher, a critical view of the way the goals of the course were met.

Going back to the medical physics example of interdisciplinary learning, the above factors would apply as follows:

Factors to be considered when planning an interdisciplinary curriculum	Relevance to medical physics
The ultimate aim of the course	To educate students to become medical physicists of service to various areas of medicine, technology, industry and environment.
The connection between disciplines	It is known that radiation oncologists treat cancer patients using radiation. We should ask why is radiation useful in treating cancer cells? To answer this question, the future medical physicist should have knowledge on cancer cell biology (from the cell biology course) as to know how cells respond to the effect of radiation, also about different types of radiation, since they affect the cell differently (radiation physics), and eventually, to put the information together (radiobiology).
The switch from multidisciplinary teaching to interdisciplinary education	Instead of running two separate lectures on chemistry and atomic/nuclear physics, respectively, incorporate the two fields into 'radiation chemistry' - saves time and shows the student the value of the course.
To what extent the student would benefit from interdisciplinary teaching	As long as the main inter-related courses are focused on the basic knowledge that the student needs to understand the relations between disciplines and also the applicative side of them, the benefits can reach higher scale.
Communication between teachers and the flexibility they should show when teaching applied areas of their field of knowledge	The cell biology course aimed for medical physics should compulsorily contain a detailed chapter on *cancer* cell biology, otherwise it does not serve its purpose. Also, genetics and epidemiology courses designed for medical physicists should be structured with the 'radiation' parameter in mind (radiation genetics, radiation epidemiology)
Examples of project / examination topics illustrating to need for interdisciplinary teaching	1. Describe the radiobiological parameters of a tumour that initiated the idea of "individualised treatment". 2. Explain why a low dose of radiation may produce a cancerous transformation while a higher dose is likely to kill a cell. 3. Describe two methods used in dosimetric measurements and discuss their clinical applicability showing also their advantages and disadvantages.

Similarly to several examples in science when synergistic rather than additive effect is achieved when combining various biochemical agents, physical quantities or parameters, in education as well, the additive effect of multidisciplinary teaching on student learning can be transformed into a synergistic effect trough interdisciplinary approach.

CONCLUSIONS

With today's evolving science and technology, there is a desperate need for retailoring science education. Teachers and researchers altogether should seek for interaction between disciplines and encourage teaching of new areas of research for broadening the vision upon present and future science. Noticeably, the term 'interdisciplinary' is increasingly gaining meaning to the new generation of researchers and educators as the novel approach to all areas of science. However, one has to find the way to transform the multidisciplinary teaching into interdisciplinary approach.

The aim of the present paper was to illustrate, particularly, the branching science of medical physics, the need for its correlation with molecular biology, chemistry, computing, mathematics and technology, and to underline its ultimate goal: to be of service, as an adjuvant field, to the novel areas of medicine.

The status of clinical medical physicists and the medical physics service varies largely throughout Europe. This depends on several factors but normally is related to the existence and standard of education and training in medical physics and to the standard of service provided. Countries at an early stage of development of medical physics (like Romania) that are currently developing medical radiation physics service, need a careful structuring of the medical physics programme with strong involvement from related disciplines. Only through interdisciplinary education of science one can achieve high standards and broader visions upon the emerging research areas.

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