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PhD Thesis

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A STRATEGIC DEVELOPMENT MODEL FOR THE EDUCATOR ROLE OF THE BIOMEDICAL PHYSICS-ENGINEERING ACADEMIC IN FACULTIES OF HEALTH SCIENCE IN EUROPE

Prague 2006

DECLARATION OF ORIGINALITY

To the best of my knowledge and belief, this work contains no material which has been previously published or written by any other person, except where due reference has been made in the text.

Carmel J. Caruana

ABSTRACT

Title: A STRATEGIC DEVELOPMENT MODEL FOR THE EDUCATOR ROLE OF THE BIOMEDICAL PHYSICS-ENGINEERING ACADEMIC IN FACULTIES OF HEALTH SCIENCE IN EUROPE

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Although BioMedical Physics-Engineering (BMPE) academics provide educational services in the majority of Faculties of Health Science (also known as Faculties of Medicine) in Europe their precise role has never been appropriately defined or researched. In this study, role theory and open-systems organizational theory were used as frames of reference to inform a study of the role whilst strategic planning theory was utilized to produce a strategic role development model. Central to the study was a position audit which was conducted using the well-established SWOT methodology. Internal strengths and weaknesses of the role were identified through a Europe-wide qualitative survey of BMPE departments and of curricula delivered to healthcare professionals by BMPE academics. External environmental opportunities and threats were inventorized via a systematic analysis of the higher educational and healthcare professional literature. The thematic data from the SWOT audit was used as input to the construction of the role development model. The latter was in turn used to lay the foundations of a curriculum development model for the perusal of role practitioners. The main conclusions of the study were that although the role of BMPE educator has intrinsic strengths which can be exploited, and several instances of good practice exist, the role has been generally weakened by neglect from role holders who have not practiced proper role balance amongst their various academic roles - in particular the educator role has not been given its due importance as a result of an over-emphasis on the discipline research role. However, the opportunities for the role are tremendous and should role holders rise to the occasion a good future is assured. This thesis has indicated the way forward through the setting up of strategic role development and curriculum development models based on evidence and not mere opinion or speculation. We have also demonstrated that high quality, practice-oriented curriculum development is possible through concrete examples by producing elements-of-competence inventories for specific healthcare professionals namely Diagnostic Radiography, Medicine and Nursing.

Keywords: biomedical physics, biomedical engineering, biophysics, medical education, healthcare professions; academic role development.

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PUBLICATIONS AND PRESENTATIONS

The following publications and presentations are based on this thesis. Copies of the most relevant articles can be found as an appendix at the end of the dissertation.

Publications:

Caruana, C. J., & Plasek, J. (2006).
An inventory of biomedical imaging physics elements-of-competence for diagnostic radiography education in Europe.
Published in the journal *Radiography* (Elsevier), 12(3), 189-202.
doi:10.1016/j.radi.2005.07.005

Caruana, C. J., & Plasek, J. (2006).
A SWOT audit for the educator role of the biomedical physics academic within Faculties of Health Science in Europe.
Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2006. Modeling in Physics and Physics Education. Amsterdam, Netherlands. ISBN Not yet available.

Caruana, C. J., & Plasek, J. (2006).
An initial biomedical physics elements-of-competence inventory for First Cycle nursing educational programmes in Europe.
Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2006. Modeling in Physics and Physics Education. Amsterdam, Netherlands. ISBN Not yet available.

Caruana, C. J., & Plasek, J. (2005).
A biomedical physics elements-of-competence inventory for undergraduate medical education in Europe.
Proceedings of the 14th International Conference of Medical Physics, Nuremberg, 2005. Published in *Biomedizinische Technik* Vol 50 Supplementary vol.1 Part 1. ISSN 0939-4990

Caruana, C. J., & Plasek, J. (2005).
A systematic review of the biomedical physics component within undergraduate medical curricula in Europe.
Proceedings of the 14th International Conference of Medical Physics, Nuremberg, 2005. Published in *Biomedizinische Technik* Vol 50 Supplementary vol.1 Part 2. ISSN 0939-4990

Caruana, C. J. (2004).
Basic biomedical device physics elements-of-competences for nursing. Incorporated in the Tuning document *Summary of Outcomes - Nursing.* Accessible from the Tuning

Educational Structures in Europe website at:
http://tuning.unideusto.org/tuningeu/index.php?option=content&task=view&id=112&Itemid=139#competences

Caruana, C. J., & Plasek, J. (2004).
Generic learning objectives in the domain of medical device physics
Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2004. Teaching and learning physics in new contexts. Ostrava, Czech Republic. ISBN 80-7042-378-1.

Caruana, C. J., & Plasek, J. (2004).
An initial set of exploratory case studies regarding the role of the biomedical physics-engineering educator as practiced in health science faculties in Europe
Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2004. Teaching and learning physics in new contexts. Ostrava, Czech Republic. ISBN 80-7042-378-1.

Caruana, C. J. (2002).
The role of the medical physics educator in a faculty of health sciences.
Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2002 Physics in new fields and modern applications. Lund, Sweden.
No ISBN available. Downloadable online from:
http://www.girep.fysik.lu.se/abstracts/fullText/114.pdf

Presentations:

Caruana, C. J. (2006).
From broad subject-specific-competencies to tutor-expertise-specific elements-of-competence: a case study in biomedical imaging physics for diagnostic radiography.
Report of the conference of the Higher Education Network for Radiography in Europe (HENRE), Malta, February 2006. Downloadable from: www.henre.co.uk

Caruana, C. J. (2004).
A medical imaging physics elements-of-competence inventory for radiography education in Europe (work in progress)
Report of the conference of the Higher Education Network for Radiography in Europe (HENRE), Malta, October 2004. Downloadable from: www.henre.co.uk

Caruana, C. J. (2003).
The medical physics educator and the education of health professionals: the medical physics educator as medical device educator.
Proceedings of the European Congress of Medical Physics of the European Federation of Organizations of Medical Physics (EFOMP), Eindhoven, The Netherlands. Abstracted in *Physica Medica*, 19 (1), 71.

ACRONYMS USED IN THE THESIS

BMPE	Bio-Medical Physics Engineering Bio-Medical Physicist Engineer
EC	European Commission
EFOMP	European Federation of Organizations for Medical Physics
EHEA	European Higher Education Area
ESEM	European Society for Engineering and Medicine
EU	European Union
FHS	Faculty of Health Science (alternatively known as Faculty of Medicine)
GIREP	Groupe International de Recherche sur l’Enseignement de la Physique
HCP	Health Care Profession, Health Care Professional
HE	Higher Education
ICT	Information and Communication Technologies
PBL	Problem-Based Learning
PEST	Political Economic Social Technological - Scientific
SWOT	Strengths Weaknesses Opportunities Threats

DEFINITION OF TERMS USED IN THIS DISSERTATION

Biomedical Physics - Engineering department: a subunit of the FHS that groups BMPE academics. Alternatively known as biophysics, medical physics, bioengineering, medical engineering, clinical physics, clinical engineering, radiological physics, imaging physics, medical technology and others.

Biomedical Physics - Engineering educator: a university academic with physics or engineering background teaching in a FHS.

Competence: a dynamic combination of knowledge, understanding, skills, attitudes, values and abilities which educational programmes should enable learners to achieve. Competences are in turn subdivided into elements-of-competence (Blackmore, 1999).

Element-of-competence: see 'competence'.

Entity: in this dissertation the word 'entity' is a general term representing organization, university, department or role.

Entry-level programme: the basic qualification required for entry into a HCP. This is now generally accepted to be a First or Second Cycle degree for most HCP in the majority of EU countries.

Faculty of Health Science (alternatively known as Faculty of Medicine): a university faculty entrusted with the education of one or more HCP.

First Cycle level: the term used within the European Higher Education Area for the Bachelor level degree.

Healthcare client: patient or other person using services provided by a healthcare organization.

Healthcare organization: any organization providing some form of healthcare services. This includes hospitals, health centers, spas and others.

Higher Education organization: an educational organization (university or equivalent institution) providing education at First Cycle level and possibly at higher cycles.

Higher education client: student or other person using services provided by a higher education organization.

Medical device: "any instrument, apparatus, appliance, material or other article, whether used alone or in combination, including the software necessary for its proper application intended by the manufacturer to be used for human beings for the purpose of:
- diagnosis, prevention, monitoring, treatment or alleviation of disease,

- diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap,
- investigation, replacement or modification of the anatomy or of a physiological process,
- control of conception,

and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means (EC, 1993).

"In vitro diagnostic medical device" means any medical device which is a reagent, reagent product, calibrator, control material, kit, instrument, apparatus, equipment or system, whether used alone or in combination, intended by the manufacturer to be used in vitro for the examination of specimens, including blood and tissue donations, derived from the human body, solely or principally for the purpose of providing information:
- concerning a physiological or pathological state, or
- concerning a congenital abnormality, or
- to determine the safety and compatibility with potential recipients, or
- to monitor therapeutic measures:

Provided that - Specimen receptacles are considered to be in vitro diagnostic medical devices; and "Specimen receptacles" are those devices, whether vacuum type or not, specifically intended by their manufacturers for the primary containment and preservation of specimens derived from the human body for the purpose of in vitro diagnostic examination. Products for general laboratory use are not in vitro diagnostic medical devices unless such products, in view of their characteristics, are specifically intended by their manufacturer to be used for in vitro diagnostic examination" (EC, 1998a).

Position audit and SWOT audit: A position audit is a systematic assessment of the current situation of an entity. This normally involves conducting a SWOT audit, that is a report of the internal Strengths and Weaknesses of the entity and the external environmental Opportunities or Threats that it faces. The position audit is a vital tool in designing future strategies. Opportunities and threats are those factors in the external environment within which an entity functions which would impact the entity respectively positively or negatively. Strengths and weaknesses are those factors in the internal environment of an entity which would improve or reduce the ability of the entity to make the most of external opportunities or which if not addressed would lead to negative effects on the entity (Soanes & Stevenson, 2003).

Role: The behaviours expected of individuals who occupy a specific post within an organization (Calhoun, 2002).

Role development and role development model: role development is an umbrella term for the making, elaboration, redefinition, modification and expansion of a role. A strategic role development model is a strategic plan for the development of a role.

Second Cycle level: the term used within the European Higher Education Area for the Masters level degree.

Strategic plan: A plan for the development of an entity in relation to its market, competitors, resources and so on (Moles and Terry, 1997).

SWOT audit (also known as SWOT analysis)**:** see ‘position audit’.

TABLE OF CONTENTS

1 INTRODUCTION TO THE STUDY

1.1 OVERVIEW OF THE CHAPTER

This chapter presents the problem addressed in the study which is reported in this dissertation. This is followed by a background to the issues underlying the problem as well as the specific purpose, scope and significance of the study. Guiding theoretical frameworks are then briefly explained and the databases and keywords used for the literature review listed. An outline of the research design is then presented and ethical considerations discussed. The chapter ends with an overview of the rest of the dissertation.

1.2 STATEMENT OF THE PROBLEM

Although BMPE academics provide educational services in the majority of FHS in Europe, their precise role (also known as 'mission') with respect to the *entry-level* education of HCP has not been appropriately defined nor studied in a systematic manner. No role development model to guide role practitioners has been published.

1.3 BACKGROUND TO THE STUDY

A well-developed body of literature exists regarding the education of HCP. There are however, very few articles regarding the BMPE component. The few papers that exist are mostly limited to the medical *post-graduate* specialization*s* of radiology and oncology and frequently reveal a concern regarding the principles that should guide the selection of physics content within the respective curricula (Balter, 1992; Dennis, Rzeszotarski, & Hendee, 2003; Frey, Dixon, & Hendee, 2002; Saba & Poller, 1999). However, there is very little regarding the BMPE component of entry-level HCP curricula.

In practice, entry-level BMPE servicing in Europe varies tremendously and ranges from general non-applied physics to physical biochemistry, biomolecular and cellular science, physiological physics, the effects of physical agents on the human organism and the physics of medical devices. The curriculum setting scenario within Europe is also very variable. In quite a number of universities it still reads as follows. The physics or engineering faculty of the university is contacted by the board of studies of the particular HCP for physics servicing. The physics or engineering faculty then transfers this request to a member of its staff who has had some form of contact with the biomedical field. The latter is in turn presented with a remit by the course coordinator of the particular HCP. Often this remit is quite vague as the various HCP are themselves not completely clear on what is required of the BMPE educator except that their students need some ‘physics’. The BMPE educator then sets up learning objectives based on those areas of physics within his area of expertise which in his opinion are relevant to this remit. This approach however, has in the past often lead to learning objectives that are far removed from the everyday practicalities in the exercise of the HCP. To improve the situation, in some universities, biomedical physicists or engineers working in the BMPE department of a local hospital are asked to do the teaching. This approach has in general lead to an improvement in the general relevancy of content, however, problems have been known to arise owing to insufficient academic background or teaching ability on the part of the physicist or engineer. The consequence of these ‘ad-hoc’ arrangements has perhaps too often been unsatisfactory learning, leading to a low level of satisfaction on the part of the students (Pabst & Rothkotter, 1996). In order to improve the situation there has been a trend towards the setting up of BMPE departments *within the FHS itself*. A higher success rate in terms of student and staff satisfaction has been observed. In such cases the BMPE educator is part of the FHS milieu and therefore closer to the day-to-day problems of the clinical setting. However the BMPE educator has often been at the margin of things, as often he does not have a clear and easily identifiable role within the FHS.

Meanwhile, the European Higher Education Area process in Europe (often referred to as the ‘Bologna’ process) is encouraging institutions involved in HE to take a critical look at their curricula and ensure that the latter are more in agreement with the present and future learning needs of the professions. The Tuning Educational Structures in Europe initiative is promoting the active use of practice-driven curriculum development in which programme end-points are expressed in terms of the competences that students should acquire by the time they finish their studies. The BMPE educator cannot play a significant role in this process unless he has a clear view of his own role and is in possession of role and curriculum development models based on this role definition.

1.4 PURPOSE OF THE STUDY

The specific objectives of this study were the following:

a) To carry out a Europe-wide position audit for the BMPE educator role based on the SWOT methodology,
b) To inventorize curricular challenges impacting BMPE practice emerging within general HE and the HCP education environment,
c) To conceptualize a strategic role definition (alternatively known as 'mission statement') for the BMPE educator based on the results of the position audit,
d) To propose a strategic role development model for the perusal of role holders based on this role definition and the results of the position audit and curricular challenges inventory,
e) To propose a generic curriculum development model for the perusal of role holders based on this role definition and the results of the position audit and curricular challenges inventory,
f) To illustrate the use of the proposed curriculum development model in the setting-up of learning outcome BMPE elements-of-competence inventories for chosen specific HCP in Europe.

1.5 SCOPE OF THE STUDY

The scope of the study was delimited to the following:

a) The educator role of the BMPE academic (the other roles of the academic were addressed in the light of the educator role),
b) HE *degree* awarding institutions,
c) HE institutions from states which were EU members either before or which became EU members on the first of May 2004,

d) Entry-level qualification programmes.

1.6 SIGNIFICANCE OF THE STUDY

The significance of the study for the various stakeholders is as follows:

a) Significance for the BMPE educator: the study will provide role and curriculum development models for the guidance of role holders,
b) Significance for the FHS: BMPE educators who can make a more effective contribution to the organizational educational objectives of the faculty,
c) Significance for the HCP: BMPE educators who can make a more effective contribution to the professional educational objectives of the various HCP,
d) Significance for healthcare organizations: BMPE educators who can make a more effective contribution to the production of effective, safe and efficient HCP,
e) Significance for FHS students: BMPE educators who can make a more effective contribution to the professional educational needs of FHS students,
f) Significance for clients of healthcare organizations: BMPE educators who can make a more effective contribution to quality healthcare through the education of more effective, safe and efficient HCP.

1.7 THEORETICAL CONCEPTUAL FRAMEWORKS GUIDING THE STUDY

The theoretical conceptual frameworks guiding the study were the following:

a) Role theory and organizational theory: Role theory and organizational theory are used extensively to analyse the workings of organizations and roles within organizations. In this study the organization is the FHS, the role is the BMPE educator role.

b) Strategic planning theory: Strategic planning provides a framework for the construction of development models for entities. In this study the strategic planning approach was utilized to generate the role development model for the educator role of the BMPE academic as a member of the FHS.

1.8 RESEARCH DESIGN

a) Research paradigm: The underpinning research paradigm of this study is practitioner research, which is research carried by practitioners with the aim of improving their own practice and the general practice of their profession. In the case of this particular study, the author is a member of the profession 'BMPE academic in a FHS'. This is a profession which straddles *three* professions: physicist-engineer, HCP and educator. The idea for the project arose from recognition by the author, who is himself a practicing BMPE academic, that the absence of a clear role definition and development model for the educator role of the BMPE academic was seriously hampering the development of his own practice and that of the profession.

The need for the study was initially presented to the BMPE educator practitioner community in the following conference paper and presentation abstract:

Caruana, C. J. (2002). The role of the medical physics educator in a faculty of health sciences. *Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2002, Physics in new fields and modern applications.* Lund, Sweden No ISBN available. Retrievable also online from: http://www.girep.fysik.lu.se/abstracts/fullText/114.pdf

Caruana, C. J. (2003). The medical physics educator and the education of health professionals: the medical physics educator as medical device educator. *Proceedings of the European Congress of Medical Physics of the European Federation of Organizations of Medical Physics (EFOMP),* Eindhoven, The Netherlands. Abstracted in *Physica Medica*,19 (1), 71.

A copy of both article and presentation abstract can be found at the end of the dissertation.

b) Research approach: The research approach was primarily qualitative. Qualitative methods are essential in research which is exploratory in nature and for subjects about which little is known. Such is the case regarding the role of the BMPE educator in the FHS. Furthermore, in the construction of developmental models it is crucial to uncover the full range of relevant themes and to probe these deeply enough for a comprehensive understanding. Qualitative methods are again essential in such studies.

c) Philosophical perspective: The philosophical perspective of this project as a whole was pragmatic.

d) Methodology: Fundamental to the construction of an effective development model is an accurate position audit of the entity for which the development model is targeted. In this project the position audit was carried out using the SWOT audit methodology. Internal strengths and weaknesses of the role as presently exercised in Europe were inventorized via a Europe-wide qualitative multi-case study survey of BMPE departments and the BMPE component of present European HCP curricula. Present and envisaged future external environmental opportunities for the role, threats to the role and curricular challenges for the role were inventorized via a document analysis involving a comprehensive review of the HE, biomedical and HCP education literature. Semi-structured interviews and correspondence conducted with a select group of BMPE practitioners provided an element of the social-constructivist and advocative-participatory perspectives which are important in role development research.

1.9 LITERATURE DATABASES AND PRINCIPAL KEYWORDS

The research literature databases and principal keywords used in this study were the following:

a) Healthcare databases: Medline, Cinahl (keywords: physics, engineering, role, SWOT, strategic planning, curriculum),

b) Educational databases: Eric and International Eric (keywords: role, SWOT, medicine, nursing, allied health, higher education, curriculum development, strategic planning),
c) Social Science databases: Sociological Abstracts (formerly known as Sociofile), Sociology of Education Abstracts, PsycINFO (keywords: role development),
d) Management databases: Emerald (keywords: strategic planning, SWOT, higher education).

1.10 ETHICAL CONSIDERATIONS

Documents used in this study are public documents available from university websites and bookshops. All persons interviewed were informed of the purposes of the research before the interview. Owing to the sensitivity of some of the issues, the interviews were not taped to ensure the authenticity of the views expressed. It is the view of the researcher that analysis of the practice of others is above all the discernment of what is good and essentially an inventory of good practice. All data has been reported in a way that the sites or persons cannot be identified.

1.11 OVERVIEW OF THE REST OF THE DISSERTATION

The rest of the report is structured as follows. Chapter two provides a critical review of the literature regarding role, organizational and strategic planning theories, faculties of health science as organizational systems, models and components of the role of academic in HE, and the present state of the role of the BMPE educator as evidenced in the literature. Chapter three describes the research design whilst chapters four, five and six provide respectively the results of the internal strength-weaknesses audit, the external environmental opportunities-threats audit and the curricular challenges inventory. Chapter seven presents the role-development model, the curriculum development model and the application of the latter to the development of learning outcome BMPE elements-of-competence inventories for chosen HCP (diagnostic radiography, medicine and nursing). Chapter eight presents conclusions from the study, reflections on the study, limitations of the study and recommendations for future research. The text of the dissertation is partially based on the papers listed in the initial pages under the heading “Publications and presentations”. Parts of the dissertation are copied verbatim from the original papers, however, where necessary the original text was modified to improve readability.

2 LITERATURE REVIEW

2.1 OVERVIEW OF THE CHAPTER

This chapter provides a review of the literature regarding those areas of role, organizational and strategic planning theories relevant to the study of the FHS as an organizational system and the BPME educator as an academic member of the FHS. This is followed by a review of models of the role of the academic in HE. The present state of the role of the BMPE educator as evidenced in the literature is then analyzed.

2.2 ROLE AND ORGANIZATIONAL THEORY

The inter-relationship between organizational and role theories

Role theory and organizational theory are inter-related and together provide a framework for the study of professional roles within organizational systems. Role is defined as the set of behaviours expected of individuals who occupy a specific post within a given organizational system, together with the attendant responsibilities (and associated competences) and privileges (Calhoun, 2002). On the other hand organizations can be regarded as systems of interacting roles (Katz and Khan, 1978, p. 43). The study of roles within organizations follows two general approaches. The *top-down functionalist* perspective associates fixed roles with positions in the organization in which the behaviour expected of the role holder is prescribed by the goals of the larger organizational structure. *Bottom-up interactionist* approaches emphasize the ability of role holders to interpret, negotiate and develop their own roles in response to changes in the environment in which the organization operates (Calhoun, 2002). This thesis is based on the view that roles in an organizational system are to a significant degree determined by the organizational purposes of the larger system, however a degree of autonomy in role-making is essential for role holders if they are to solve the challenges arising from changing conditions. This is particularly relevant in the case of HE and healthcare as the rapid advances in knowledge and technology are leading to a proliferation of new roles and an ongoing need for the redefinition and development of existing roles (Briggs, 2005; Conway 1978a, p. 23).

Role theory concepts relevant to the study

The following are the main concepts that characterize a role which will be utilized in this dissertation. Concepts which are closely related, have been grouped together for convenience:

a) Focus role, role-set, role expectations, self-perceived role, role definition (or specification) and role negotiation: The focus role is the role under study, whilst the role-set is the set of other roles within an organization with which a focus role holder interacts to a significant extent. Each member of the role-set has prescriptions and proscriptions with respect to the role. These are known as role expectations. These role expectations are subject to an element of role negotiation as the different role-holders negotiate mutual expectations. The sum of the expectations of the role-set defines (specifies) the role. Each role is a member of its own role-set in the sense that each role-holder has a self-perceived role-definition regarding what should be the activities of the office and this has a major influence on roles (Katz & Kahn, 1978, pp.185-194).

b) Role ambiguity (also known as role uncertainty): A role is ambiguous when the set of expected behaviours emanating from the role-set are incomplete or insufficient to guide behaviour (Biddle, 1979, p. 323). Ambiguity is often a source of unhappiness for role holders. On the other hand total role-specification is undesirable, as it does not allow the role-holder flexibility in role-development (Katz & Kahn, 1978, p. 206). Ambiguity can be present regarding what should be done (expectation ambiguity), when it should be done (priority ambiguity), how it should be done (process ambiguity), and behaviours that should be exhibited (behaviour ambiguity) (Singh & Rhoads, 1991).

c) Role conflict: this is defined as incompatible demands on the role-holder by different members of the role-set including incompatibilities between the self-expectations of role-holders and those of other members of the role-set (Katz & Kahn, 1978, p. 204).

d) Role overload and underload: Role overload occurs when a role-holder is confronted with excessive expectations from the role-set. Role underload refers to the opposite situation in which the expectations from the role-set are too low, leading to possible trivialization of the role (Hardy, 1978).

e) Role stress and strain: role stress occurs when the expectations of the role are difficult or irritating to meet. Sources of role stress include role ambiguity, conflict, overload and underload. The state of distress experienced by the role holder is termed role strain. Role strain may impede effective role performance (Hardy, 1978).

f) Role complementarity, interdependence, differentiation, overlap, specialization, integration and fragmentation: two or more roles are complementary when specific organizational goals are achieved through their joint performance. Roles are interdependent when they facilitate or hinder one another. Roles are differentiated when the sets of expectations of the roles have few common elements. Conversely, roles overlap when the sets of expectations have common elements which are significant. When different persons perform differentiated roles the roles are said to be specialized. Roles within an organizational system are well integrated if they fit well together (Biddle, 1979, p. 393-394). An over differentiation and specialization of roles (even if well integrated) can lead to excessive role fragmentation in which existing satisfying roles are chopped up into smaller roles each of which would be unsatisfying to role holders (Bullough, 1978).

g) Role distancing: demonstration by a person of unwillingness to enact a role or a component of a role (Katz & Kahn, 1978, p. 207).

h) Role location: the location of a role within the organizational structure. The location of a role has an impact on the possibilities available for role development (Katz & Kahn, 1978, p. 210).

i) Role balance: the ability of the role holder to manage his various subroles (e.g., in terms of time allotted to each role) in an optimal way (Briggs, 2005).

Organizational theory concepts relevant to the study

Organizations are today diagnosed and strategies constructed on the basis of the 'open-systems model' (Fig 2.1). This model can be used to guide the study of organizations, subunits and roles within organizations (Harrison, 2005, p. 27).

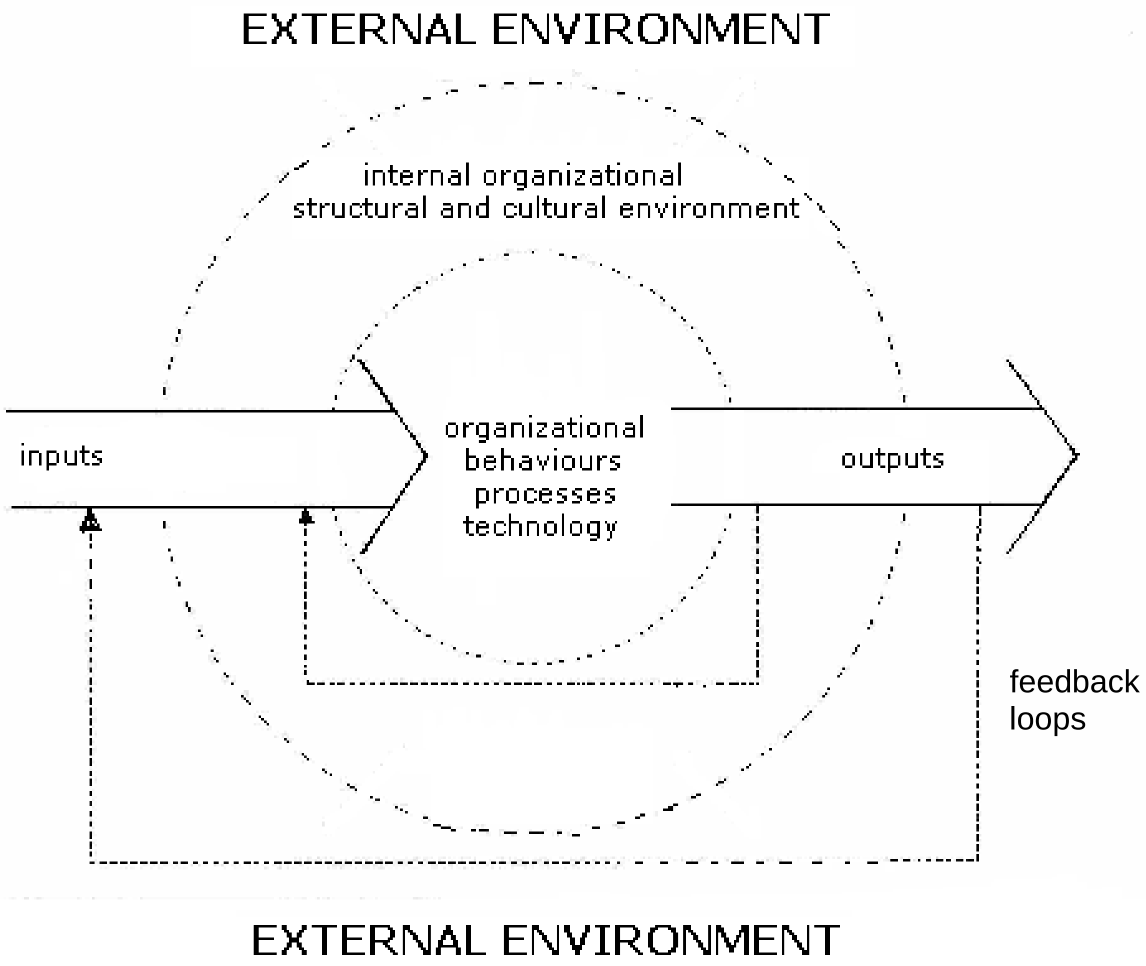

Fig 2.1 The open-systems model of organizations. The outermost dashed line indicates system boundary (Harrison, 2005, p. 28).

The term 'systems' emphasizes that changes in one part of an organization influences other parts. The 'open' highlights the fact that organizations, subunits and roles are impacted by the external environment in which they operate. External environment includes clients, markets for products or services, legal regulations, state of technology and knowledge, and cultures in which the organization operates. From an open-systems point-of-view changes in the external environment have to be continuously monitored by the entity, as its success depends on its ability to fit to its environment or shape that environment. Role development is also impacted by the internal organizational environment, that is the structure and culture of the organization. As role-development is carried out within organizational milieus it is essential for role-holders to study those characteristics of the external and organizational environment which directly or indirectly impact role-development. This ensures that they may be better able to understand how they fit into organizations, how their roles are affected by the organization, and how they can develop their roles within organizations (Conway, 1978b, p. 111).

The main components and characteristics of open-system organizations are the following (Katz & Kahn, 1978, pp. 23 – 33; Harrison, 2005, pp. 27-29):

a) Outputs: open system organizations export to the external environment products or services which are of importance to outside groups. Such outputs provide a rationale for the existence of the organization. Katz and Kahn (p. 19) define organizations as a "social device for efficiently accomplishing through group means some stated purpose". However it must be kept in mind that whether the organization thrives will depend on the continued desirability of the product or service by the external environment.

b) Importation of inputs from the environment: In order to thrive an organization must continuously renew its inputs. Inputs are of two types - production inputs and maintenance inputs. Production inputs are those that are transformed into outputs, whilst maintenance inputs are those that sustain the organization itself.

c) Organizational behaviour, processesing and technology: these cover all those activities that contribute directly or indirectly to the main task of an organization, that is the transformation of inputs to outputs.

d) Negative feedback loop inputs: research about organizational outputs furnish the organization with information inputs that would ensure production of the right quality and quantity of products or services desired by the external environment.

e) Organizational structure: large social organizations move towards the multiplication and elaboration of roles (role differentiation and specialization). This may lead to role fractionation, however it does not necessarily lead to a fractionation of the system, as in most organizations roles are interdependent. Moreover as differentiation increases, it is countered by the creation of coordinative roles that bring the differentiated roles together for streamlined functioning.

f) Organizational culture: further integration of differentiated roles occurs through shared expectations, norms, values, and understandings regarding the nature of the organization.

Organizational effectiveness and role development

Harrison (2005, p. 40) gives a table of effectiveness criteria for organizational entities that are deemed relevant to developmental models. The following criteria are considered to be the most relevant to this study:

a) Degree of alignment (or 'fit') with the external environment,

b) Quantity and quality of outputs with respect to the level agreed to by the various stakeholders,
c) Competitive position with respect to other claimants to inputs,
d) Efficiency (minimum cost per unit output consistent with the agreed standard of output quality),
e) Quality of work life for role holders within the organization, including level of consensus and collegiality within the organization and employee involvement,
f) System fit (alignment of subcomponents and features) including work-flow, coordination and cooperation between subunits.

The effectiveness of an organization is largely dependent on how the role system within the organization is aligned with the goal of satisfying the above criteria. From a *top-down functionalist* perspective management should adjust existing roles or create new roles to maximize organizational effectiveness. From a b*ottom-up interactionist* perspective role holders are to re-interpret, re-negotiate and develop their own roles to ensure that the role makes a significant contribution to organizational effectiveness.

FHS as open organizational systems

Universities and their faculties are open organizational systems that mainly cater for the educational, research and service needs of society. This dissertation focuses on the educational aspects. The main educational outputs of the FHS are effective, safe and efficient new HCP. The most important inputs for a FHS are new students, the human effort and motivation of the academic, administrative and technical staff and monetary sources gained by 'selling' its outputs (i.e., HCP students) to healthcare and related organizations (e.g., hospitals, pharmaceutical companies). Monetary inputs are being increasingly directly linked to the quantity and quality of student output. The FHS must study the domain within which it markets its output 'products'. Hence if an FHS recognizes that the healthcare system would require a greater number of employees of a certain profession it would align its strategic plan in such a direction. This would ensure adequate funding for the future. Examples of organizational behaviour and processes within a FHS include teaching, creation of a learning environment, supervision of student research, student assessment, curriculum development, provision of role models and others. Organizational technology in the case of the FHS refers to equipment (e.g., student practical skills laboratories and research laboratories), tools (e.g., presentation and communication tools) and techniques (e.g., pedagogical techniques), which are required to transform inputs (new students) to outputs (competent HCP).

Whether role changes within a FHS are brought about principally by functionalist or interactionist processes depends on the organizational climate within the faculty. In general academics have a higher degree of freedom in exercising their roles than other professions. Although top-down managerial approaches are making swift inroads in many countries, academic freedom is still a highly regarded value within universities. In such situations the onus is on the individual academic to align his role with the effectiveness goals of his faculty. Academic educators should be encouraged and given the necessary resources to develop their role in line with changes in university and faculty goals.

BMPE departments as subunits of the FHS – A short history

Historically medical schools were practice oriented apprenticeship systems within hospitals. Associated biomedical sciences like anatomy, physiology, physics, and chemistry were taught outside the hospital setting by practitioners who devoted part of their time to teaching. The university based medical school based on the tradition of 'academic scholarship' developed in German speaking Europe. The latter led to a more scientifically based study of medicine (Pallie & Carr, 1987). The realization of the physical and chemical foundations of physiology and the developments in pharmaceuticals and medical devices (notably x-ray imaging devices) in the latter half of the 19th century led to an emphasis on the importance of the learning of the basic sciences. Flexner (1910) in a report which determined the shape of US medical curricula for most of the 20th century recommended foundation courses in physics, chemistry and biology for medical programmes.

Originally most of the science taught to medical students was delivered by academics based in science i.e., non-medical faculties. However it was soon realized that:

> "Lacking experience or interest in medicine, these specialist-teachers often found it difficult to shape their teaching methods to the needs of medical rather than science students. In addition they found their chief professional rewards in basic science research and the teaching of non-medical graduate students" (Hayter, 1996).

This led to the setting up of departments of human biology, biochemistry and biophysics situated within FHS. However the problem still persists. Weaver et al (2004) investigated the reasons for the low attendance of members of such departments at medical education meetings in the US. The low attendances were the result of pressure on academic time as a consequence of the effort required in obtaining research funding - research which is a pre-requisite for achieving academic promotion.

2.3 STRATEGIC PLANNING THEORY

Introduction to strategic planning

Strategic planning (also known as strategy development) involves the formulation of specific plans which would take an entity from its present state to a desired enhanced future state. Strategic planning was originally developed for military reasons, however it has been used extensively in business and more recently by service and not-for-profit organizations. Its aim is to achieve a competitive position. Strategic planning is the first step in strategic management, which consists of strategy development followed by strategy implementation (and evaluation). *This thesis focuses on strategic planning for the BMPE educator role.*

Strategic planning concepts relevant to the study

The following are the main strategic planning theory concepts utilized in this dissertation. The definitions have been taken from Kotler and Murphy (1981), Raynor (1998), Lerner (1999) and Killen, Walker and Hunt (2005).

a) Planning paradigm: a conceptual framework which during the planning process allows the planner to perceive facts abstractly, interpret them, and relate them to each other in a coherent and unified way.

b) Marketing paradigm (also known as marketing philosophy): a planning paradigm which recommends that in order to be successful an entity should aim to produce a good fit between client needs and expectations and the product or service offered by the entity.

c) Substitutability: the extent by which the products and services of one entity can be substituted by others from a competing entity.

d) Core competences: role competences which serve to differentiate an entity from others in such a way as to provide advantage over other entities. Through continued use, these competencies would be made stronger and more difficult for competitors to imitate. Identifying the core competences of an entity is essential to defend against substitutability.

e) Mission statement: The mission statement is a definition of the role an organization gives itself within society or a role gives itself within an organization. It is a concise statement regarding its commitment towards its clients and regarding those core competences which will allow the entity to address successfully the needs of that specific client group:

> "… defining the mission is critically important because it affects everything else. A well worked out mission statement provides the institution with a shared sense of opportunity, direction, significance and achievement. The mission statement acts as an "invisible hand" that guides a college or university's diverse personnel to work independently and yet collectively towards the realization of the organization's goals... An effective mission-statement should be market-oriented, feasible, motivating and specific" (Kotler & Murphy, 1981).

f) Vision: the desired future state of an entity within the arena of activity defined in its mission. Well articulated vision statements enhance collegiality and inspire action and common purpose.

g) Gap analysis: an analysis of the differences between the present state of an entity and its future desired state as expressed in the vision statement.

h) Strategies: Strategies are general approaches by which gaps identified in the gap analysis are reduced and hence vision achieved.

i) Actions: specific tasks to advance a strategy.

j) Client analysis: client analysis aims to answers questions like: Who are the different types of clients? What are their expectations? Why do some of them present bigger opportunities?

k) Benchmarking: the technique of comparing practice between different entities in order to identify best practice, areas for improvement and look for new ideas. Through an ongoing systematic benchmarking process entities find a reference point for setting their own vision state and for improving practice. Benchmarking is increasingly being used in HE to set academic standards for educational programmes (Laugharne, 2002).

l) Values: principles of intrinsic worth for guiding strategy formulation and the achievement of vision.

m) Market forces: environmental conditions which indicate a future state of affairs which would be of high relevance to an entity.

n) Forecasting: assessment of expected future trends, essential for strategic planning which is intrinsically a future oriented activity.

o) Portfolio analysis: a process of analysis of the various products or services offered by an entity to enable strategic decisions regarding options of increased development, mere continuation, reduction or termination of products or services. A very important part of portfolio analysis is the identification of core competences.

Strategic planning theoretical frameworks

There are several theoretical frameworks for the formulation of strategies - however they are all basically underpinned by the open-systems and marketing planning paradigms and the SWOT methodology. Input-Output (IO) strategy development approaches emphasize the need for an entity to adapt its resources and competences to opportunities arising in the external environmental. Resource-Based-Planning (RBP) and Competence-Based-View (CBV) strategy development approaches emphasize the exploitation of the core competences of an entity either by moving to environments which include opportunities to match core competences or to use relations with external agencies to create opportunities to fit core competences. There is also an emphasis on the development of the core competences and the creation of new ones. The Total Quality Management (TQM) strategy development approach emphasizes continuous improvement of every aspect of organizational life in particular with respect to vision and client and employee involvement in the formulation of strategy. The Quality Function Deployment (QFD) strategy development approach emphasizes client expectations, client analysis and key strategic opportunities. There is an overlap of the various approaches. These theoretical frameworks were developed in the manufacturing industry and later modified to make them suitable for the services industry. In such contexts one refers to say Total Quality Service (TQS) instead of Total Quality Management (Sureshchandar, Rajendran & Anantharaman, 2001). Education and healthcare are both service providers and these adjustments must be taken into account when developing strategic plans.

Strategic planning in HE

Strategic planning in HE should take place at all levels of the organization: university, faculty, department, subject group, research group and individual. Planning is essential to ensure the future success of the various levels. Planning is also important as no organizational unit within a university can meet all possible expectations. A strategic plan provides a statement of what the unit intends to do more or less of, helps identify what makes it distinct from other units and creates a sense of common purpose. Plans should be positive and aim for ‘win-win’ situations particularly when difficult decisions regarding priorities need to be taken (Taylor & Miroiu, 2002). Various forms of the open-systems and marketing paradigms (complemented with various levels of state-supervision via appropriate HE authorities) are increasingly dominating strategic planning in HE as universities face pressures regarding financial accountability in the use of public funds, competition from alternative private educational and training institutions, need to attract fee-paying students and pressures on available resources.

In order to ensure success in strategic planning in HE it is important to recognize that strategic planning in HE needs to differ slightly from strategic planning in the world of business. The reasons are based on differences in values, guiding paradigms and an ambiguity regarding the true identity of the university’s clients:

a) Democratic values: Although modern strategic planning models emphasize on the importance of involving employees in the strategic planning process, planning and governance in the business world is basically founded on a top-down hierarchical authority structure which can impose change. Universities however value their consensus-based processes. Universities have been described as ‘loosely coupled systems’ in which departments and research groups continuously and simultaneously seek a balance between autonomy and interdependence, distinctiveness and commonality (Glassman, Rossy & Winfield (n.d.), cited by Lerner, 1999). It is therefore important to take the opinions of academics and survey present practices during the strategic management process to ensure that proposed strategies build on what already exists and what has been accepted as good practice in the past.

b) Dominant guiding paradigms: although the marketing paradigm is taking hold within HE, universities are fundamentally learning organizations with a focus on the personal and educational development of students and staff - the profit motive is not as dominant as in the business environment. Some services are still offered even though demand is low as they are considered part of a university's heritage or culture.

c) Customer definition: defining who the client is, is not so straightforward in the case of universities. In particular, in the case of professional courses (as in the FHS) students can be either considered as customers, products or something in between (student role ambiguity). Students can be considered as customers buying educational programme products from the ‘selling’ HE institution. Product evaluation in this case should ideally be carried out by the students who ‘buy’ that product. In universities that use the student-as-customer paradigm, universities compete for students, as state funding is dependent on the number of students who choose to study in the particular university. Students can also be considered as products with future employers and society at large as customers. The HE organization is then considered as a value-adding system and the products - the students - are evaluated indirectly by employers, professional associations and society at large through the presence of their representatives on programme validating and standards-of-proficiency setting bodies and in the case of some professions statutory regulatory control (Conway, Mackay and Yorke, 1994; Taylor and Miroiu, 2002).

2.4 THE ROLE OF THE ACADEMIC IN HIGHER EDUCATION

The role of the academic in HE is composed of several component roles which are interdependent. Hence, although this study is focused primarily on the educator role, this cannot be done in isolation from the other component roles. This element of interrelatedness is considered essential with respect to the HE educator role as perceived in this study and as implied in the current general HE educational literature. This section of the literature review surveys models of the academic role as found in the literature with particular emphasis on the educator role. It then describes briefly each of the component roles forming part of the academic role and their respective sub-roles and their relationship to the educator role. It is important to realize that each role requires a different set of competences and that a high level of competence in one particular role does not ensure competence in another.

Models of the role of academic in HE and FHS

There has been, unfortunately, little research on the role of the academic in HE. Harden and Crosby (2000) lament that even with respect to the well-established educator role (in this case in medical education) "we have been preoccupied with the details of curriculum planning, with the content of the teaching programme and with the range of education strategies adopted. We have failed to take a broader view of the role of the teacher in these tasks". In a study regarding changes in academic roles, Brew and Boud (1996), focused attention on the generation of new academic roles brought about by the extension of the responsibilities of universities in response to the move towards mass HE and the narrowing gap between universities and the society in which they operate. "There is a shift away from an emphasis on educating high flying students, towards the integration of professional and vocational education". The role of the academic is also changing as a response to the expanding use of ICT technology and in particular with the advent of on-line universities. Briggs (2005) in an exploratory study of the possible differences in academic roles in traditional and on-line universities proposed a generic model for the role of the HE academic that is applicable to both traditional and on-line universities. The model shown in Fig 2.2 consists of an inner circle of eight core roles each with associated component roles. Briggs considers that the eight core roles of researcher, consultant, knowledge expert, educator, designer / planner, manager / administrator, counselor and team-worker are in general performed by all academics however the relative importance given to the roles would vary amongst individual academics. Though different, the eight roles are interconnected. Harden and Crosby (2000) proposed a model for the teaching role of the academic within a FHS (Fig 2.3). In this model the educator role is considered to consist of 12 component roles: learning facilitator, mentor, student assessor, curriculum evaluator, curriculum planner, course organizer, study guide producer, resource material creator, clinical / practical educator, lecturer, teaching role-model and 'on-the-job' (i.e., clinical practitioner) role-model. The model was validated by means of a questionnaire by academics at the medical faculty of the University of Dundee (UK).

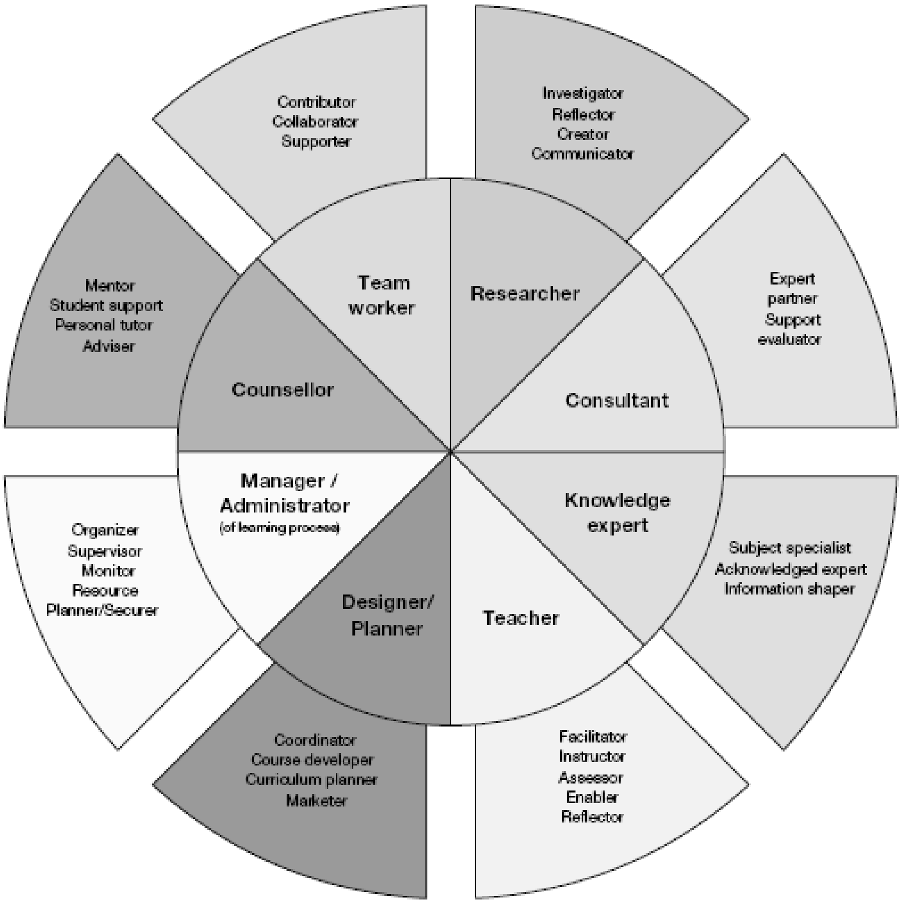

Fig 2.2: The Briggs model of the roles of the academic Briggs (2005).

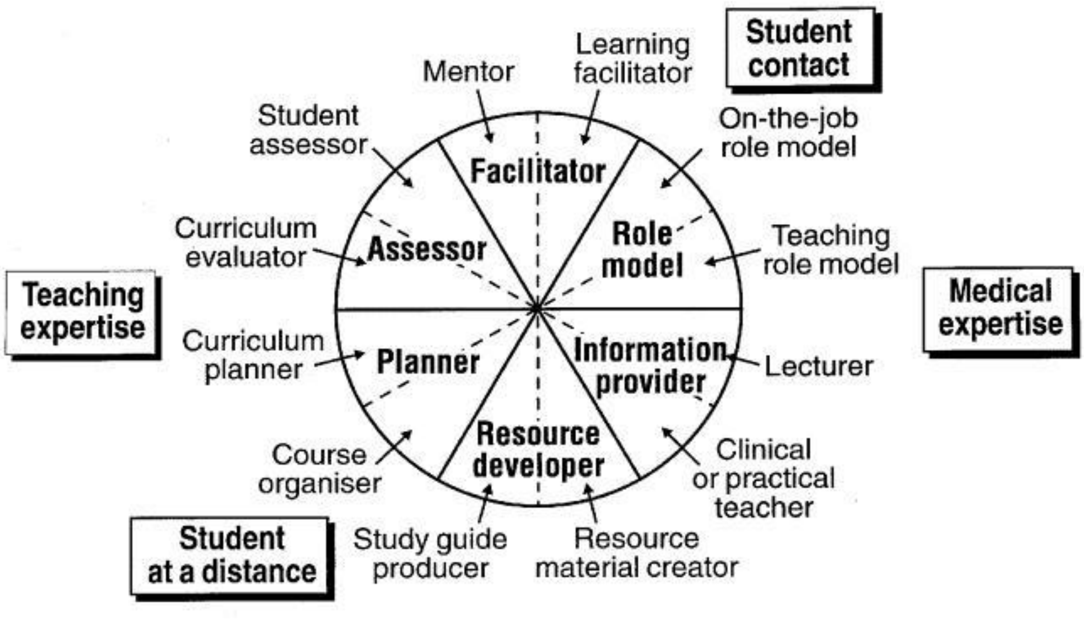

Fig 2.3: The Harden and Crosby model for the role of the medical educator (Harden & Crosby, 2000).

The Briggs model has the advantage that it allows for research into the interconnectedness of the eight core roles. It however suffers from some important omissions, in particular the absence of emphasis on the important roles of role-model (Harden & Crosby, 2000), that of change-agent (Doring, 2002) and that of guardian of professional standards of proficiency. The model of Harden and Crosby in focusing exclusively on the educator role misses out on the interrelationship between the educator and other roles and the importance of this interconnectedness. This element of interrelatedness is manifested in many ways in the daily exercise of the profession. Astin and Chang (1995) argue that the roles of educator and researcher are complementary. The active involvement of students in the research process would lead to both higher learning and higher research output (Barr & Tag, 1995). Moreover, it would be unwise for an academic to supervise research unless he is himself an active researcher. A good educator attracts research students to his research group. It is the view of the author of this thesis that the complete academic involves himself not only in research within the domain of knowledge in which he possesses expert knowledge but also in educational research in the teaching of that domain. In fact, the educator role itself offers opportunities for research and publication in the realm of HE educational research. The consulting role provides practical case studies which can be used for teaching. It also ensures that the academic maintains his expertise in the societal applications of his area of expertise and is also an opportunity for educating via role modeling. Mitchell and Rebne (1995) in a large sample quantitative study of university academics found that up to four hours of consulting and up to eight hours per week of teaching facilitate research productivity. It is important to realize that although the multiple roles forming part of the HE academic role overlap and coexist within a particular academic, it would be unrealistic to expect that all academics would be highly proficient in all the roles simultaneously. The role that an academic would focus on would vary with time according to present preferences, career development needs, faculty requirements and the necessity of role balance. However the presence of all roles within a faculty at a particular point in time is necessary for organizational effectiveness.

The academic as expert

a) The *discipline specialist*: This is the traditionally the fundamental role of each academic and to be acknowledged by peers as such is a source of much professional pride. As a result of the rapid expansion of all domains of knowledge academics are specialists in subdomains and indeed particularly in large faculties such as the FHS, role differentiation and specialization on the basis of subdomain have become the norm. The discipline specialist is the person to whom the faculty turns to when advice is required regarding issues which can be impacted by factors arising within the particular discipline.

b) The *discipline 'champion'*: every discipline within a faculty needs someone to promote that discipline within the faculty. As Scott (2000) so eloquently puts it:

> "In the absence of an expert, a subject becomes an orphan. Each subject needs a champion. It is very common for subject matter to disappear from the curriculum when a content expert leaves, or for "new" curriculum to appear when a content expert arrives".

c) The *information shaper*: owing to the information explosion and rapid expansion in information communication systems there is a growing societal need for information to be selected, evaluated, checked for accuracy and structured into meaningful and easily navigable forms. This is known as 'information shaping'. As knowledge expert, the academic has a duty in filtering the information within his area of expertise and ensuring that quality information reaches his peers, students and the general public. This role is particularly important in the case of healthcare as the well-being of patients and other healthcare clients is at stake.

The academic as educator

This section describes the sub-roles of the academic which relate to his duties in the professional formation of students. As the subject of this thesis is the educator role, this role of the academic will be discussed in more detail.

a) The *student learning facilitator*: The view of education as a simple transfer of knowledge from the educator to the student has long been rejected by constructivist cognitive psychology. Learning can only take place when the learner actively constructs his knowledge and the role of the educator is to set up learning opportunities, which would facilitate the learning process for the student. The facilitating process consists of the following steps: specification of learning outcomes, preparation of learning opportunities for these outcomes to be achieved (these opportunities may consist of teaching, tutorial, skill demonstration, practice in basic science and professional skills laboratories, practice within the clinical environment and others), enhancing student motivation by communicating the importance of achieving the learning outcomes, advancing learning towards these outcomes, giving feedback to students on how well these outcomes are being achieved with respect to the standard required (formative assessment), providing remedial assistance, and evaluating each step of the process. Such systematic facilitation would ensure the avoidance of ineffective and inefficient trial-and-error learning. This shift of perspective from the teaching of the academic to student learning may be seen as reducing the worth of the educator role, however this is not correct as evidence clearly shows that "in all phases of education, student achievement correlates with the quality of the teacher" (Harden & Crosby, 2000).

b) The *information provider*: In higher education the main methods of advancing learning towards learning outcomes have traditionally been and still are the educator presentation, small-group tutorial and skill demonstration (in the case of the FHS this could be in the basic science laboratory, clinical skills laboratory or the clinical areas). Harden and Crosby (2000) note that with respect to presentation:

> "Despite the availability of other sources of information, both print and electronic, including exciting interactive multimedia learning resource materials, the lecture remains as one of the most widely used instructional methods. It can be a cost-effective method of providing new information not found in standard texts, of relating the information to the local curriculum and context of medical practice, and of providing the lecturers' personal overview or structure of the field of knowledge for the student … A lecture in which the infectious enthusiasm of an

> expert, who is also a good communicator, excites or motivates the students has much to commend it".

Demonstration of skills is critical for student learning. Whilst basic science laboratory demonstration and practice have been a staple of science courses for many years, it is only recently that the importance of clinical skills laboratories within the university setting (as opposed to the hospital setting) has come to the fore in HCP education (Snyder, Fitzloff, Fiedler & Lambke, 2000). The setting up of skill laboratories within the FHS should however not detract from the importance of instruction and skill demonstration within the clinical setting as:

> "The clinical setting, whether in the hospital or in the community, is a powerful context for the transmission, by the clinical teacher, of information directly relevant to the practice of medicine … Good clinical teachers can share with the student their thoughts as a 'reflective practitioner', helping to illuminate, for the student, the process of clinical decision making" (Harden & Crosby, 2000).

With time the presentation, tutorial and skill demonstration have evolved to take into consideration new knowledge of the psychology of the learner as he constructs his own knowledge and the use of new content formats made possible by modern ICT technologies. However on the other hand an over-reliance on educator dominated information provision with mere passive reception by the learner is considered as a negative factor in modern education and should be avoided.

c) The *curriculum developer*: curriculum development is one of the key roles of the academic. Harden (1986) considers that curriculum development presents a "significant challenge" for the academic and that special expertise is required. He considers that the following issues need to be specified during a curriculum development process:

   a. The needs that the curriculum should meet
   b. The expected learning outcomes
   c. The content to be included
   d. The organization of the content
   e. The education strategies
   f. The teaching methods
   g. The assessment procedure
   h. Communication about the curriculum to staff and students
   i. The educational environment
   j. Procedures for managing the curriculum (including evaluation)

d) The *course developer*: once a curriculum has been developed it is essential that the process translates down to the level of the individual courses. As Harden (1986) so clearly states: "the best curriculum in the world will be ineffective if the courses which it comprises have little or no relationship to the curriculum which is in place". Course development involves planning of course outcomes, learning experiences, choice of texts and assessment modes. In this regard, the fact that educators in HE exert more control over content than educators at lower educational levels carries with it a higher level of responsibility.

e) The *developer of learning resources*: effective and efficient student learning is highly dependent on the availability of appropriately selected and adapted study-guides, resource packs, laboratory practical worksheets and other learning materials. The advent of multimedia authoring packages has increased the opportunity for the development of more exciting and stimulating learning objects. In particular the production of hard-copy and / or online study guides has become vital at a time when face-to-face student-academic contact time is decreasing as a result of the rapidly increasing student numbers and the pressures on academic time exerted by other non-teaching academic roles.

> "Study guides … can be seen as the student's personal tutor available 24 hours a day … Study guides tell the student what they should learn - the expected learning outcomes of the course, how they might acquire the competences necessary - the learning opportunities available, and whether they have learned it - the students assessing their own competence" (Laidlaw and Harden, 1990 as cited in Harden & Crosby, 2000).

f) The *student research supervisor*: The undergraduate research project is considered as an essential part of the undergraduate curriculum and therefore HE academics are expected to supervise projects which fall within their area of expertise. The modern approach to research supervision is to look upon the process as a research apprenticeship in which the student learns the craft of research. The ultimate objective is for the student to be able to evaluate his own work (Phillips and Pugh, 1994, p. 160). The role includes both educational and psychological components. The latter is particularly relevant at the undergraduate level (Cook, 1980).

g) The *mentor*: Mentoring refers to the situation in which an educator acts as a trusted guide to a student over a longer period of time. Mentoring "is about helping a person to learn within a supportive relationship" (Harden & Crosby, 2000) without leading to dependency (Ronan, 1997 cited by Harden & Crosby, 2000). Walker, Kelly & Hume (2002) cite the following definition of mentoring which perhaps best embodies the essence of mentoring:

> "Mentors are resource persons and counselors with whom protégés clear their thinking or sound out the validity of an important decision. A mentor is an individual whom the protégé can trust to have his or her best interest at heart, someone who would risk telling them what they need to know even though it might be painful to them. A mentor is someone whose perspective and judgment a protégé values and trusts implicitly" (Missirian, 1982).

The aim of mentoring is that of helping students become at ease with the practice environment and culture of the profession of which they will ultimately form part including advice on career development. It requires donation of precious time from the side of the academic and respect and appreciation from the side of the student (Walker, Kelly & Hume, 2002). Mentoring is particularly important in the case of the HCP as novices strive to become accustomed to a hectic and often stressful clinical environment.

The academic as researcher

a) The *discipline knowledge researcher*: this concerns the role of the academic in advancing the state of knowledge within his discipline. This role has been the dominant role of HE academics since the 19^{th} century.

b) The *practitioner researcher*: Practitioner research is research carried by practitioners with the aim of improving their own practice and the general practice of their profession. In the case of the HE academic this refers to research into how the practice of the various academic roles can be improved. Research into the practice of the educator role in HE has been given much importance over the last few years under the concept of "scholarship of teaching" introduced by Boyer (1990). The term basically refers to the "reflection on experience-based knowledge and research-based knowledge in teaching" (Kreber & Cranton, 2000).

The academic as team-worker

This refers to the need to collaborate with others in the organization and delivery of educational programmes and in research. In particular as healthcare and consequently HCP education are intrinsically multi-disciplinary the BMPE academic needs to work on an ongoing basis with other healthcare disciplines. The number of specializations in academic healthcare grows every year and curriculum delivery is increasingly being carried out by multi-professional teams. As knowledge and as a result educational programmes become increasingly multidisciplinary, the traditional mono-disciplinary approaches need to be modified and the academic must function increasingly as a team member with other subject specialists (Harden & Crosby, 2000).

The academic as manager

a) *Educational and research programme planner, organizer, administrator and monitor*: As educator the academic needs to have skills in managing programmes set up by his department. The history of HE is rife with instances of good ideas which fail owing to unsatisfactory management.

b) *Learning and research resource manager*: resource management is becoming increasingly important as universities and university departments have to make do with insufficient resources.

c) *Marketer*: As universities and departments come under increased pressure to look for alternative sources of funding, educational and research programme marketing is becoming more and more an essential role of the academic. It is also important to publicize the programmes offered by a department within the FHS and university as a whole, as it is useless having well-designed and delivered programmes if nobody knows about them!

The academic as consultant

Academics have as consultants often been at the forefront in the development of services within local, regional, national and European communities for the benefit of both the public and private sectors. In particular academics within FHS often supply consultancy services to academic health centers and other healthcare organizations.

The academic as agent of change

Through their commitment to quality standards, teaching, and research and through their position of prestige, academics have always considered themselves as agents of change in the society in which they operate (Doring, 2002). “The notion of an academic as a change agent emerges from the intellectual and personal transformation associated with teaching and research in the advancement of knowledge” (Ramsden, 1998, cited by Doring, 2002). Change is brought about either directly through involvement of the academic in community affairs or by producing personal transformation of students through dialogue and inter-personal interaction - thereby producing students who can be effective future agents of change within society. However Doring makes the argument that the pressures being exerted on academics for greater output in research and in teaching ever increasing student populations may lead to the de-prioritizing of this role amongst academics and to a reduction in quality time dedicated to authentic academic dialogue - in effect “denying the students the opportunity to be influenced”.

The academic as a guardian of professional standards of proficiency

Standards of proficiency are standards of competence that professionals are to achieve before they are allowed to practice within society. These standards are particularly important in the case of the HCP as effective and safe practitioners are a must to ensure the well-being of patients and other healthcare clients. The academic contributes to ensuring such standards by acting as guardian of educational programme quality and by rigorous summative assessment of students.

HE academics have traditionally given much importance to ensuring the quality of their programmes through a system of self-regulation by which the standard of the progammes offered are subjected to the scrutiny of both internal academics and forms of benchmarking exercises by academics from other universities (e.g., external examiner system). However as the move to quality in HE gathers momentum academics are increasingly under the scrutiny of external agencies (e.g., professional bodies, statutory bodies and accreditation agencies). The trend is for collaborative regulation where there is an ongoing interaction between external regulators and HE institutions.

> “The key challenge for higher education is to develop an external process which provides a level of accountability which satisfies political requirements but which does not inhibit institutions from developing their own mechanisms and approaches to self-regulation” (Jackson, 1997).

Summative assessment is being “perceived more and more as a matter of central significance in higher education” (Holroyd, 2000). Producing summative assessment instruments which are seen to be valid (i.e, test standards of proficiency in a rigorous manner), reliable (i.e., give consistent results) and fair requires not only a deep knowledge of subject content but also specialized knowledge, attitudes and skills. Holroyd argues that assessment involves several types of activity some of which are: the design and management of assessment systems, the creation of constructed-response test-items, objective test-items, skills assessment instruments, the marking and grading of student responses, the monitoring and modification of assessment performed by others, the decision-making procedures of boards of examiners, and the development of educator-managed and self-assessment instruments for students to be able to prepare themselves for summative assessments. There is a general move away from a single one-off end-of-programme assessment to ongoing forms which are spread over the whole programme (albeit with higher weighting to the later years) and to employ a variety of instruments (e.g., the use of portfolios).

The academic as lifelong learner

The pursuit of new knowledge via research and scholarship means that academics have always been lifelong learners. Academics need to learn continuously in order to keep up-to-date and effective within all their roles. This is particularly important in the FHS owing to the fast pace of developments in both medical knowledge and medical education.

The academic as role model

Role models are people with whom others identify, who possess qualities that they would like to have, or who have succeeded in posts that they aspire to, or who are seen as possessing standards of professional excellence. Role modeling, which is a form of observational learning, is an essential element of HCP education and is very effective in promoting learning, suitable behaviours, good professional values and correct attitudes in students. Lewis and Robinson (2003) cite Ficklen, Browne, Powell and Carter (1988) who suggested that role modeling should be considered as an integral part of medical education. The value of role modeling must be recognized and the achievements of academics and in the case of healthcare also clinician-academics should be recognized and highlighted so that they may serve as inspiration to others (Maudsley, 2001). Academics in the FHS should strive to be role models in all their roles. In their educator role academics should be models in terms of being good motivators and communicators, fair assessors and promoters of quality education. In their clinical consultancy roles academics should be exemplars of effective, safe and efficient practice, empathic patient care and teamwork. The latter role needs good role models as the management of patient care has often been lacking owing to dysfunctional HCP teams and excessive inter-professional and intra-professional rivalry. The British Medical Association (2005, p. 3) recognizing the importance of role models states:

> "The need for appropriate role models in all areas of medicine is imperative. Good role models will inspire, teach by example, and stimulate admiration and emulation. Medical schools have traditionally depended on good role models as part of an informal curriculum of medical professionalism and in this way, professional values, attitudes and behaviours have been passed on."

Wright & Carrese (2002) studied the attributes of respected physician role models. They conducted interviews with 29 highly regarded physician role models at two large US teaching hospitals and used content analysis to identify attributes within three major thematic categories: personal qualities, teaching skills and clinical skills. Themes within the category 'personal qualities' included interpersonal skills, a positive outlook, a commitment to excellence and growth, integrity and leadership. The category ‘teaching’ included establishing rapport with learners, developing specific teaching philosophies and methods, and being committed to the growth of learners. In the category ‘clinical skills’ higher order clinical skills were necessary. The authors also studied perceived barriers to effective role modeling. These included being impatient and overly opinionated, being too quiet, being overextended, and having difficulty remembering names and faces. Interestingly, all informants described that they consciously think about being role models when interacting with learners - an attitude the authors term “role modeling consciousness”. Wright & Carrese end their paper by stating: “Many of the attributes identified by our informants represent behaviours that can be modified or skills that can be acquired. We hope that identifying these attributes will prove helpful to individuals and institutions interested in enhancing effective role modeling.” Lewis and Robinson (2003) studied and compared the importance of various role model traits for role model identification for radiographers and radiation therapists. Both professional groups identified patient welfare and advocacy, communication skills and ethical conduct as the most important characteristics for a role model to have. On the other hand Paice, Heard and Moss (2002) found that students also meet negative role models who demonstrate poor professional attitudes and unethical behaviour. Such individuals cause “confusion, distress, and anger in young doctors and students under their supervision”. This correlates with results from the work of Wright & Carrese (2002) in which informants felt that “being a strong clinician was regarded as necessary but not sufficient for being an exemplary physician role model”. As a result, Paice et al. conclude that “role models may not be a dependable way to impart professional values, attitudes, and behaviours” and that in particular “professional behaviour and ethics should be explicitly taught through peer group discussion, exposure to the views of people outside medicine, and access to trained mentors”. It seems that relying exclusively on role modeling for the acquisition of important values, attitudes, and behaviours is too much a hit-or-miss affair and this puts more responsibility on academics to provide the role modeling necessary which students may miss out on in the practice areas.

2.5 THE PRESENT STATE OF THE ROLE OF THE BMPE EDUCATOR IN THE FHS AS EVIDENCED IN THE LITERATURE

This section first gives a historical overview of the role of physicists and engineers in clinical medicine as a backdrop to a better understanding of their present role in the education of the HCP. It then presents a critical review of the role of the BMPE educator in the FHS in relation to entry-level HCP education as evidenced in the literature. Included are relevant papers published in MEDLINE (1950 to present), CINAHL (1982 to present) and ERIC (1966 to present) with the words ‘physics’ or ‘biophysics’ or ‘engineering’ in the title.

The historical relationship between physics, engineering and medicine

The importance of the contribution of physics and engineering to healthcare has long been appreciated. In 1856, Fick edited a book called ‘*Medizinische Physik*’ and Brockway published a book with the title ‘*Essentials of Medical Physics’* in 1891.

However the influence of physics in medicine registered a quantum leap after the discovery of x-rays by Roentgen (1895) and radioactivity by Becquerel (1896). Stieve (1990) reports that the first two x-ray laboratories were established in Berlin in 1896, one at the Institute of Orthopedics and Pneumotherapy of Max Immelmann - only one year after the discovery of x-rays. Immelmann also promoted the 'Roentgenvereinigung' consisting of 14 medical doctors, physicists and engineers. The first chairperson of this first 'Roentgen society' was Walter Wolf, a physicist (Stieve, 1991, citing Goerke, 1980). The first radiological society in England was formed in 1897 - that is only 2 years after the discovery of x-rays, and the first president was Silvanus Thomson, a professor of physics. The developments in the first ten years were mostly in radiodiagnosis. The involvement of physicists in radiotherapy started in 1910 (Stieve, 1991). Stieve citing Cook (1972) says that the first full time physicist in radiotherapy was employed in 1912 in the radiotherapy department of a hospital in Munich. From then onwards, the involvement of physicists and engineers in medicine increased rapidly. The first society of medical physicists (the Hospital Physicists' Association) was set up in the UK in 1943. The first comprehensive medical physics text was the three volume encyclopedia '*Medical Physics'* by Glasser (1944 -1960) who listed 23 domains of medicine which required close collaboration between physicists and medical specialists. Laufman (2002) who has reviewed the role of engineering in medical progress cites in detail the milestone contributions of Roentgen in radiology, Bovie in electrosurgery and Greatbatch in implantable cardiac pacemakers. Today medical physics and engineering play a part in all areas of medicine. Established areas are continuously being developed and new areas emerging (Sharp & Perkins, 2000). The future holds devices for biomolecular, cell, tissue and organ engineering, optical imaging, nano-instrumentation and lab-on-a-chip systems for laboratory and home diagnostics (Griffith and Grodzinsky, 2001). Indeed medical physics and engineering have come a long way since those early days of radiodiagnosis and radiotherapy! The advice of a BMPE is today considered essential in ensuring effectiveness and safety in the adoption of new medical devices (Bergmann, 2003), and regulatory bodies are increasingly making the presence of BMPE mandatory in various areas of healthcare. For example, EC Directive 97/43/Euratom regarding the use of ionizing radiation in healthcare states that:

> "In radiotherapeutic practices, a medical physics expert shall be closely involved. In standardized therapeutical nuclear medicine practices and in diagnostic nuclear medicine practices, a medical physics expert shall be available. For other radiological practices, a medical physics expert shall be involved, as appropriate, for consultation on optimization including patient dosimetry and quality assurance including quality control, and also to give advice on matters relating to radiation protection concerning medical exposure, as required."

Scales (1965) emphasized the importance of collaboration between the disciplines of biology, medicine, physics and engineering, whilst Adelstein (2001) in describing the development of radioiodine studies of the thyroid makes the remark that "the cooperation between physicists and physicians that made their accomplishments possible stands as a model example for interdisciplinary collaboration".

The teaching role of the BMPE in the FHS as evidenced in the literature

Although there have been many instances of interdisciplinary collaboration between BMPE practitioners on one side and HCP on the other in the clinical and research environments, and although most BMPE organizations e.g., EFOMP (1984), ESEM (2006) do speak of the importance of the educator role with regard to the HCP within their policy documents, there is very little published evidence regarding such educational activities. The scant literature regarding the topic seems to indicate that the collaboration experienced in the clinical and research environments did not transfer satisfactorily to the educational milieu. In fact, a search of the main health and education research databases resulted in very few relevant references. The few references that do exist are mainly confined to undergraduate medicine, radiography and radiation therapy, and the *postgraduate* medical specializations of radiology and radiotherapy.

BMPE teaching in courses of medicine

There is, a quasi-total absence of articles regarding the BMPE component in medical curricula even though BMPE educators have provided teaching in the majority of medical programmes in Europe. The few papers that exist send contradictory signals regarding the effectiveness of teaching.

Hayter (1996) describes the work of J. K. Robertson, professor of physics teaching at the Queen's University Faculty of Medicine in Canada in the years 1909 to 1951. Robertson started teaching medical students in 1909 at a time when the physics component in the medical curriculum was minimal. The number of lectures were two per week for a single term and concerned general non-applied physics (mechanics, properties of matter, heat, light, sound, electricity and magnetism) with some laboratory work added in 1911. Robertson considered this inadequate and following an intra-mural report by a certain Dr Third regarding the inadequacy of instruction in the uses of radiation and radioactivity in medicine instituted a course entitled 'X-Rays and the Physics of Electro-Therapeutics' as an option for final-year medical students also with a frequency of two sessions per week (at the time radiology was not considered a medical speciality and could be practiced by all medical practitioners). A second objective of the course according to the same report would be to ensure that future physicians would be able to make informed decisions regarding the purchase and use of such equipment. The course was very comprehensive and also included radiation doses, radiation protection and a comparison of various forms of devices. However this course was not a success. The reasons given by Robertson were two. First, he found that students who had learned their electricity and magnetism in the first year course of physics had forgotten everything by the final year. Secondly, final year students perceived that this final year course would be similar to the non-applied first year course and preferred to attend classes in areas directly relevant to their clinical practice. Robertson solved the problem by convincing the faculty to move the final year course to the second year of the course. He then transformed this second year course into a combined electricity and magnetism plus 'X-Rays and the Physics of Electro-Therapeutics' course, hence combining scientific principles with clinical practical application in a single course. Hayter reports that Robinson aimed to make physics as attractive as the clinical disciplines by showing its direct relevance to medicine. Robertson stressed the applications of physics as opposed to pure theoretical principles and used a lot of demonstrations as opposed to chalk-and-talk methods. Hayter considers that Robertson's second year course combining pure and clinically applied physics in one course "challenged the linear, rigidly structured medical curriculum of the day, with its strict separation of basic and applied science" and that Robertson himself considered his work as an experiment in medical education. Hayter quotes Robertson's advice to fellow physicists:

> “The physicist who teaches medical students should recognize that the mental approach to a scientific subject by those whose primary interest is medicine is not the same as that of the physicist and he should govern himself accordingly” (Robertson, 1954).

Hayter finally affirms that:

> “Robertson’s success in this endeavour was based largely on two factors: his sympathetic understanding of the needs of medical students and his innovative combination of basic and applied science in one course - factors that are as important to medical teaching today as they were 50 years ago”

Britton and Brown (1968) in a debate on the need or otherwise of physics in the medical curriculum point out that the physical laws often taught to medical students are applicable only in simple and closely defined contexts. They warn that students should be made aware that the application of such laws to the complicated systems found in the body must be done with careful consideration to the applicability or otherwise of the assumptions of the simplified models.

Fasce et al. (2001) report an interesting attempt at introducing problem-based-learning and team-teaching in the physics teaching of medical students. First year medical students were separated into two groups, one group being taught in the traditional manner and the second group using problem-based-methods by a team of physicists, a biochemist and three medical doctors. There was no significant difference in assessment scores between the two groups at the end of the course, however the problem-based-learning group was more satisfied with the course. The areas of physics involved were forces, fluid dynamics, electricity and waves. The paper is interesting in the sense that it is the only one in which physics was taught using problem-based-learning methodology, however unfortunately there is no indication what the actual cases were and how the physics was integrated within the clinical cases.

There are indications that the absence of systematic research and published studies regarding BMPE curricula in FHS seems to be resulting in unsatisfactory learning outcomes with an unacceptably high theory-practice gap. Pabst & Rothkotter (1996) carried out a retrospective evaluation of the medical curriculum by final year students at the Hannover Medical School. Students were asked to express their opinion on the relevance of the various subjects in their medical training. Physics was considered to be the least relevant of all the subjects with a ‘necessary subject rating’ of only 18% compared with 48% for chemistry and 54% for biology. 33% of respondents thought that physics was ‘superfluous’ as opposed to the 5% who expressed a similar opinion with regard to chemistry and biology. The data were considered as representative as the response rate was over 90% and the cohort large (n =323). In a similar study by the same authors (Pabst & Rothkotter, 1997) similar results were obtained this time with physicians at the end of their specialization periods (on average seven years after graduation). Although curriculum evaluation by students is more an assessment of the level of subject acceptance than valid evaluation and that such evaluations are influenced by local conditions such negative results do indicate issues which should be studied and problems to be addressed.

EFOMP has only published one syllabus for medical undergraduates. This syllabus, confined in scope to radiation protection issues only (Dendy, 2005a), was the response of the federation to a call by the European Commission that “Member states shall encourage the introduction of a course on radiation protection in the basic curriculum of medical and dental schools” (EC Directive, 97/43/Euratom, Article 7). The syllabus is not competence based and is therefore not consonant with modern medical curriculum design. Moreover the voluntary nature of the course has resulted in minimal effects on the radiation protection education of medical practitioners. (Jacob, Vivian & Steel, 2004).

Dusek and Bates (2003) in a paper analyzing European medical school teaching programmes compared the number of class hours in the various subjects with the numbers recommended by a tentative set of recommendations of the European University Association (EUA). This document, which the authors claim to have been in their possession, recommended a total of 206 hours of BMPE teaching in the pre-clinical stage. The authors found an enormous range of variability in the number of hours dedicated to medical physics ranging from 6 to 350! All the medical schools studied with the exception of one (Naples, Italy) actually devoted less than the recommended number of hours for physics. However it seems that the EUA document was never officially endorsed as a thorough search of the literature and the Internet revealed no trace of the document.

Of particular significance is an appeal by Mornstein (2005) for BMPE educators to include many more lectures on medical devices apart from established topics like general and molecular biophysics, biophysics of perception, nuclear physics and optics in their BMPE curricula for medical students. The author particularly is of the opinion that principles of biosignal instrumentation and processing should be considered as fundamental.

BMPE teaching in courses of radiography

Physics has been included in the curriculum for radiographers since the beginning of formal radiography education. Snelling (1963) speaks of “an estimation of the necessity for physics in the training of the radiographer”. This seems to have led to a symposium on the subject (Franklyn, 1964) and finally a basic syllabus (Mussell, 1965), however no further updated work has been published in the literature. The European Federation of Medical Physics has published in association with the European Association of Radiology (EAR) an imaging physics syllabus for *postgraduate* radiology (Dendy, 2005b), whilst the American Association of Physics in Medicine has published a guide for teaching physics also to *postgraduate* radiologists (Barnes, Berry & Dennis, 1999). Surprisingly neither organization has published an equivalent document for radiographers notwithstanding the fact that the role of the radiographer invites a higher level of interaction with devices than that of the radiologist. The College of Radiographers, United Kingdom (2003) did include sections on ‘physical sciences’ and ‘technology’ in its curriculum framework for radiography. However given the of necessity broad nature of the document further specification is required to produce learning outcome competence statements that are directly usable in the educational environment. Most schools of Radiography publish a locally developed physics syllabus under such diverse names as ‘radiation physics’, ‘principles of radiation science’, ‘imaging equipment’, ‘imaging science and instrumentation’, ‘radiation protection’ and others (Price, High & Miller, 1997) but there is no evidence of a systematic and studied approach. A document published by the European Commission offers direction, however competences are mostly restricted to ionizing radiation protection only (EC, 2000).

BMPE teaching in radiation therapist programmes

Radiotherapy is the only area in which physicists and other HCP have worked together in a concerted and systematic manner and on a European scale to produce curricula and educational materials. An extensive curriculum development programme has been carried out as part of the project ESQUIRE (**E**ducation, **S**cience and **QU**ality **A**ssurance for **R**adiotherapy) which is run under the auspices of the European Society for Therapeutic Radiology and Oncology (ESTRO) and financed by the EC (Europe Against Cancer initiative). Important outcomes of the project included endorsed guidelines for European core curricula for all three professions within radiation therapy i.e., medical physicists, radiotherapists and radiation therapists (Heeren, 2005). For the BMPE educator it is important to note that, in the case of radiation therapists the project led to a European core curriculum for radiation therapists (Coffey, Vandervelde, Van der Heide, Adams, Sundquist, Ramalho, 1997). A revised version has an improved BMPE component under the headings of 'physics' and 'equipment' (Coffey, Degerfalt, Osztavics, Van Hedeld, & Vandervelde, 2004). A weakness of the curricula is that they are not outcome competence based but simply present a list of topics to be covered.

BMPE teaching in the postgraduate specializations of radiology and radiotherapy

Although the study of the BMPE contribution to the medical postgraduate specializations of radiology and radiotherapy does not lie within the scope of this theses, the articles in these areas will also be reviewed as they often reveal engaging arguments regarding the justification for BMPE teaching and choice of BMPE content which are very much applicable also to undergraduate BMPE teaching.

The Committee on Training of Radiologists of the American Association of Physicists in Medicine (1989), published the results of a survey conducted among recently certified radiologists regarding their perceptions of radiological physics training and the importance of the various physics topics included in the radiological physics curricula at the time. The most important results of the survey for this study were the following:

a) 72% of the respondents had a negative opinion of physics as presented in their programs at the time, however, *the same percentage continued to attend physics training even after graduating and notwithstanding the fact that they were not obliged to do so for certification reasons*! This clearly indicated that "radiologists actually do consider physics to be a worthwhile endeavor".

b) The respondents indicated that they would have liked to have "an emphasis on subjects that are directly relevant to everyday practice" as they felt that "although they acknowledged the need for an understanding of basic physics principles, they clearly perceived that theory had been overemphasized". The respondents wanted a greater emphasis on those topics relevant to the production of quality images and means of reducing radiation doses to patients.

The results of the survey triggered a discussion that has gone on unabated in some form or another since then. Saba & Poller (1999), argued that it is indeed the superior knowledge that radiologists have of physics that gives radiologists an edge over other clinicians who attempt to read medical images, as medical images are "a combination of both anatomical and physical information" and that the "anatomic and physical information form an inseparable unit". Moreover:

> "It is the job of the radiologist to combine his knowledge of anatomy, disease, and image production in formulating an interpretation. If one of these elements is missing, the interpretation is at best incomplete, if not incorrect. This is what happens when a clinician who has a thorough knowledge of the specific anatomy and disease process attempts to interpret radiologic images without an understanding of image production".

Saba & Poller then go on to give several convincing examples of the misdiagnoses that can occur through an inadequate knowledge of the imaging physics. Balter (1992) echoes similar sentiments in saying that "radiologists may be able to use their equipment in a safer and more effective manner than would be possible without such knowledge".

Frey (Frey, Dixon, & Hendee, 2002) in a point-counterpoint discussion argued that owing to the pressures on radiologists' learning time only physics knowledge that is derived from the clinical practice should be taught. This has the advantage of demonstrating directly the relevance of physics knowledge. The best educators of physics for radiologists and by extention all HCP are those who have both physics and clinical knowledge, *as the physicist must "translate" the physics to the clinical situation*. Another advantage of this approach is that the student is more likely to retain the material after graduation. But perhaps the greatest advantage is that this approach "preserves the image of the physicist as possessing valuable and occult knowledge" and that when complex situations arise in their practice the radiologists would feel the "need to consult with their medical physics colleagues". Dixon countered these arguments by saying that it is more important to use the time available to build firm broad conceptual foundations as there are physical concepts which though not relevant at the time of learning could become relevant later in particular with the rapid expansion of technology. He cites as example the case of magnetic resonance imaging (MRI) by saying "in the 70s who would have thought that nuclear spins would play any role in radiology".

A more recent debate (Dennis, Rzeszotarski, & Hendee, 2003) includes a discussion on whether developments in molecular imaging imply that the physics taught to radiologists would need to become more quantitative and mathematical in nature. Rzeszotarski argued against the proposition as there is simply no available curriculum time and that medical students do not tend to be mathematically inclined: "While a physicist is comfortable working with integrals and exponentials, these incite fear and anxiety in most residents. Unfortunately, there is insufficient time to teach the fundamentals of mathematics along with the essential physics". Teaching, he adds, "should be performed using qualitative nonmathematical methods that are both understandable and pragmatic. These methods require more preparation time by the medical physicist, but the end is improved comprehension". It is much more important to provide future radiologists with the background knowledge necessary for them to be able to recognize those instances during their future careers when they would need to seek out assistance from physicists. Dennis' arguments in favour of the proposition are general statements on the lines that more sophisticated technology requires more physics knowledge, however his arguments are not felt to be convincing.

Current BMPE curricular content for HCP education

The following particular BMPE content areas were identified as current curricular content areas within the BMPE component of undergraduate HCP programmes. The areas were identified from an analysis of the content found in European BMPE textbooks targeted to HCP (a list of the textbooks can be found at the end of this chapter). The major content areas identified were:

- General non-applied physics
- Biomolecular and cellular physics
- Physical biochemistry
- Biophysical devices (spectrometry, flow cytometry, x-ray crystallography and others)
- Biomechanics
- Cardiovascular haemodynamics
- Biophysics of perception
- Electrophysiology
- Signal-processing
- Physiological measurement devices
- Microscopy (including modern microscopy devices: fluorescence, confocal laser, near field, electron, atomic force)
- Biomedical laboratory devices
- Laser based biomedical devices
- Rehabilitation devices
- Biomedical imaging devices
- Radiotherapy devices
- Electrotherapy devices
- Safety (radiation protection and dosimetry)
- Safety (physical agents other than ionizing radiation)
- Other (modeling, cybernetics, prosthetic devices and others)

EUROPEAN BMPE TEXTBOOKS TARGETED TO HCP

Aurengo, A., Petitclerc T., & Grémy, F. (1997). *Biophysique* (2nd ed.). Paris: Flammarion Médicine-Sciences.

Beneš, J., Stránský, P., & Vítek, F. (2005). *Základy lékařské biofyziky*. Prague: Karolinum Press.

Dam, T., Lip, R., & Weissman, F. (ed.) (1997). *Techniek in de radiologie*. Elsevier/ De Tijdstroom: Utrecht.

De Ru, V. J., Scheuleer, J. S., Wellewweerd, J., & Wesselink, M. L. (ed.) (2003). *Radiobiologie en stralingsbescherming* (4th ed.). Elsevier Gezondheidszorg: Maarsen.

Dendy, P. P., & Heaton, B. (1999) *Physics for diagnostic radiology* (2nd ed.) Bristol: Institute of Physics.

Dylevský, I., Kubálková, L., & Navrátil, L. (2001). *Kineziologie, kineziterapie a fyzioterapie* (1st ed.). Prague: Manus.

Ďoubal, S., & Horáčková, I. (2000). *Biofyzika pro studenty farmacie.* Prague: Karolinum Press.

Hálek, J. a kol. (2002). *Biofyzika pro bakaláře* (2nd ed.). Olomouc: Univerzita Palackého.

Harten, U. (2002). *Physik fur mediziner* (10th ed.). Berlin: Springer-Verlag.

Horáčková, I., Hamerníková, M. & Ďoubal, S. (2002). *Praktická cvičení z biofyziky.* Prague: Karolinum Press.

Hrazdíra, I. & Mornstein, V. (2001). *Lékařská biofyzika a přístrojová technika.* Brno: Neptun.

Kitchen, S. (2002). *Electrotherapy - evidence based practice* (11th ed.). Elsevier Science.

Martin, C. J., Dendy, P. P., & Corbett, R. H. (Eds.). (2003). *Medical imaging and radiation protection for medical students and clinical staff.* London: Bitish Institute of Radiology.

Morris, S. (2001). *Radiotherapy physics and equipment.* Churchill Livingstone.

Navrátil, L., & Rosina, J. (ed.) 2003. *Biofyzika v medicíně* (1st ed.). Prague: Manus.

Parisi, M. (2001). *Temas de biofísica.* (1st ed.) McGraw-Hill

Pedroso de Lima, J. J. (2003). *Biofisíca Médica.* Coimbra: Imprensa da Universidade.

Pedroso de Lima, J. J. (1999). *Introducao a mecanica e a outros temas em medicina dentária*. Coimbra: Imprensa da Universidade.

Van Oosterom, A. & Oostendorp, T. F. (2003). *Medische fysica* (2nd ed.). Elsevier Gezondheidszorg: Maarsen.

Vítek, F. (2004). *Lectures on medical biophysics*. Prague: Karolinum Press

Weissman, F., & Welleweerd, J. (ed.) (2000). *Stralingsfysica* (2nd ed.). Elsevier Gezondheidszorg: Maarsen.

Zitko, M. a kol. (2003). *Praktikum z lékařské biofyziky* (1st ed.). Prague: Triton.

3 RESEARCH DESIGN

3.1 OVERVIEW OF THE CHAPTER

This chapter first details the research paradigm, approach and philosophical perspective guiding the project. This is followed by a short description of the strategic planning model used in this thesis. There is particular emphasis on the methodologies used to inventorize the SWOT themes for the position audit as an accurate SWOT audit is the basis of any successful strategy formulation process.

3.2 RESEARCH PARADIGM: PRACTITIONER RESEARCH

The fundamental research paradigm of this study is practitioner research. Practitioner research is research carried by practitioners with the aim of improving their own practice and the general practice of their profession. The fundamental characteristics of practitioner research are that it is intended to produce practical benefits, that it is ‘insider’ research and that the principal focus is the practice of the profession. Practitioner-researchers are professionals who conduct research to develop their own practice concurrent with practicing their profession (Jarvis, 1999, p. 5). The view of practitioner research on which this study was based was that it is fundamentally concerned with researching issues arising from practice to enhance future action. This reflects the ‘technicist’ type of practitioner research (Zuber-Skerritt, 1996 cited by Burchell, 2000).

3.3 RESEARCH APPROACH: QUALITATIVE RESEARCH

The research approach of the study was primarily qualitative. A research approach is qualitative when the overall purpose is theory generation as opposed to theory confirmation. Findings can be concepts (often known as ‘constructs’), themes, categories, typologies, or tentative hypotheses. Qualitative methods are essential in studies which are fundamentally exploratory in nature, that is, when very little is known about the area of research. This is the situation regarding the role of the BMPE educator in the FHS. Qualitative research is inductive and inferences are developed in cumulative increments based on data acquired during each stage of the study. In qualitative research, data is not collected via randomized sampling but via purposeful sampling, that is cases are chosen according to the *purposes of the study*. Data collection is stopped when no new concepts, themes and relationships are emerging. This is known as data saturation.

3.4 PHILOSOPHICAL PERSPECTIVE: PRAGMATISM

The main philosophical research traditions used in modern research are: postpositivism, social-constructivism, participatory-advocacy and pragmatism (Creswell, 2003, p. 6). The philosophical perspective of this project as a whole was pragmatic. Pragmatism is problem-centered, ‘real-world’, practice-oriented and concerned with “what works”. The problem is the main focus of attention and the researcher uses any methodology or combination of methodologies which would promote greater understanding of the problem and lead to practical tentative solutions (Creswell, 2003, p. 11).

3.5 THE STRATEGIC PLANNING PROCESS USED IN THIS STUDY

The strategic planning process for role development used in this study is a pragmatic blend of the various theoretical frameworks described in Section 2.3 adapted for use to academic role development in HE. The main steps are:

a) Identification of paradigms to guide the strategic planning process,

b) Identification of core values to guide the strategic planning process,

c) A position audit of the educator role of the BMPE using the SWOT methodology. An accurate SWOT audit is the basis of all strategic planning and was given major importance in this study,

d) Setting up of an inventory of curricular challenges facing the BMPE educator,

e) Portfolio analysis (identification of clients and core competences) from the results of the SWOT audit,

f) The identification of benchmarking themes from the SWOT audit,

g) Forecasting of key ‘market forces’ from the SWOT audit and curricular challenges inventory,

h) The formulation of a mission statement (role-definition) for the role,

i) The formulation of a vision statement for the role,

j) The carrying out of a gap-analysis,

k) The formulation of specific strategies and actions for gap reduction using the SWOT matrix technique.

3.6 PARADIGMS GUIDING THE STRATEGIC PLANNING PROCESS

The paradigms guiding the planning process were the open-systems and marketing paradigms. The open-systems model emphasizes that role development occurs within an external environment (political, economic, social, technological-scientific) and often as a response to changes within that environment. The marketing paradigm is a reminder that in current HE managerial systems BMPE services will only be requested (and in some countries bought and paid for) by HCP because they are seen as being of value *to them*.

3.7 IDENTIFICATION OF CORE VALUES

Core values were identified through the study of mission and policy statements of BMPE societies (particularly those of The EFOMP and ESEM), HCP societies, suggested value systems published in the literature (e.g., Shumway, 2004), and informal discussions at EFOMP and GIREP conferences.

3.8 THE SWOT AUDIT

A position audit entails a study of organization-environment relations. Harrison (2005, pp. 105-114) proposes three methodologies for carrying out position audits i.e., the Environmental relations assessment (ERA), the SWOT audit and the Open Systems Planning methodologies. All three methodologies are based on the open systems model of organizations. The SWOT methodology is a competitive strategy that is increasingly being used by public entities as the latter face increased contention for funds, clientele and public support from other public agencies or private organizations (Harrison, 2005 p. 109). BMPE departments also face contention for limited curriculum time, faculty material assets and students (in the case of optional units and research students) from other faculty departments.

From its formalization by Weihrich (1982) the SWOT-matrix (also known as the 'TOWS'-matrix technique) technique has become one of the most popular techniques used in strategic forward planning for both profit and non-profit organizations. The SWOT methodology is a framework that seeks to match internal organizational strengths and weaknesses with external environmental opportunities and threats in order to help leaders of any entity strategically position their organization. Essentially the process starts by the carrying out of an audit of SWOT themes by members of the same entity and other stakeholders particularly clients. The themes identified via the SWOT audit are used as inputs to the strategic plan.

Use of the SWOT audit in healthcare and education research

Although the use of the SWOT audit was originally limited to industrial and commercial applications its use was very quickly taken up in both healthcare and education as such organizations seek to make strategic adaptations to rapidly evolving health care and educational environments. As early as 1993, Casebeer advocated that "given the complex nature of modern health care systems, the ability to use this type of technique can enable health professionals to participate more fully in the analysis and implementation of health care improvement". Gordon et al (2000) used the methodology to identify strategies for enhancing the learning environment of medical students in the clinical setting, whilst Westhues, Lafrance and Schmidt (2001) used it to produce a development model for social work and social work education in Canada. Higginbottom and Hurst (2001) employed SWOT to develop a quality assurance strategy for a physiotherapy and occupational therapy services unit whilst Gibis et al (2001) describe how an international group used the technique to formulate a general strategy for the development of a health technology assessment programme. Gibson et al. (2001) used the technique to study the potentialities of using information and communication technologies in programmes targeted at the academic development of the staff in HE whilst Christiansen (2002) describes a SWOT analysis of the Danish health care system.

McCluskey and Cusick (2002) used SWOT to develop strategies for introducing evidence-based-practice among occupational therapy professionals in Australia whilst Jinks and Green (2004) used SWOT to find ways to enhance the research activities of nursing professionals by aligning the research and development strategies of nurses and midwifes in a large acute teaching hospital with those of a FHS. El Ansari et al. (2003) used SWOT methodology to identify the factors that advocates of a public-health-orientation for healthcare curricula must consider. Dyson (2004) reports the use of SWOT analysis in the formulation of strategy at the University of Warwick (UK) whilst Storr and Hurst (2001) used the methodology in the development of a quality assurance framework for in-service training and development within the Harrogate Health Care Trust (UK). Lee et al. (2000) used SWOT in developing strategies for vocational education in Hong Kong.

Definition of Strengths, Weaknesses, Opportunities, Threats as applied in this study

The definitions of strength, weaknesses, opportunity and threat as applied to this study are the following:

Strength: A resource (qualification, competence, value, reputation, practice, etc.) which focus role holders *possess* which would put them in a strong competitive position with respect to other roles in the organization in fulfilling present and future stakeholder expectations.

Weakness: A resource which focus role holders *lack* which would put them in a weak competitive position with respect to other roles in the organization in fulfilling present and future stakeholder expectations.

Opportunity: A present or future external environmental circumstance or trend which is attractive to role-holders (in terms of monetary terms, prestige etc.) or which would lead to new unserved stakeholder expectations for which focus role holders are in a strong competitive position to fulfill with respect to other roles in the organization.

Threat: A present or future external environmental circumstance or trend which would lead to the withdrawal of present stakeholder support for the role or inability to make the most of significant opportunities leading to the possibility of the eventual decline of a role within an organization.

Research strategies for identifying SWOT themes

Internal strengths and weaknesses of the role as presently exercised in Europe were inventorized via a Europe-wide qualitative multi-case-study survey of BMPE departments (which in practice range from large departments to individuals) and BMPE educator roles as elicited from the BMPE component of present European HCP curricula. External environmental opportunities for the role and threats to the role were inventorized via a comprehensive systematic review of the HE, biomedical and HCP education literature. Themes were sorted within standard Political, Economic, Social and Technological-Scientific (PEST) categories.

The qualitative survey for inventorizing S-W themes

The qualitative Europe-wide survey was carried out over a period of two and a half years (starting December 2003). A preliminary exploratory survey was carried out via an analysis of FHS web-pages across Europe. A purposive sample of universities was then chosen from each country to ensure a Europe-wide cross-sectional perspective. Criteria of choice of universities within a particular country included level of BMPE educator activity within the FHS, range of HCP serviced, level of participation in European initiatives, the provision of examplars of good practice and the availability of updated documentation within web-sites. In general universities within capitals were included as these provided the best data for the aims of the project. Other institutions outside the capitals were chosen when new themes were indicated and in the case of the larger European states.

S - W themes collection techniques and instrument

The main data collection techniques in case-study research are document analysis, direct observation during on-site visits and interviews (Creswell, 2003, p. 187; Yin, 2003, p. 86). The main data collection technique in this study was document analysis. Document data was collected from web-sites, published documents, curricular materials and textbooks. Document analysis has several advantages: it represents data which has been given thoughtful attention by participants (particularly in public documents such as internet sites), can be accessed at any time convenient to the researcher and as written evidence saves transcribing time and expense. The technique is unobtrusive and avoids the biasing of responses or observations created by the researcher's presence during interviews and direct observations (McKernan, 1996, pp. 148-150; Creswell, 2003, p. 187). The document analysis was supplemented when necessary with semi-structured interviews, e-mail correspondence and direct observation during on-site visits. The interviews conducted with a select group of BMPE practitioners and educational leaders of various HCP provided an element of the social-constructivist and participatory-advocative perspectives, which are important in role development research. Social-constructivism emphasizes the collaborative construction of knowledge whilst participatory-advocacy is political and change oriented (Creswell, 2003, pp. 8 - 9). The interviews with HCP educational leaders were considered essential as the viewpoints of the HCP (who are the clients of the BMPE educator) are considered crucial within the marketing paradigm. Interviews were not recorded in order not to artificialize the situation, as some issues are particularly sensitive. The data was checked for updates as documentation - in particularly web-site documentation - constitutes a "moving-target" (McMillan, 2000). Data from all sources was collected with the help of a purposely-designed theme collection instrument. The theme-sheet itself was used as an interview guide for semi-structuring the interviews (Kvale, 1996, p. 129). The thematic datasheet was piloted and subsequently improved recursively as new themes emerged. Prior to data collection country HCP education information regarding the general organization of HCP education in the country, the degree of alignment of HCP education with the EHEA cycle system and a general overview of BMPE education for HCP in the country was collected. An initial version of the thematic datasheet was piloted at the First Faculty of Medicine of Charles University, Prague, Czech Republic, the College of Life Sciences, University College Dublin, Republic of Ireland and Fontys University of Applied Sciences, Eindhoven, the Netherlands. These countries and faculties were chosen for the pilot study as it was felt that between them they would involve most of the relevant data collection issues that would be encountered (Yin, 2003, p. 79). Documentation from the webpages of all three faculties were analysed and curricular documents and textbooks analysed. All three faculties were visited for direct on-site observation and interviews conducted with both BMPE and HCP. Preliminary results of these case studies have been published in the following article:

Caruana, C. J., & Plasek, J. (2004). An initial set of exploratory case studies regarding the role of the biomedical physics-engineering educator as practiced in health science faculties in Europe. *Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2004 Teaching and learning physics in new contexts.* Ostrava, Czech Republic. ISBN 80-7042-378-1. pp 67-68.

A copy of the article can be found at the end of the dissertation.

The theme collection instrument was divided into 10 sections. All sections except the first included a column for noting S - W themes that could be inferred from the data. A description and rationale for these sections follows. An example of a filled-in datasheet is shown at the end of this chapter. All data that could identify the particular FHS has been blanked out to preserve the anonymity of the FHS and respondents.

Section 1: Country, University and FHS data: This section describes the general context in which the BMPE educator operates i.e., country, HCP education organization in the country, university, FHS and HCP undergraduate degrees offered by the faculty.

Section 2: BMPE organization, location within faculty structure and mission: This section contains data regarding the organization, location within faculty structure, any formal mission of BMPE within the FHS and the role as perceived by the other HCP.

Section 3: Client Analysis: Extent of BMPE educator involvement in the COMPULSORY programme modules of the various HCP: This section describes BMPE educator involvement in the *core compulsory* programme modules of the various professions. The rationale behind this section is to help identify present major client groups.

Section 4: BMPE curriculum content analysis - compulsory modules (in units of ECTS credits): Magnitude of BMPE serviced content areas in the compulsory modules (in ECTS units): This section attempts to identify the relative importance of the particular BMPE content areas, in the BMPE component of the various compulsory core modules. The rationale behind this section is to identify which BMPE content areas are most in demand hence providing an indication of core competences.

Section 5: BMPE curriculum content analysis: elective modules (in units of ECTS credits): Elective modules carry opportunity as the BMPE can use these optionals to publicize his activities. However an over dependence on electives can be risky as any pressure on the curriculum would lead easily to their elimination.

Section 6: Role expansion opportunities: Programme modules which would be enhanced through the involvement of a BMPE educator: This section describes modules which do not at the time of the data collection include BMPE involvement but which have strong potential for future BMPE involvement. Such modules would provide opportunity for eventual role extension.

Section 7: Curriculum development (CD) themes within the FHS impacting the BMPE role: This section presents curriculum development themes within the FHS which could highlight strengths and weaknesses.

Section 8: Exemplars of good BMPE curricular practice: This section highlights any exemplars of good BMPE curricular practice. Exemplars of good practice often indicate role strengths whilst absence may indicate role weaknesses.

Section 9: Research carried out by the BMPE: This section describes research (both discipline and educational research) carried out by the BMPE department, the presence or absence of which indicates role strengths and weaknesses.

Section 10: Miscellaneous: This section would list any miscellaneous themes not included in the other sections.

Section 11: Verbatim quotes: This section includes verbatim quotes from documentation, email correspondence or interviews which were considered important enough with respect to role strength and weaknesses to be recorded and highlighted.

The literature survey for inventorizing O-T themes

Opportunity-Threat themes were inventorized via an extensive literature scan involving a comprehensive systematic review of the HE, biomedical and HCP education literature:

Main Higher Education journals:

- HE in Europe,
- HE,
- HE quarterly,
- J of Further and HE,
- Active Learning in HE,
- Assessment and Evaluation in HE,
- HE Research and Development,
- International Journal on Teaching and Learning in HE,
- Journal of Further and HE,
- The Journal of HE,
- Research in HE,
- Studies in HE,
- Teaching In HE,
- Tertiary Education and Management.

Main general HCP education journals namely:

- Advances in Health Sciences Education,
- Education for Health: Change in Learning and Practice.

Main educational journals for specific HCP:

- Medical Education,
- Medical Teacher,
- Academic Medicine,
- Medical Education Online,
- BMC Medical Education,
- Teaching and Learning in Medicine,
- Journal of the International Association of Medical Science Educators (IAMSE),
- Nurse Education in Practice,
- Nurse Education Today,
- Radiography,
- Physiotherapy,
- British Journal of Occupational Therapy,
- European Journal of Dental Education,
- American J of Pharmaceutical Education,
- Pharmacy Education,
- Midwifery.

The systematic review included an assessment of relevance of articles from January 2000 to present. The criteria for relevance were possible impact on the role of the BMPE educator and general applicability across the HCP. Further relevant earlier papers were identified by checking the reference list of the retrieved articles until data saturation was reached i.e., no further relevant themes were identified.

O - T Themes collection instrument

The themes identified from the HCP education and HE journals were sorted according to the well established Political, Economic, Social, Technological / Scientific (PEST) categories and according to whether they presented a potential opportunity or threat to the role. The O - T collection thematic sheet is shown below.

Theme	PEST Category				Opportunity or Threat	Comments	References
	Political	Economic	Social	Tech-Scientific			

Fig 3.1: The Opportunity - Threat theme inventory datasheet.

3.9 SETTING UP THE CURRICULAR CHALLENGES INVENTORY

The curricular challenges facing the BMPE educator within HE and FHS education were also inventorized via a comprehensive systematic review of the higher education, biomedical and HCP education literature.

3.10 PORTFOLIO ANALYSIS

Data collected during the survey was used to carry out a portfolio analysis of BMPE curricular areas. The following two questions were asked of each BMPE curricular area:

a) Would it be difficult for other roles within the faculty to satisfy (hence avoiding transfer to other potentially politically stronger roles)?

b) Is it being requested by HCP and is it a future growth area offering further access to important HCP groups at entry level (i.e., is it marketable)?

A curricular area would be labeled as a core competence if the above questions applied to the curricular area *both* give affirmative answers (Tampoe, 1994; De Toni & Tonchia, 2003). These criteria were used to identify the core competence curricular areas of the BMPE educator.

3.11 IDENTIFICATION OF BENCHMARKING THEMES

Benchmarking themes were elicited from the results of the SWOT audit.

3.12 FORECASTING OF KEY ‘MARKET-FORCES’

Key ‘market-forces’ were elicited from the results of the SWOT audit and curricular challenges inventory.

3.13 CONSTRUCTION OF MISSION AND VISION STATEMENTS

The construction of the mission and vision statements was based on the model proposed by Raynor (1998) and exemplars of mission and vision statements of universities of good standing gleaned from the Internet. Mission statements define a role in terms of core competences, clients served, and behavioral values of importance to role holders. It is also a motto for role members to rally round and a signpost publicizing the importance of the role for all stakeholders to see. It should be a celebratory maxim of a role's culture giving role holders who read it a good feeling about their membership of the role. The Raynor model is shown in Fig 3.2.

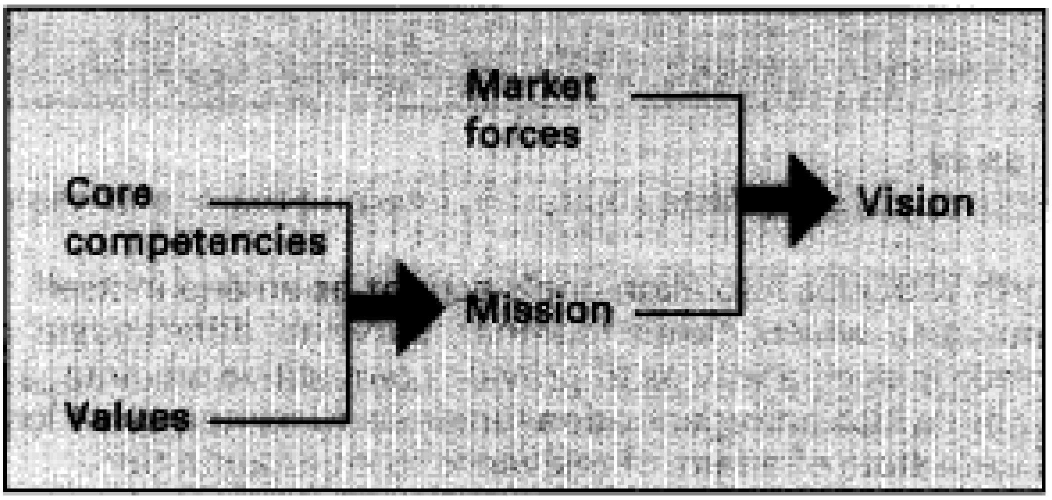

Fig 3.2: The Raynor model for constructing mission and vision statements (Raynor, 1998).

Alternative versions of the possible mission statement for the BMPE educator were evaluated against the criteria for good mission statements shown in Fig 3.3. (Campbell, 1997).

Do You Have a Good Mission Statement?

Does the statement describe an inspiring purpose that avoids playing to the selfish interests of the stakeholders?
Does the statement describe the company's responsibility to its stakeholders?
Does the statement define a business domain and explain why it is attractive?
Does the statement describe the strategic positioning that the company prefers in a way that helps to identify the sort of competitive advantage it will look for?
Does the statement identify values that link with the organization's purpose and act as beliefs that employees can feel proud of?
Do the values 'resonate' with and reinforce the organization's strategy?
Does the statement describe important behaviour standards that serve as beacons of the strategy and the values?
Are the behaviour standards described in a way that enables individual employees to judge whether they are behaving correctly or not?
Does the statement give a portrait of the company, capturing the culture of the organization?
Is the statement easy to read?

Fig 3.3: Criteria for evaluating mission statements (Campbell, 1997).

3.14 THE GAP ANALYSIS

The gap analysis was carried out by analyzing the differences between the desired future state of the role and the actual present state as determined from the SWOT analysis.

3.15 FORMULATING STRATEGIES: THE SWOT MATRIX

The SWOT matrix is a systematic framework for linking strengths and weaknesses with opportunities and strengths in order to formulate strategies. The matrix used in this study (Fig 3.4) is in the form originally suggested by Weihrich (1982) but which includes developments in strategic planning theory since the publication of the original matrix.

	INTERNAL STRENGTHS (S)	**INTERNAL WEAKNESSES (W)**
EXTERNAL OPPORTUNITIES (O)	**SO Strategies**: 1. Specialization: only pursue existing and emerging opportunities which are a best fit to core competences. Such 'focusing' is particularly relevant in difficult times when a role is under pressure. 2. Innovation: increase customer base by using core competences to produce new services which address unsatisfied and unarticulated needs. 3. Core competence development: Use opportunities to develop further the core competences (competence building) and hence strengthen competitivity. 4. Promotion: use opportunities to publicize core competences.	**WO strategies**: 1. Strengthening weak competences: create / use training opportunities to address competence deficiencies which are limiting the ability of role holders to take on opportunities. 2. Diversification: If the existing client base is narrow use opportunities to diversify to other client segments hence reducing dependence on a small number of client groups. 3. Develop weak resources: every role needs resources to be effective. Use opportunities to acquire or develop resources for the role. 4. Develop weak organization: in today's highly internationalized environment strong organization is essential. Use opportunities to improve organization.
EXTERNAL THREATS (T)	**ST Strategies**: 1. Alliances and mergers: Use strengths to form alliances with other roles to defend against threats. Consider mergers with other similar roles for increased influence.	**WT Strategies**: 1. Elimination of critical weaknesses: eliminate weaknesses which would expose the role to unacceptable levels.

Fig 3.4: The Weihrich SWOT strategy matrix (Weihrich, 1982).

Strategies linking external opportunities with internal strengths are termed SO strategies. Similar definitions apply to strategies described as WO, ST, and WT. SO strategies are the strategies which tend to produce maximum benefits. WO strategies are strategies in which opportunities are used to reduce weaknesses. ST and SW strategies are essentially defensive strategies.

It is important to examine the resulting set of proposed strategies for consistency. Moreover it will often not possible to pursue all strategies and trade-offs are often required. Some of the strategies need to be tackled at the European level whilst others at the national and local FHS level. At all levels, priority should be given to strategies according to level of urgency, attractiveness, probability of success and the probability and severity of occurrence of negative effects on the role if the strategy is *not* adopted (Kotler & Murphy, 1981). Gordon et al (2000) suggest that one should choose strategies that would be "most feasible and most likely to promote positive change".

THE CASE STUDY STRENGTHS - WEAKNESSES THEME COLLECTION INSTRUMENT

Date: 30 04 05
Updates: 20 02 06

1. Country, University and FHS data

Variable	Data					
Country	**Country X**					
Name of University	**University Y**					
City	**City Z**					
HCP edu. to EHEA?	Yes	x	No			
Overall organiz. of HCP educ. in the country.	There is only one type of university - the traditional comprehensive university. Originally the universities offered only Masters programmes in medicine, dentistry and pharmacy. The new Bachelor based HCP have been integrated within the traditional faculties of medicine.					
Type of university	Traditional Comprehensive University	x	Medical University		University of Applied Sciences	
Uni. homepage	-					
Name of FHS	Faculty of Medicine					
FHS homepage						
FHS structure	Discipline based	x	Profession based			
FHS homepage						
Entry-level programmes offered	Masters: medicine, dentistry, pharmacy. Bachelors: physiotherapy, radiography-radiation therapy, nursing,					

2. BMPE organization, location within faculty structure and mission

<table>
<tr><th>Variable</th><th colspan="8">Data</th><th>S-W Themes</th></tr>
<tr><td>Is there a BMPE department?</td><td>Yes</td><td>x</td><td>No</td><td></td><td>If not, are there any BMPE educators?</td><td>Yes</td><td></td><td>No</td><td>The BMPE department is autonomous (S).</td></tr>
<tr><td>Name of BMPE dept.</td><td colspan="8">Medical physics. Similar depts. in the same country called biophysics or clinical physics.</td><td>Absence of a unique name (W).</td></tr>
<tr><td>Number of BMPE acad.</td><td colspan="8">4 full-time
Teach mostly students of medicine, dentistry and pharmacy. Two part-time BMPE employed separately by the department of radiography - radiation therapy and one part-timer by the department of physiotherapy to teach their own respective students.</td><td>BMPE are highly academically qualified and have extensive research experience compared to the new HCP; equally qualified and experienced with respect to the traditional HCP (S). Number is very low compared to other disciplines - caused mostly by role underload (W). Role fragmentation is a problem (W). There is a low level of collegiality and communication between BMPE educators - part-timers rarely meet the full-timers (W). There is no forum for curriculum development at the departmental level (W).</td></tr>
<tr><td>Dept. location in faculty structure</td><td colspan="8">One of fundamental science departments within the Faculty of Medicine.</td><td>There is little involvement in faculty educational affairs and this leads to a low level of influence on HCP curricula (W).</td></tr>
<tr><td>BMPE department homepage</td><td colspan="8">No departmental webpages</td><td>Indicates low marketing competences (W)</td></tr>
<tr><td>BMPE curriculum webpage</td><td colspan="8">No curriculum webpages</td><td>Indicates low importance given to education (W)</td></tr>
<tr><td>Mission</td><td colspan="8">No formal mission statement.</td><td>Absence of a unifying mission concept among the BMPE (W).</td></tr>
</table>

BMPE role as perceived by other HCP	The professions that are device intensive (radiography-radiation therapy and physiotherapy) are very receptive to BMPE input.	Device intensive HCP consider the BMPE educator as an asset and as highly competent in the field (S). There are serious problems with the curricular inputs to medicine and dentistry as they are not seen as relevant to the overall curricula (W). The pharmacy curriculum is perceived to be satisfactory.

3. Client Analysis: Extent of BMPE educator involvement in the COMPULSORY programme modules of the various HCP

Profession	**Module Information**			**BMPE ECTS**	**S-W Themes**
	Module Title	Year of Programme	Total ECTS		
Medicine	Medical physics	1	3	3	It seems that the BMPE contribution was higher in the past. Reduced recently owing to pressure on curriculum time and low relevancy of the material offered by the BMPE (W). Medicine is a large and powerful group within the faculty and should be given more attention. Indication of low strategic planning competences (W).
Dentistry	Medical physics	1	3	3	Comments similar to medicine.
Pharmacy	Physics	1	4	4	The title of the module does not reflect a biomedical physics-engineering approach (W).
Radiography - Radiation Therapy	Ionizing radiation physics Radiation protection I Ultrasound imaging Ionising radiation imaging and therapy devices Radiation protection II	1 1 2 1 & 2 3	4 2 2 8 4	4 2 0.2 2 4	Strict legal requirements protect the radiation protection (RP) component of the role (S). On the other hand owing to the pressure exerted by outside RP accredit. agencies the BMPE prefer to limit their role solely radiation protection (and the underlying basic ionizing radiation physics). As a result non-ionizing imaging device physics (e.g., ultrasound, MRI) and a significant part of ionizing rad. imaging and

					therapy devices are taught by non-BMPE leading to role underload (W).
Physiotherapy	Electrotherapy Biomechanics	1 - 3 1	3 2	3 0	Biomechanics was previously taught partly by BMPE, now totally serviced by anatomy, a case of role overlap in the past and subsequent role substitution - indicating insufficient reflection on role complementarity and core competences (W).
Nursing	No BMPE input	-	0	0	Nursing is by far the biggest HCP within the faculty; the lack of BMPE input is a missed opportunity and indicates lack of strategic planning, particularly at a time when there is extensive role development within the nursing profession (W).

4. BMPE curriculum content analysis - COMPULSORY modules (in units of ECTS credits)

Module Title	BMPE Content Area																				S-W Themes
	general non-applied physics	biomolecular and cellular science	physical biochemistry	biophysical devices	biomechanics	cardiovascular haemodyn.	biophysics of perception	electrophysiology	signal-processing	physiological measurement devices	Microscopy (including modern microscopy devices)	biomedical laboratory devices	laser based biomedical devices	rehabilitation devices	biomedical imaging devices	radiotherapy devices	electrotherapy (current, SW, US)	safety (rad. protection and dosim.)	safety (physical agents other than ionising radiation)	other (modeling, cybernetics , prosthetic devices and others)*	
Medical Physics (med.)	0.1	0.1	0.1	0.3	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3			0.5	0.1	0.1	0.1	0.1		The medical curriculum exemplifies the 'physics is the basis of all things' approach. The approach is the result of pride in the discipline which of course is a very positive factor (S), however the time constraints imposed by a bursting curriculum leads to shallow learning with little practical clinical application (W).
Medical physics (dent.)		0.1		0.3	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3			0.5	0.1	0.1	0.1	0.1	0.2	The dentistry curriculum is the same as that for medicine (the two groups are taught together), some added biomaterials for dental prosthetic medical devices. Separate teaching would produce a more relevant curriculum for both groups (W).

Physics (pharmacy)		0.5	0.3	1				0.1	0.5	0.1	0.3	1						0.2			Too much basic non-applied physics. Biomolecular and cellular science and physical chemistry overlap with the physiology and chemistry curricula. Indications of insufficient reflection on role complementarity and core competences (W).
Ionizing rad physics															2	2					Mostly radiation physics for radiation protection, little on devices, role underload (W).
Radiation protection I																		2			
Ultrasound imaging															0.2						Very low ultrasound input (W).
Ionizing rad imag & RT																2					
Radiation protection II																		4			
Electrotherapy																	2		1		Emphasis on safety indicates awareness of topical issues (S).
Totals (ECTS units)	0.1	0.7	0.4	1.6	0.2	0.2	0.4	0.5	0.9	0.5	0.7	1.6	0	0	3.2	4.2	2.2	6.4	1.2	0.2	

5. BMPE curriculum content analysis - ELECTIVE modules (in units of ECTS credits)

Profession	Module Information			BMPE Involvement		S-W Themes
	Module Title	Year of Programme	Total ECTS	Description of BMPE Involvement	BMPE ECTS	
Medicine	Radiation protection	5	2	Module offered entirely by BMPE dept	2	The Electives offer is on the whole poor and does not help to expand and publicize the role as it is limited to radiation protection only (W).
Dentistry	Radiation protection	5	2	Module offered entirely by BMPE dept	2	

6. Role expansion opportunities: Programme modules which would be enhanced through the involvement of a BMPE educator

Profession	Module Information			BMPE Involvement	S-W Themes
	Module Title	Year of Programme	Total ECTS	Description of possible BMPE involvement	
Medicine	Various	3 - 5	Var.	Several modules involve the use of devices and provide ample opportunity for the BMPE to expand his role.	Many opportunities for role expansion particularly in the medicine and radiography-radiation therapy programmes are being lost indicating low strategic planning competences and low importance given to the educator role when compared to the discipline research role. Indicates inadequate role-balance (W).
Radiography - Radiation Therapy	Nuclear medicine	3	4	More involvement in devices would be appropriate.	
Radiography - Radiation Therapy	Magnetic resonance imaging	3	2	Devices and safety.	
Radiography - Radiation Therapy	Quality Assurance	3	2	The BMPE can help improve the module by contributing to quality control of devices.	
Pharmacy	Radiopharmacy	4	4	The BMPE can contribute to radiopharmacy devices and radiation protection in the radiopharmacy.	
Nursing	Various	1-3	Var.	Several modules involve the use of devices and provide ample opportunity for the BMPE to expand his role.	

7. Curriculum development (CD) themes within the FHS impacting the BMPE role

CD Component	Themes	S-W Themes
Philosophy	Competence-based-education, practice-based-learning, evidence-based-healthcare, active learning, importance of generic competences, context-based-learning (‘the way things are done, the way people work together, the circumstances’)	No research has been carried out by BMPE regarding such issues (W).
Content	Very profession specific	Very little research work has been carried out by BMPE re profession specific content (W).
Delivery	Extensive use of problem-based-learning (one case per week), extensive use of ICT resources (intranet, computer lab), integrated module based, cooperative-learning strategies, active learning .Inter-professional education being planned.	BMPE have a good background in ICT use (S). Few BMPE teaching resources are available, none for PBL, inter-professional learning, should be a priority area for future research (W).
Learning Resources	Amazing onsite skills-labs.	Self-imposed role limitations on the role means the available resources are not utilized by the BMPE (W).
Assessment	‘To test student competences in authentic and realistic situations’ (Ref: assessment regulations document), criterion-referenced assessment	No BMPE competence-based-assessment tools available (W).

8. Exemplars of good BMPE curricular practice

CD Component	Exemplars of Good Practice	S-W Themes
Philosophy	The physics is spread throughout the course and is integrated with other subjects in the case of both radiography - radiotherapy and physiotherapy. This ensures that students appreciate the relevance of the material covered for their particular profession and the physics is delivered as needed.	There is a lot of good practice in radiography - radiotherapy and physiotherapy (S). This is in sharp contrast to the BMPE curricula for medicine and dentistry (see above).
Content	In the case of RP the objectives set up by the BMPE follow stipulated guidelines set up by the national RP agency.	
Delivery	Radiography: specially designed RP practicals, specific RP calculations sessions to improve math skills.	
Learning Resources	Purposely written readers make up for inadequacies in textbooks. Easy availability of national legislation and EU directives and documentation regarding RP for students.	
Assessment	Tests are school based and approved by the national RP agency. They include both a multiple-choice test which covers the whole syllabus and a separate paper consisting of a set of in-depth open-book calculation questions. Students are specifically trained for these calculations.	

9. Research carried out by the BMPE:

Research Area	Description	S-W Themes
Discipline research themes	The BMPE mostly carry out research work in areas of physics related to the professional subject area of the school in which they teach (e.g., radiation protection in the case of Radiography - Radiation Therapy).	BMPE have been educated at trad. research oriented depts. -they have more research experience than the HCP particularly in medical device based research (S).
Educational research themes	BMPE seems to give little importance to educ. research.	BMPE have little research experience in the educational and social sciences which are essential for education research (W).

10. Miscellaneous:

Theme	Description and Comments	S-W Themes
-	-	-

11. Verbatim quotes:

"Our BMPE educator is very responsive to our requirements. He is also very proactive. When all this talk of patient safety started in the media he immediately suggested that we include it in the curriculum, which of course we accepted immediately" (physiotherapy programme leader)

"We always turn to our physics colleague whenever we need advice regarding imaging devices and radiation protection particularly when we are doing research. We have not a lot of experience when it comes to research" (radiography programme leader)

"Teaching to non-physicists with their much lower physics and mathematical abilities is not 'real' physics and not as satisfying as teaching physics or engineering to physics or engineering graduates" (BMPE member of staff teaching in medicine)

"What is the point of preparing a lot of lectures when they can then be abolished by the stroke of a pen, teaching what is required by law ensures that I do not carry out a lot of preparation for nothing" (BMPE member of staff teaching in radiography-radiation therapy)

4 STRENGTH - WEAKNESS THEMES FROM THE EUROPEAN SURVEY

4.1 OVERVIEW OF THE CHAPTER

This chapter first presents typologies of universities hosting FHS and FHS departmental structures that we have found in Europe. These typologies present the various contexts in which the BMPE educator functions and have a direct effect on the role. This is followed by a description of the universities and FHS forming the sample. The internal strengths and weaknesses of the role identified during the qualitative survey are then presented and discussed.

4.2 TYPOLOGY OF UNIVERSITIES IN EUROPE HOSTING FHS

Three main types of universities hosting FHS have been identified:

a) The Comprehensive University (CU): This type of university is the traditional university and the FHS is one of many faculties which altogether cover most areas of knowledge. The FHS in this type of university traditionally only offered programmes in medicine, dentistry and pharmacy. In some of these universities the professions are housed within a single faculty (often still known by its traditional name as Faculty of Medicine) whilst in others each profession has a separate faculty. Some of these universities now also offer programmes in the newer HCP either based within the medical faculty itself or within a separate institute or college. These universities are traditionally very research oriented and tend to give less importance to education. However these FHS are coming under increased pressure from political, economic and social forces to improve the educational quality of the programmes they offer. The Comprehensive University is still the most common type of university in Europe.

b) The Medical University (MU):
This type of university consists essentially of a single institution dedicated to healthcare studies. Again these originally only offered medicine, dentistry and perhaps pharmacy programmes but most of these now also offer programmes in the newer HCP either based within the medical faculty itself or within a separate institute or college. This type of university seems to be on the increase as biomedicine expands and the number of medical specializations and HCP mushroom (e.g., The Medical University of Vienna, formerly the Faculty of Medicine of the University of Vienna, became an independent university on January 1, 2004. The independence of medical schools from comprehensive universities was part of a larger reform of the Austrian university system enacted in 2003).

c) Universities of Applied Sciences (UAS): These have been set up more recently in many countries in Europe (UK, NL, DE, AT). They are more professional practice oriented and often include only the new HCP. There is however a significant effort to increase research activity. Their numbers is continuously on the increase and the number of students in their healthcare faculties often far outnumbers the number in medical faculties within traditional universities.

The type of university has a direct influence on the BMPE educator role as explained later on in this chapter.

4.3 TYPOLOGY OF FHS DEPARTMENTAL STRUCTURE

Two general types of FHS departmental structural models have been identified:

a) Discipline Based (DB) departmental model: In this model the FHS consists of both professional discipline departments (e.g., medicine, dentistry, pharmacy, nursing, physiotherapy, radiation therapy) and fundamental biomedical science discipline departments (e.g., anatomy, physiology, pathology, biochemistry, epidemiology, BMPE). All departments are expected to contribute to the various undergraduate professional programmes as required by the various HCP curricula. The BMPE is often a fundamental biomedical science department and not a professional department within these faculties as programmes for the BMPE profession itself are normally hosted in faculties of physics or engineering (either within the same university or within separate universities of technology). In this type of FHS there is a balance of influence on curricular affairs between the professional departments and the fundamental biomedical science departments. This type of departmental structure is usually found in the Comprehensive and Medical universities.

b) Profession Based (PB) departmental model: In the second model fundamental biomedical science departments do not exist and the faculty consists entirely of professional discipline departments. In this type of FHS, fundamental biomedical science academics (including BMPE) are employed independently as necessary by the various professional departments and form part of that profession specific department (or shared in an agreed manner by several professional departments). In this type of FHS structure policy and curricula are mostly determined by the professional discipline departments. This type of structure is usually found in the Universities of Applied Sciences.

The two types of structures are shown diagrammatically in Fig 4.1 and Fig 4.2. Between these two structural poles one finds many variants which are largely determined by local policies.

The FHS departmental structure has a direct influence on the BMPE educator role. In the case of the discipline based departmental structure the BMPE educators are organized within a formal department. This brings enhanced prestige, collegiality and higher opportunities to influence the curriculum. However there can be negative aspects particularly if the BMPE do not involve themselves sufficiently in practice-oriented HCP curriculum development. In the case of the profession based departmental model the BMPE is often employed to deliver pre-specified curricula which have been determined by the professions. This often means that there is little leeway in curricular affairs. However on the plus side, such educators can have a much more engaging relationship with the HCP and often produce more appealing practice-oriented teaching. One should perhaps here add that it is possible to have a rewarding teaching experience in any type of department provided one can strike the right positive balance between one’s own physics-engineering interests and the learning needs of the HCP.

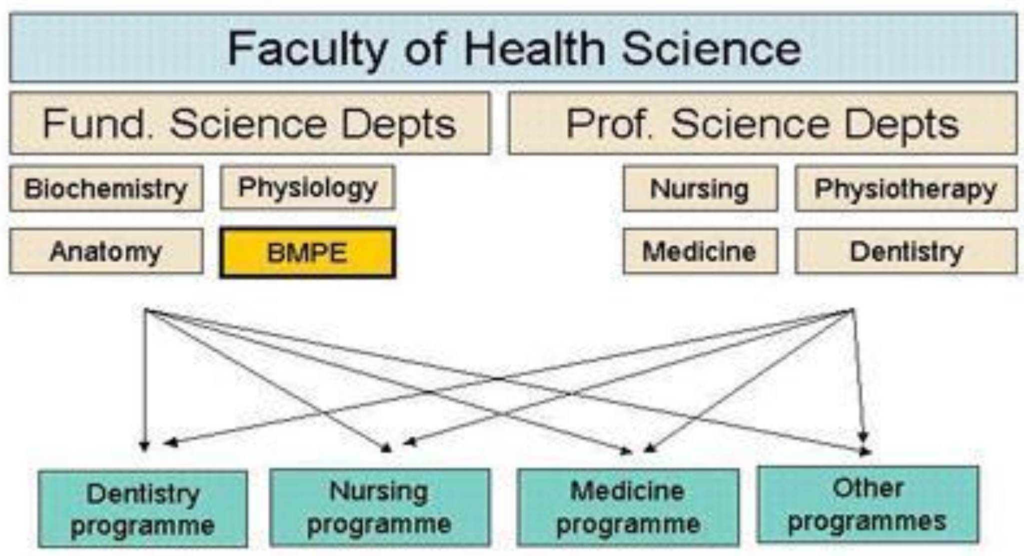

Fig 4.1: Role position of the BMPE in a Discipline Based FHS structure.

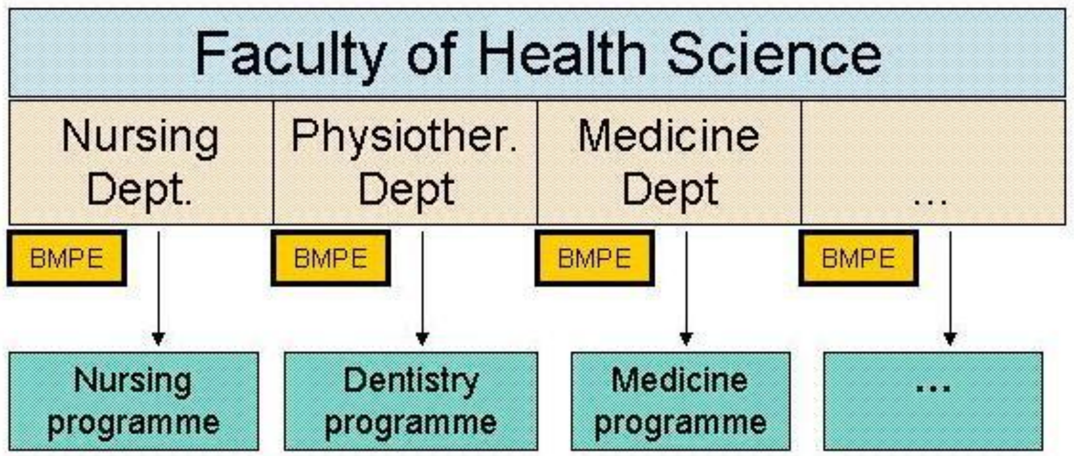

Fig 4.2: Role position of the BMPE in a Profession Based FHS structure.

4.4 SURVEY UNIVERSITIES AND FHS

The list of universities and faculties surveyed is shown at the end of the chapter. The table gives the country, name of university, type of university, name of faculty, faculty code as used in this study and type of faculty departmental structure. The total number of universities surveyed was 67. The distribution of universities by type in the sample is shown in Table 4.1. In general FHS within comprehensive universities and medical universities had a discipline-based structure whilst FHS in the newer Universities of Applied Sciences had a profession-based structure. Some comprehensive universities and medical universities had discipline-based structures for the medical, dental and pharmaceutical faculties and a profession-based structure for separate institutes housing the newer HCP.

Type of University	Number in sample
Comprehensive Universities	47
Medical Universities	7
Universities of Applied Sciences	13
Total number of universities	67

Table 4.1: The distribution of universities by type in the sample.

4.5 STRENGTHS OF THE ROLE

The following are the strengths of the role as elicited from the survey of European BMPE entities.

S1) Highly qualified academics

Physics and engineering have been established within HE for a much longer time than most HCP programmes (with the exception of medicine, dentistry and perhaps pharmacy). Some BMPE academics are therefore heavily involved in helping the new HCP in the transition of educational programmes from non-HE to HE. This is particularly true in the setting up of the curricula for those HCP which are device intensive (e.g., radiation therapy, radiography, physiotherapy). Wherever BMPE academics have used this superior academic background in a positive manner in their dealings with other HCP within the faculty they are highly respected members of the academic staff.

S2) High level of subject pride

BMPE academics have enormous pride in their subjects. This is a very positive factor that we have found throughout practically all the universities we have studied and visited. It is a feeling based on an awareness of the achievements of physics and engineering throughout the last century, including the achievements in biomedicine. This often translates into more enthusiastic teaching.

S3) High esteem for BMPE amongst HCP

A common theme particularly among HCP educational leaders that we have talked to was the high standing with which these professions regard physics and engineering. In the words of one physiotherapy educational leader “Although we are having a lot of difficulties with the quality of the servicing of physics we insist on keeping it in the curriculum as it looks good on our curriculum document and on the *curriculum vitae* of the students”.

S4) Strong medical device competences

BMPE educators have a level of expertise regarding the underlying principles of the scientific, effective, safe and efficient use of medical devices which is vastly superior to that of the other HCP. Essential device processes like the evaluation of device specifications, calibration, considerations of accuracy and precision, statistical analysis of data, quality control and others which are so important within the clinical environment (where often the patient's health is at stake) are second nature to the BMPE. This is not so in the case of the other HCP in whom these competences are often sorely lacking. We have therefore invariably found that this device expertise is highly sought after by the HCP. In the words of one radiography leader: "My understanding in a few words of the role of a medical physicist associated with radiography: in the production of optimized diagnostic images there are two complementary fields: complex physical theories underpinning practices and the radiation delivery producing images in a safe and effective way. The physicist is the interface between these two areas …. whenever I have a problem or I am unsure of which radiation dosemeters are best to use in a given circumstance I always turn to my physics colleague. This not only ensures that my readings would be accurate and precise but also saves me a lot of time, as it would take me several weeks of background physics reading to do it myself. I see it as a good opportunity for academic team-working" The wide scientific physical knowledge base of physicists and engineers leads to a high capability of early adoption and application of new devices. In the case of magnetic resonance imaging for example BMPE staff had to be employed for teaching, as the principles underlying the technology were completely new to all the other HCP. As another radiography leader told us "When MRI was developed we wanted to introduce it into our curriculum, yet none of us could understand the principles. Nuclear spin was a new concept for us. Our physicist came to the rescue! The same is happening at present in the emerging areas of optical and fluorescence imaging". One ex-BMPE educator we interviewed and who has published one of the most widely read internationally acclaimed standard books of radiological physics suggested that what needs to be done is to "study what we have done in the case of medical imaging and radiotherapy devices and then apply the same principles in the development of curricula for the other HCP". Some BMPE departments are recognizing the importance of medical devices in modern healthcare by setting up new undergraduate programmes in the area of medical device technology.

S5) Strong competences regarding safety with regard to *physical* agents

BMPE educators are strongly positioned with respect to other roles to teach protection from physical agents (electrical, electromagnetic, ionizing radiation, thermal, laser etc) for both patients and HCP. Such safety measures are used constantly in physics and engineering laboratories. They are also increasingly required in the clinical areas as the emphasis on patient and occupational safety increases. Training in some areas is already required by law as a result of European directives (e.g., ionizing radiation protection curricula for radiography, radiation therapy and dentistry). Moreover the number of directives in this section of BMPE expertise is expected to increase. Curricula which are based on legal requirements have the advantage of direct relevancy and also promote role protection. Proactiveness by BMPE educators in curriculum development in the area of patient and occupational safety and protection from the deleterious effects of physical agents on the human organism is highly appreciated by the HCP. As one physiotherapy programme leader told us “Our BMPE educator is very responsive to our requirements. He is also very proactive. When all this talk of patient safety started in the media he immediately suggested that we include it in the curriculum, which of course we accepted immediately”

S6) Strong ICT competences

Education and healthcare are both increasingly ICT based and BMPE staff with their strong traditional ICT skills are well placed to take on these challenges. The BMPE is highly sought after in research in which programming skills are required and for teaching ICT skills to FHS students. BMPE are also using their ICT skills in the delivery of the curriculum. We have come across cases of use of multimedia rich presentations. Moreover many BMPE academics are increasingly being asked to use their ICT skills to produce multimedia and online teaching materials for the HCP. One of the BMPE educators we spoke to (E. Vano, Complutense University, Madrid) has produced a multimedia project for radiation protection training for interventional radiology for radiographers and radiologists with the help of EU funds (*Multimedia and Audio-visual radiation protection training in interventional radiology*, Office for the Official publications of the European Communities, Luxembourg). We have also found that often the installation of new hardware or software or the updating of existing ICT facilities within the FHS is entrusted to BMPE academics. This is particularly true in those FHS where there are no separate departments of health informatics.

S7) Strong research competences

Many BMPE have very strong research records as most of them have been educated in traditional research oriented physics or engineering departments within traditional research oriented comprehensive universities. This makes make them highly suitable for undertaking clinical research - in particular when the research is biomedical device or modeling based. Moreover as biomedical research is becoming increasingly quantitative and rigorous analysis of data fast becoming a condition for acceptance for publication of both clinical and research results, BMPE expertise is being increasingly sought after. The highly conceptual and mathematical nature of physics and engineering education leads to strong analytical competences that put the BMPE academic in a strong position to be able to conduct also research studies in educational processes which are based on cognitive science. This is possible provided the BMPE academic comes to term with the fact that biomedical and educational research often involve a substantial amount of quasi-experimental and non-experimental research. In this type of ‘real world research’ variables are less under the control of the researcher than in physical sciences research.

BMPE academics also tend to have strong scientific and research norms and values. Such standards of behaviour are becoming increasingly important as the movements for ensuring that healthcare and educational practice become more evidence-based gain momentum all over Europe and globally. The insistence on rigour in instrument choice, data collection and analysis, which are the hallmark of the physical sciences, have often been in the past sadly lacking in the healthcare and educational spheres. The BMPE educator is therefore strongly positioned to promote such practices amongst the HCP in his teaching.

4.6 WEAKNESSES OF THE ROLE

The following are the weaknesses of the role as elicited from the survey of European BMPE entities.

W1) Absence of a clear mission and role ambiguity

There is clearly a lack of a well-defined, agreed role definition whilst mission statements are practically non-existent. In the absence of such a definition each BMPE educator practices according to his self-perceived role modulated to local expectations. We have noticed that the question "What do you consider to be your role in the education of HCP?" seems to put many BMPE academics off balance. Whilst the question "What do you think your role will be in the future?" produces even more difficulty. The result is a high level of role ambiguity. This is to be contrasted with anatomy, physiology, pathology and biochemistry that all have clear well known missions even when these are not formerly articulated.

W2) Inappropriate role boundaries

The self-perceived role varies enormously within Europe. In some BMPE departments the prevailing perspective are the very general "physics is the basis of all things including all areas of healthcare" or "the application of physics to healthcare" paradigms. Such standpoints which would appeal to physics audiences have little meaning to non-physicists who require seeing direct relevance of a particular subject to their future professional practice and who actively demand justification for its inclusion in an already congested curriculum. Such BMPE educators often set up curricula which involve a range of BMPE topics which is too wide - leading to role overload. In addition, owing to time constraints this extensive role boundary inevitably leads to shallow content which rarely leads to the point of significant clinical application. Consequently students get a feeling that the subject seems to be of little use in the clinical context. In the words of one BMPE academic of high international standing and who has worked a lot with HCP. "In attempting to show the wide relevance of physics in all areas of medicine some BMPE academics end up giving the opposite impression - that biophysics is everything and nothing" We have also encountered the other extreme. Some BMPE academics refuse to teach what does not have strictly established legal foundations (e.g., ionizing radiation protection) leading to role underload, contraction and impoverishment. Such academics justify their approach by stating: "what is the point of preparing a lot of lectures when they can then be abolished by the stroke of a pen, teaching what is required by law ensures that I do not carry out a lot of preparation for nothing". Another issue is that some BMPE academics do not involve themselves sufficiently in HCP student research.

W3) Absence of international networking

There is very little networking between BMPE educators at international levels (and in big states even absence at national levels). Europe is full of BMPE educators who work on their own with little feelings of international collegiality. The result is a professional group with little cohesiveness. The European Federation of Organizations for Medical Physics has no special interest group dedicated to the BMPE education of HCP. This is in direct contrast to other discipline groups. BMPE academics in some countries do organize meetings at which some papers with educational topics are presented (e.g., Days of Medical Biophysics in the Czech Republic, Meetings of the Collège National des Enseignants de Biophysique et de Médecine Nucléaire in France) however unfortunately proceedings are not published in the international literature, which means that any beneficial effect remains local.

W4) Absence of harmonization of curricular content

There is no international consensus (and often especially in the larger countries no national one either) over BMPE content for the HCP. Whilst in the case of other biomedical sciences there have been deliberate attempts at producing harmonized national and international curricula this has not happened in the case of BMPE. Even in states where the curriculum is specified by law (e.g., FR) there is a tendency in practice for the choice of topics to be based on the research interests of the particular academic or on personal subjective viewpoints. This contributes further to role ambiguity. On the international scale it is mostly an effect of W3.

W5) Absence of a unique name for the discipline

There is no internationally accepted unique name for the BMPE department. Some names we have encountered include Medical Physics, Biophysics, Biomedical Physics, Clinical Physics, Radiological Physics, Imaging Physics, Medical Engineering, Biomedical Engineering, Bioengineering, and Medical Technology. Names vary even within the same country and are often a reflection of the particular research emphasis of the department or of previous departmental history. This is in direct contrast to other fundamental biomedical sciences like anatomy, physiology and biochemistry which have single, unique internationally agreed and recognized names.

W6) Low awareness of importance of educational research

There is a low level of systematic curriculum development and pedagogical research and low awareness of the increased importance being given to quality in education. There is a lack of an overarching curricular framework based on systematic curriculum development and too much content is still based solely on personal opinion. As a consequence many curricula are not really clinical practice-oriented and do not address the learning needs of HCP students. The end effect is often an insufficient contribution to the outcomes described in HCP competence frameworks and not enough recognition that curriculum development for non-physicists requires a different approach than that for physicists. There is an absence of good textbooks specifically for undergraduate HCP students. Many books tend to be either magisterial books which are more meant to demonstrate the expertise of the author (and hence too complex for students) or simple

locally produced booklets and scripta with little appeal in terms of presentation. The BMPE textbooks available pale in comparison with what is available to other disciplines within the FHS. Most BMPE educators have not yet reacted sufficiently to modern developments in HE in general and HCP education in particular. Issues such as, integrated vs. discipline based curricula, problem-based vs. presentation based learning, outcome competence vs. discipline based curricula which have been on the HCP educational agenda for many years have not yet been incorporated into BMPE education.
Education at BMPE conferences (education for both HCP *and* BMPE itself) is given little priority, there is no journal dedicated to BMPE education research and BMPE journals do not promote educational research. This is in direct contrast to the other main biomedical science disciplines, which have journals specifically dedicated to education e.g., Advances in Physiology Education, Pathology Education, Biochemistry and Molecular Biology Education. These journals not only dedicate articles to education for students of the respective disciplines but also feature regular articles regarding education for the HCP, keeping members informed on an ongoing basis regarding developments in HCP education. There is no established forum in which BMPE education research can be published and disseminated and hence there is little incentive to conduct such research in the first place. There are only a handful of presentations regarding education of HCP at biomedical physics conferences. As a consequence of all this, the amount of teaching resources available for the BMPE educator is very low when compared to educators in other disciplines. Many disciplines have research groups dedicated to education with their own internet sites including repositories of resources for download. For example GRIPE (Group for Research in Pathology Education, was founded in 1971 at the University of Iowa. GRIPE has since then increased its membership to include 78 institutions and 236 individuals representing many different countries. The American Physiological Society has a similar 'Teaching of Physiology Section'.

W7) Low client group base

As a result of the traditional emphasis of BMPE on imaging and radiotherapy the customer base for BMPE education has been mostly restricted to students of radiation therapy, radiography and medicine (in the case of medicine BMPE is mostly restricted to the pre-clinical curriculum). This means that potentially large target groups like physiotherapists and nursing have been largely ignored. This puts the role at risk. If traditional customer segments decide to drop BMPE from the curriculum there are no ready alternative client groups - leading to a reduced need for the employment of BMPE academics. This has already happened in some European states (e.g., in the UK the role in medicine has been lost). It is encouraging to note that in other countries BMPE educators are moving into new areas hence expanding their client base (e.g., audiology in NL).

W8) Insufficient reflection on core competences

In some countries there is significant curriculum and consequently role overlap with other roles particularly with physiology and sometimes anatomy (e.g., basic biomolecular physics, cellular processes, physiological physics, physics of the senses, biomechanics). This blurring of role boundaries can have positive effects particularly if it leads to more team-teaching and where the organizational culture perceives the two roles as complementary yet distinct. However it also indicates a lack of strategic thinking by BMPE educators regarding core competences and substitutability issues (i.e., where one role can be easily substituted by another). For example the overlap of roles with physiology has been observed to lead to negative effects. In some universities pressure on curriculum time led to BMPE being dropped from the curriculum with some leftover BMPE material included within the physiology component of the curriculum. The words ‘biophysics’, ‘medical physics’ and ‘biomedical engineering’ are sometimes still there, but teaching is done by members of the physiology department! In some cases the word ‘physics’ disappeared totally from the curriculum - a disservice to both the BMPE community and to the students, who will never have the opportunity to experience a worldview from a physicists’s perspective. In other cases BMPE has ended up simply as a preparatory subject to physiology. For example in Germany the Bundesministerium fur Gesundheit *Approbationsordnung fur Artze,* which is the statutory document specifying curriculum content for programmes in medicine speaks of ‘Physics *for* Physiology’. This is a tendency which ignores the fact that BMPE is a separate domain of professional biomedical science with its own distinct knowledge base - a knowledge base which would improve the scientific norms, effectiveness, safety and efficiency of HCP and hence the service to healthcare patients and other clients. The situation is also precarious when BMPE choose to teach content which can be better serviced by other roles. In some cases we have noticed that BMPE teach aspects of physiology which can be better delivered by physiology specialists (e.g., ophthalmic and audiological physiology). In such cases substitution of the BMPE role by other roles becomes the order of the day. Although rigid disciplinary boundaries should not be unduly emphasized in intrinsically multi-disciplinary programmes such as HCP programmes, yet major overlap may lead to easy substitution. Moreover from an organizational point of view role significant overlaps represent a waste of FHS resources. The BMPE educator should strive towards role complementarity and avoid role overlap within the FHS.

W9) Low educator competences

The educator role requires a different set of competences than the other academic component roles and many BMPE educators lack educator competences. This is a crucial weakness which needs to be addressed if BMPE educators are to be able to take up the educational opportunities available and play an active part in present educational developments in Europe. There is an attitude common among some BMPE academics that the educator role is not as important as other roles particularly the discipline research role. This often leads to low teaching levels and reputation and an impression amongst HCP that the subject is extraordinarily difficult. In some countries this has had led to a fear of the subject which manifests itself as a resistance to its introduction into HCP curricula.

W10) Small or absent departments

In the case of the traditional Comprehensive Universities, BMPE departments within the FHS are small with respect to other biomedical sciences (many departments consist of a handful or even one individual). In some traditional universities physicists-engineers are dispersed in various FHS departments (e.g., radiology, physiology, biomolecular science). Often this leads to a very low level of influence on faculty policy. In FHS with a profession-based departmental structure the faculty structure precludes the existence of a

BMPE department. BMPE are recruited by the various health professions and are members of the department of that particular HCP.

W11) Low strategic planning, marketing and publicizing competences

BMPE professionals and academics have low planning, marketing and publicizing competences - they are either unable or perhaps unwilling to analyze, develop, publicize and ‘sell’ their services. Basic planning and marketing strategies like client and portfolio analysis which should be done on a proactive and ongoing basis are rare and often only carried out after the curriculum slice awarded to BMPE comes under fire from other roles within the faculty! Even within hospitals publicizing of the role amongst other HCP is practically non-existent! Most HCP in many European hospitals do not know that there is a BMPE department within the hospital - let alone the role of the department! This contrasts with other HCP groups that are actively using all available opportunities to advertise their profession. As most HCP do not have a clear idea what BMPE do, their idea of BMPE education is formed by the physics they were taught in their pre-university education (mostly Newtonian mechanics and basic electromagnetism). The problem is also compounded by the fact that BMPE education programmes in most countries are not found within the FHS but in faculties of Physics or Engineering and often in Technical Universities (e.g., CZ, NL), so the HCP do not even know that a BMPE profession exists. All of this leads to consequences for the BMPE educator in the FHS, as HCP leaders who often come from a clinical background do not know what expectations they can have of the role when they transfer to academia. This leads to the absence of a universally known referral protocol (i.e., when should HCP curriculum planners ask for BMPE services?).

W12) Role conflict between the self-perceived role and the role expectations of the HCP

It is important for BMPE academics to realize that when a physicist or engineer moves from a physics or engineering department to the FHS his role set changes and consequently so do role expectations. Unfortunately owing to the low importance given to education among BMPE, there exists no help to facilitate this necessary and often difficult role transition. There is no literature to help the new BMPE in this psychological paradigm shift. When this shift is unresolved at the personal level by the BMPE there is a feeling that “teaching to non-physicists with their much lower physics and mathematical abilities is not ‘real’ physics and not as satisfying as teaching physics or engineering to physics or engineering graduates”. This attitude is very detrimental to the profession and has sometimes led to uncalled for friction between BMPE and the HCP. The result of all this is often role conflict between the self-perceived role and the role expectations of the HCP.

W13) Low competences in the social sciences and management

The BMPE is often ill-equipped to shift to a multiprofessional milieu where sociological, psychological and people management competences are as important as physics-engineering competences for both day-to-day work and role development. This is a weakness of traditional physics-engineering educational programmes.

W14) Low awareness of the ethical and humanistic aspects of healthcare

Healthcare is a highly ethical and humanistic endeavour. It is important for BMPE academics to keep in mind that when one moves to healthcare one is using his skills for humanistic reasons, that is to improve the healthcare of the community. Some BMPE fail to develop sufficient competences in the ethical and human disciplines and are sometimes perceived as being too 'technical'.

LIST OF CASE STUDY UNIVERSITIES AND FACULTIES

Country	Name of University	Uni. Type	Name of Faculty	Fac. Code	Fac. Type
Austria	Medizinische Universität Wien	MU	Medizinische Universität Wien	AT1	DB
Belgium	University of Ghent	CU	Fac. of Medicine and Health Sciences Fac. of Pharmaceutical Sciences	BE1 (1) BE1 (2)	DB DB
	University of Antwerp	CU	Fac. of Medicine Fac. of Pharmaceutical, Biomed. and Veterinary Sciences	BE2 (1) BE2 (2)	DB DB
	European University College, Brussels (EHSAL, Brussels)	UAS	Healthcare Professions Division	BE3	PB
Cyprus	University of Cyprus	CU	There is no medical faculty in Cyprus.	-	-
Czech Rep.	Charles University	CU	First Fac. of Medicine - Prague Second Fac. of Medicine - Prague Fac. of Pharmacy - Hradec Králové	CZ1 (1) CZ1 (2) CZ1 (3)	DB DB DB
	Masaryk Uni., Brno	CU	Fac. of Medicine	CZ2	DB
	Palacký Uni., Olomouc	CU	Fac. of Medicine and Dentistry	CZ3	DB
	Uni. of South Bohemia, České Budějovice	CU	Fac. of Health and Social Sciences	CZ4	DB
Denmark	Kobenhavns Universitet	CU	Faculty of Health Sciences	DK1	DB
	Sundheds CVU Nordjylland, Aalborg (CVU= Uni. College)	UAS	Single entity.	DK2	PB
Estonia	University of Tartu	CU	Faculty of Medicine	EE1	DB
	Tartu School of Health Care	UAS	Tartu School of Health Care	EE2	PB
Finland	University of Helsinki	CU	Fac. of Medicine	FI1	DB
	University of Oulu	CU	Fac. of Medicine	FI2	DB
	Oulu Polytechnic	UAS	School of Health and Social Care	FI3	PB
France	Université Pierre et Marie Curie (Paris VI)	CU	UFR Médecine Pitié - Salpêtrière UFR Stomatologie et chirurgie maxillo-faciale	FR1 (1) FR1 (2)	DB DB
	Uni. René Descartes (Paris V)	CU	Faculté de Médecine Faculté de Chirurgie Dentaire Fac. des Sciences Pharmaceutiques et Biologiques de Paris UFR Biomédicale des Saints-Pères	FR2 (1) FR2 (2) FR2 (3) FR2 (4)	DB DB DB DB
	Uni. Claude Bernard (Lyon I)	CU	UFR Médecine Grange Blanche Institut Pharmacie (ISPB) UFR Odontologie	FR3 (1) FR3 (2) FR3 (3)	DB DB DB
	Lycée Guy Mollet, Arras	UAS	Sect. Enseignement Professionnel	FR4	PB
Germany	University of Erlangen - Nuremberg	CU	Faculty of Medicine	DE1	DB
	Humboldt University and Free University, Berlin	CU	Medical University - Die Charité	DE2	DB
	University of Aachen (RWTH-Aachen)	CU	Faculty of Medicine	DE3	DB
	IB Medical Academy	UAS	Schools for various healthcare professions.	DE4	PB
Greece	University of Athens	CU	School of Health Sciences	GR1	DB

	University of Patras	CU	School of Health Sciences	GR2	DB
Hungary	Semmelweis University, Budapest	MU	Faculty of Medicine Faculty of Dentistry Faculty of Pharmacy College of Health Care	HU1 (1) HU1 (2) HU1 (3) HU1 (4)	DB DB DB PB
	University of Debrecen	CU	Medical and Health Science Center	HU2	DB
Ireland	University College Dublin	CU	College of Life Sciences	IE1	PB
	Trinity College Dublin	CU	Faculty of Health Sciences	IE2	DB
Italy	Universita' degli Studi di Roma (La Sapienza)	CU	Prima Facolta' di Medicina e Chirurgia Facolta' di Farmacia	IT1	DB
	Universita' degli Studi di Milano	CU	Facolta' di Medicina e Chirurgia Facolta' di Farmacia	IT2 (1) IT2 (2)	DB DB
	Universita' degli Studi di Pisa	CU	Facolta' di Medicina e Chirurgia Facolta' di Farmacia	IT3 (1) IT3 (2)	DB DB
	Universita' degli Studi Federico II, Napoli	CU	Facolta' di Medicina e Chirurgia Facolta' di Farmacia	IT4 (1) IT4 (2)	DB DB
Latvia	Latvian Academy of Medicine (now known as Stradina University, Riga)	MU	Faculty of Medicine Faculty of Dentistry Faculty of Pharmacy Faculty of Rehabilitation Faculty of Nursing Faculty of Public Health	LV1 (1) LV1 (1) LV1 (1) LV1 (1) LV1 (1) LV1 (1)	DB DB DB DB DB DB
	University of Latvia, Riga	CU	Faculty of Medicine	LV2	DB
Lithuania	Kaunas Uni. of Medicine	MU	Kaunas Uni. of Medicine	LT1	DB
	Vilnius University	CU	Faculty of Medicine	LT2	DB
Luxemb.	Université du Luxembourg	CU	Faculté des Sciences, de la Technologie et de la Communicat.	LU1	DB
Malta	University of Malta	CU	Faculty of Medicine and Surgery Faculty of Dental Surgery Institute of Health Care	MT1 (1) MT1 (2) MT1 (3)	DB DB PB
Netherl.	Universiteit van Amsterdam	CU	Academic Medical Center Academic Center for Dentistry in Amsterdam (shared with Vrije Uni.)	NL1 (1) NL1 (2)	DB DB
	Vrije Universiteit, Amsterdam	CU	Faculty of Medicine	NL2	DB
	Universiteit Maastricht	CU	Faculty of Medicine	NL3	DB
	Fontys University of Applied Sciences, Eindhoven	UAS	School of Nursing School of Paramedics	NL4 (1) NL4 (2)	PB PB
Poland	Medical University of Warsaw (MUW)	MU	First Medical Faculty Second Medical Faculty Faculty of Pharmacy Faculty of Health Sciences	PL1 (1) PL1 (2) PL1 (3) PL1 (4)	DB DB DB DB
	Jagiellonian Uni., Krakow	CU	Faculty of Medicine Faculty of Pharmacy Faculty of Health Care	PL2 (1) PL2 (2) PL2 (3)	DB DB DB
	Medical Uni. of Gdańsk	MU	Faculty of Medicine (Subfaculties of Dentistry, Nursing, Health) Faculty of Pharmacy Faculty of Biotechnology	PL3 (1) PL3 (2) PL3 (3)	DB DB DB
Portugal	Universidade de Lisboa	CU	Faculdade de Medicina Faculdade de Farmácia Faculdade de Medicina Dentária	PT1 (1) PT1 (2) PT1 (3)	DB DB DB
	ESTES - Lisboa	UAS	Single entity.	PT2	PB
	Universidade de Coimbra	CU	Faculdade de Medicina Faculdade de Farmácia	PT3 (1) PT3 (2)	DB DB

	ESTES - Coimbra	UAS	Single entity.	PT4	PB
Slovakia	Univerzity Komenského, Bratislava	CU	Faculty of Medicine Faculty of Pharmacy	SK1 (1) SK1 (2)	DB DB
	Univerzity Pavla Jozefa Šafarika, Košice	CU	Faculty of Medicine	SK2	DB
Slovenia	University of Ljubljana	CU	Faculty of Medicine Faculty of Pharmacy University College of Health Studies	SI (1) SI (2) SI (3)	DB DB PB
Spain	Complutense University, Madrid	CU	Faculty of Medicine Faculty of Pharmacy Faculty of Odontology University School of nursing, physiotherapy and podology University School of optics and optometry	ES1 (1) ES1 (2) ES1 (3) ES1 (4) ES1 (5)	DB DB DB PB PB
	Universitat de Barcelona	CU	Facultat de Farmàcia Facultat de Medicina Facultat d'Odontologia Escola Universitària d'Infermeria	ES2 (1) ES2 (2) ES2 (3) ES2 (4)	DB DB DB PB
	Universidad de Murcia	CU	Facultad de Medicina Escuela Universitaria de Enfermería	ES3 ES3	DB PB
Sweden	Karolinska Institutet, Stockholm	MU	Karolinska Institutet, Stockholm	SE1	DB
	Lund University	CU	Faculty of Medicine	SE2	DB
	Jönköping University	UAS	School of Health Sciences	SE3	PB
United Kingdom	University College London	CU	Faculty of Clinical Sciences Faculty of Life Sciences Eastman Dental Institute for Oral Health Care Sciences	UK1 (1) UK1 (2) UK1 (3)	DB DB DB
	University of Leeds	CU	Faculty of Medicine and Health	UK2	DB
	University of Dundee, Scotland	CU	Faculty of Medicine, Dentistry & Nursing	UK3	DB
	Cardiff University, Wales	CU	College of Medicine, Biology, Life and Health Sciences	UK4	DB
	University of Salford	UAS	Faculty of Health and Social Care	UK5	PB
	De Montfort Uni., Leicester	UAS	Fac. of Health and Life Sciences	UK6	PB
	University of Ulster, N. Ireland	UAS	Faculty of Life and Health Sciences	UK7	PB

5 OPPORTUNITY - THREAT THEMES FROM THE EXTERNAL ENVIRONMENTAL SCAN

5.1 OVERVIEW OF THE CHAPTER

This chapter will present and discuss the results of the external environmental scan for opportunities and threats to the role as identified through a systematic document analysis of the relevant HE and HCP literature. Both opportunities and threats have been classified under standard PEST thematic categories.

5.2 OPPORTUNITIES FOR THE ROLE

Political

O1) EU goal of facilitating worker mobility within Europe: The European Higher Education Area and the internationalization of curricula

On 24 March 2000, in Lisbon, the EU Council declared that a strategic goal for the union would be to become the most competitive and dynamic knowledge-based economy in the world. Faciltating worker and researcher mobility through the creation of a European Higher Education Area involving the greater harmonization of HE qualification systems and curricula is an essential pre-requisite to achieving this goal. It has been emphasized however that harmonization does not mean uniformity, as the diversity of European HE is one of its greater assets (Froment, 2003). The Tuning Educational Structures in Europe initiative is based on the establishment of a three-cycle (Bachelor - Master - Doctorate) system and common agreed programme outcomes. The EU Commission is financing the initiative and many HCP networks are being set-up. It is the perfect opportunity for working on the much needed international networking and international harmonization of BMPE curricula (W3 and W4).

O2) Ensuring EU competitivity: The European Research Area and the need for new undergraduate programmes

Another issue which is undermining Europe's ability to compete globally is the lack of support that basic research has been given in the recent past. The setting up of the European Research Area is the commission's response to the problem. Europe is lacking basic science researchers - the researchers who would ultimately lead the research-and development necessary to lead to new healthcare technologies. Health is one of the priority research themes for the EU and the opportunities for the BMPE are there for all to see. In the document 'Proposal for a Council Decision concerning the Specific Programme "Cooperation" implementing the Seventh Framework Programme (2007-2013) of the European Community for research, technological development and demonstration activities' (Brussels, 21.9.2005 COM (2005) 440) under the theme 'Health' the Commission unequivocally states that:

“The focus will be on a multidisciplinary approach integrating areas such as: molecular and cellular biology, physiology, genetics, *physics*, chemistry, *nanotechnologies, microsystems, devices* and *information technologies*” (our emphasis)

Some BMPE departments within FHS are setting up new programmes to address the need for medical device scientists. The BMPE with his experience in both basic science and applied research is very well poised to take on the challenge to prepare students for future multi-disciplinary healthcare research. This is an opportunity for the BMPE educator to expand his client base by encouraging the setting up of new professions which fit with his competences.

O3) EU directives: medical devices and safety from *physical* agents

The EU has set out several directives regarding medical devices, safety from physical agents and the use of personal protective equipment which are binding on all states. Three directives cover medical devices in general, in-vitro medical devices and active (i.e., requiring an energy source) implantable medical devices (EC, 1990, 1993, 1998a). These directives coupled with the many reports in the literature regarding medical device adverse incidents, inadequate medical device education and the stress experienced by HCP owing to fear of being unable to use medical devices properly (Barnard, 2000; McConnell, 1998, 1995a; McConnell, Fletcher & Nissen, 1995) have led to a realization by local health authorities for the need for proper education in the use of these devices - an education which should start within the FHS and continue in the workplace (Medical Device Agency - UK, 2000, p.12). Medical devices are all physics - engineering based and hence offer enormous opportunities for role expansion for the BMPE educator. Major opportunities are also offered by directives regarding protection (in our case patient, HCP and general public protection) from physical agents. Two major directives regard protection from ionizing radiation (EC, 1996, 1997). The first directive is important for the BMPE as it regulates the protection of HCP, hospital visitors and even unborn children whilst the second regulates protection for patients and volunteers participating in research with ionizing radiation. Both directives make radiation protection education mandatory for HCP who can be exposed to ionizing radiation or who are allowed by law to expose patients for medical reasons. A recent directive concerns occupational exposure against electromagnetic radiation (EC, 2004). This directive which must be transposed into national legislation by April, 2008 will have a direct impact on work with magnetic-resonance-imaging (MRI) when transposed to national legislation. The Personal Protective Equipment Directive (EC, 1989) includes use of protective equipment within the hospital environment (e.g., equipment used in protection against ionizing radiation emanating from radiological devices). All directives provide excellent role-expansion opportunities for the BMPE educator.

Economic

O4) The escalating cost of health care: the efficient use of medical devices and health technology assessment (HTA)

Health economics is the science of making the optimum use of scarce resources and is particularly relevant as the cost of healthcare continues to escalate and the expectations of patients become higher. For the purpose of this study health economics is most relevant with respect to the efficient use of medical devices and of HTA (EC, 1999, p. 52). The latter has been defined as the "Comprehensive evaluation and assessment of existing and emerging medical technologies including pharmaceuticals, procedures, services, devices and equipment in regard to their medical, economic, social and ethical effects". (http://www.euro.who.int/observatory/Glossary/TopPage?phrase=H). The opportunity for the BMPE educator vis-á-vis HTA lies in the reference to "devices and equipment" - the assessment of which has a very strong BMPE basis. The cost of medical devices increases constantly and HTA is a major opportunity for role expansion for all HCP (Dean, 2001; Grimes, 1993; Harris, 1988; Sacks, Marinelli, Martin & Spies, 1997; McConnell, 1995b) and in turn therefore a major opportunity for the BMPE educator to expand his role.

O5) EU Human resources requirements in the HCP sector: rising need for an expanded and better-educated HCP workforce

Appropriate human resources are essential assets in healthcare and ensuring an adequate and trained HCP workforce is becoming a major concern for European health policy makers as:

"… the infrastructure to support health workforce development is inadequate in most European countries or is, at best, composed of a fragmented patchwork of separate units, budgets and programmes, each focusing on an individual group of health workers or a narrow aspect of human resource management" (Dubois, McKee & Nolte (European Observatory on Health Systems and Policies), 2006, p. 235).

This means an expansion in the number of students joining the FHS and therefore and a higher investment in HCP education. There will be ample opportunities for all FHS academics and a greater role for the BMPE educator as it is essential to develop an educational system that can respond quickly to continuously changing conditions including the rapid advance in healthcare technologies.

Social

O6) Increased awareness of need for effectiveness standards in healthcare: evidence-based-healthcare and the effective use of medical devices

It is an established fact that the condition of too many patients deteriorates in hospitals owing to the low level of effective care within these institutions (McGlynn EA, Asch SM, Adams J, et al., 2003). Sources of non-effectiveness range from outdated management practices to inappropriate clinical protocols. Unfortunately many clinical protocols have in the past been based on anecdotal evidence and 'expert' opinion and less on scientific evidence. The evidence-based-medicine (also known as evidence-based-healthcare) movement is an attempt to rectify this situation and put clinical practice on a more scientific basis. It is also recognized that this scientific attitude to medicine must start within education, i.e., within the FHS (Chaboyera, Willmanb, Johnsona, & Stockhausena, 2004; Gay & Beaulieu, 2004; Pitkala, Mantyranta, Strandberg, et al, 2000). This presents enormous opportunities for the BMPE educator particularly in the area of the effective use of medical devices.

O7) Increased awareness of patient safety standards in healthcare: medical device safety and protection from *physical* agents

The publication of several reports highlighting incidents of adverse events within clinical settings has led to a heightened awareness that patient safety standards in hospitals are far from satisfactory (Kohn, Corrigan & Donaldson, (Committee on quality of health care in America), 2000; Wakefield, Attree, Braidman, Carlisle, Johnson, & Cooke, 2005). In response to this social situation the EC in its 'Luxembourg Declaration on Patient Safety' of the 5th of April 2005 made it clear that:

"Access to high quality healthcare is a key human right recognized and valued by the European Union, its institutions and the citizens of Europe. Accordingly, patients have a right to expect that every effort is made to ensure their safety as users of all health services"

The EC further recommends that a safety culture needs to be established within hospitals and that a fostering of this safety culture must start from the educational sector. In the list of recommendations to be found in the above document we find:

"To include *patient safety* in the standard training of health professionals combined with integrated methods and procedures that are embedded in a culture of continuous learning and improvement"

The major opportunity for the BMPE educator is embedded in the following recommendation from the same document:

"To recognize and support the user training provided by *medical devices, tools and appliances* manufacturers thereby ensuring the safe use of new *medical technology* and surgical techniques"

O8) The rise of the new HCP: HE based programmes, new HCP and expanded roles

Traditionally HCP education within universities catered only for medicine, dentistry and pharmacy whilst the other HCP were catered for by lower level non-degree awarding institutions. This is rapidly changing all over Europe as HCP insist on making a 1st cycle degree the basic entry qualification for their respective professions (Kachur, & Krajic, 2006). At the same time these HCP have been rapidly developing their roles in the clinical areas and taking on further responsibilities that require a higher level of education (Paterson, 1995; Bryant-Lukosius, DiCenso, Browne, & Pinelli, 2004). Moreover as healthcare expands new professions are continuously being created. All these developments would lead to an increased demand for educational servicing by the FHS and therefore an increased demand for more BMPE services. Diagnostic radiography education which previously included only x-ray projection radiography now includes also ultrasound, magnetic resonance imaging and radionuclide imaging - all devices which require a higher level of BMPE educator input. Many HCP are expanding their roles in directions which require more advanced BMPE competences (e.g., medical device management, routine quality control of devices and health technology assessment). Many new HCP (e.g., audiology, physiological measurement) are device intensive and offer many new opportunities for role expansion for the BMPE educator.

O9) Increased regulation of the HCP: Professional standards of proficiency in medical device use

The push for better quality standards in healthcare is leading to the setting up of standards of proficiency for safe and effective practice expected of the various HCP (e.g., Health Professions Council, 2003). Standards of proficiency are usually expressed in terms of generic competences which all HCP are expected to meet and profession specific competences relevant to each particular profession. Profession specific competences include the BMPE elements-of-competence necessary for the effective and safe use of medical devices. The inclusion of these BMPE elements-of-competence in HCP curricula is hence required by law and constitutes an excellent opportunity for role protection and expansion for the BMPE educator. They also provide guidance to the BMPE educator to ensure the development of curricula which are directly relevant to the learning needs of the various HCP.

O10) Increased awareness of occupational safety issues: protection from *physical* health hazards in work-places

Increased awareness of occupational safety is also an important recent social phenomenon and HCP are expected to take responsibility for their own personal safety and the safety of colleagues. The competences necessary for occupationally safe practices form a subset of the standards of proficiency for the professions. The inclusion of competences concerning protection from physical health hazards within HCP curricula are a legal requirement and constitute an excellent opportunity for role protection and expansion for the BMPE educator. Again they also provide guidance to the BMPE educator to ensure the development of curricula which are directly relevant to the learning needs of the various HCP.

Technological - Scientific

O11) The explosion in the number and sophistication of medical devices

The rapid increase in the number and sophistication of medical devices coupled with an insufficient level of BMPE education within the curricula of the HCP including *ordinary everyday* devices e.g., blood pressure measuring devices (Grim & Grim, 1995), ECG monitors (Drew, Ide & Sparacino, 1991), has often led to a situation in which hospitals are full of expensive devices, which are often either not used according to recommended protocols or underutilized owing to insufficient competences on the part of the users. Moreover the absence of proper BMPE education has led to HCP who are very uneasy when it comes to using devices. The situation is becoming steadily worse as devices become more sophisticated and include more and more user options. BMPE professionals within hospitals are increasingly being asked to take device training, however the HCP lack the necessary BMPE background necessary - a background which they should have acquired in their student days within the FHS. Learning must start at the undergraduate level within the FHS. The situation is a golden opportunity for the BMPE educator.

The future is very promising for medical devices as the number increases even further. Future trends in medical devices include: advanced computer applications (e.g., robotics, automation), molecular medicine devices (e.g, fluorescence imaging devices), home / self care devices, device customization, devices for minimally invasive techniques, miniaturization, nano-devices, organ substitutes and others (Herman, Marlowe & Harvey, 1998).

5.3 THREATS TO THE ROLE

Political

No threats arising from political factors have been identified.

Economic

T1) The escalating cost of HE

The escalating cost of HE is a direct threat to the BMPE academic. Although it is a problem that is being faced by all disciplinary groups within the FHS, the smaller disciplinary groups are more vulnerable owing to their lower political strength within the faculty. In some FHS the number of BMPE academics have been scaled down to the barest minimum required to satisfy existing legal requirements. In some extreme cases BMPE is taught by non-BMPE as the employment of a BMPE is seen as an extra cost to an already thin budget. The pressure to reduce the length of programmes in medicine and the subsequent pressure on curriculum time has meant that in some cases BMPE was eliminated from the curriculum (e.g., in Portugal where BMPE survived in only one of the seven medical programmes in the country after the reduction of the medical course by one year).

T2) Low incentives for BMPE to join academia

In some FHS the number of BMPE educators are low simply because none are available. The dearth of physics and engineering graduates is now an established phenomenon and those who eventually specialize in BMPE have better remuneration opportunities particularly in industry and medical device sales. Those who do decide to join academia tend to supplement their income with consultancy work. This is not necessarily a negative factor particularly if the consultancy is associated with healthcare. However there is often little time left over for educational research.

Social

T3) Resistance to multi-disciplinarity in HCP education

Unfortunately in some countries BMPE professionals and academics have to work within healthcare organizations which have a history of inter-HCP strife. One negative effect of such situations is a resistance to multi-disciplinarity in HCP education. Some HCP insist that they do all the teaching of their own profession themselves even at the expense of reduced standards. This of course would have a direct negative effect on the BMPE educator role within the FHS. At the same time one should also note that the benefits of multi-disciplinary curricular delivery is increasingly being recognized by the more enlightened HCP educational leaders.

Technological - Scientific

No threats arising from technological - scientific factors have been identified.

5.4 CONCLUSION

The BMPE educator profession is indeed blessed with many more opportunities than threats. A good strategic plan is essential in order that these opportunities are grasped and not lost. Some threats do exist. Their significance or otherwise will depend on the local context. In cases when such threats pose a significant risk to the profession *strategic planning for the role becomes vital.*

6 THE CURRICULAR CHALLENGES INVENTORY

6.1 OVERVIEW OF THE CHAPTER

In this chapter we will present an inventory of the curricular challenges facing the BMPE educator which we have identified from the literature. Most of these curricular challenges are already being implemented in the curricula of the FHS we have studied and must be taken into consideration in any role and curriculum models targeted towards the BMPE educator. The challenges are divided into two categories, those that are common to all faculties within HE and those that are particular to the FHS.

6.2 CHALLENGES ARISING FROM GENERAL HIGHER EDUCATION CURRICULAR DEVELOPMENTS

C1) Emphasis on evidence-based educational practice

Unlike pre-university education, HE educational practice has rarely been evidence-based (also known as ‘research-based’). Often HE academics in the past have given much more emphasis on advancing knowledge in their discipline then in advancing the way the discipline is to be transmitted to future generations. This is slowly changing as the role of universities change from being primarily discipline research institutions to a healthier and happier balance between discipline research and education. In the case of healthcare the Best-Evidence-Medical-Education (BEME) movement promotes the idea that just as medicine should be evidence-based as opposed to opinion-based so should medical education. BEME is the implementation, by FHS educators in their educational practice, of approaches and pedagogies based on the best educational research evidence available. The research evidence should be evaluated according to quality, utility, extent, strength, validity and relevance to the particular context (Harden, Grant, Buckley & Hart, 1999).

C2) The move to practice oriented outcome competences based curricula and new ways of determining content

Traditional HE curricula have been mostly educator-centered. Curriculum time was apportioned to the various disciplines which in turn delivered their choice of discipline content in the allotted time. Most course content has been based on personal opinion and determined largely by the relative political strength and research needs of the various disciplinary groups within faculties. This has been particularly true of the FHS (Pallie & Carr, 1987). This approach has often led to content which is often far removed from the practice requirements of the different HCP and to complaints regarding low student competences by employers. Outcomes-based curricula start by specifying programme endpoints in terms of the practice-oriented competences that the student should acquire by the end of the process i.e., outcomes-based curricula are student-centered and output-driven. Summative assessment at the end of the programme should assess whether these competences have been acquired by the student. The Tuning process in Europe demands outcome-based curriculum development in which programme outcomes are described in terms of the generic (i.e., cross-professional) and subject-specific (Tuning terminology for ‘profession-specific’) competences that a student should acquire at the end of the programme. These competences are to be agreed by the various stakeholders (academics, professional bodies, future employers, students) at the European level. Curricula are to have a clear practice orientation which would guarantee the employability of graduates. Competence based curriculum development is therefore fast becoming the norm in EU states particularly in HCP education (Harden, Crosby & Davis, 1999; Smith & Dollase, 1999; Yip & Smales, 2000). The various disciplines are expected to determine what input they could provide for the student to be able to achieve these competences. This in practice entails a process of functional analysis based deconstruction of the exit competences into elements-of-competence and identifying those which fall within the remit of the particular disciplinary group. However since many exit competences are expressed in very broad terms and hence provide insufficient guidance for curriculum development, disciplinary groups often have to analyze the roles of the various HCP through a study of the HCP literature and discussion with HCP leaders and employers. Where such methods are not adequate content might need to be determined by direct research. Examples of the latter approach can be found in the literature (Tanner, 2000; Sefton, Farrell & Noyes, 2001; Burge, 2004; Staggers, Gassert & Curran, 2002). However it should be pointed out that competence based curriculum development is not without its shortcomings and these should be taken into consideration when designing such curricula (Leung, 2002; Rees, 2004). The issue of content determination is a contentious issue and will not be solved easily (Sanson-Fisher & Rolfe, 2000; D’Eon & Crawford, 2005).

C3) The problem-based-learning (PBL) methodology of curricular delivery

Problem-based-learning is increasingly being used in all areas of HE including HCP education (Perrenet, Bouhuijs, & Smits, 2000). Traditional curricular delivery methods are based on child learning models. Learners are assumed to carry out the programme prepared for them by a teacher, have little pre-experience, are motivated by extrinsic rewards and learning is based on transmission techniques. PBL is an adult learning model designed to wean students away from dependency generation methods to a technique which would help them become independent, reflective, professional, collaborative, self-confident practitioners. Learning in PBL is constructive, task-centered, self-directed, contextual and internally motivated (i.e., interest is generated by a wish to solve the problem at hand). PBL sessions are not teaching sessions but professional strategy meetings to be conducted by student groups. The role of the lecturer in PBL is not to teach but to facilitate the session by encouraging critical reflection, suggest sources of information when required, challenge the adequacy of knowledge of the group in a helpful way - and only if at all necessary (Maudsley, 1999; Haith-Cooper, 2000; Neville, 1999).

C4) The use of Information and Communication Technologies (ICT)

The use of ICT is considered as one of the major driving forces which will shape the university in the 21st century (Van Ginkel, 2003). ICT can make curricular delivery more effective and efficient through more engaging presentations, faster information retrieval, the use of interactive media-rich learning packages, online learning, easier communication, use of reusable learning objects and simulation. Valcke & De Wever (2006), Haigh (2004) and Berger (2003) have summarized and analyzed the benefits of the use of ICT in the case of HCP education. On the other hand ICT is no panacea for bad teaching. It has been shown that use of high-tech presentations as opposed to traditional overheads does not on its own lead to better learning (Ricer, Filak & Short, 2005). Perhaps the most important use of ICT for the BMPE is in the case of medical device simulation as many of these devices are too expensive to be available for student learning. A prime example is a PC-based virtual magnetic-resonance-imaging (MRI) scanner developed by Hackländer (2005).

C5) The challenge of electives: opportunities for promoting the disciplines

Most HCP curricula are today based on a common core set of modules which are meant to be experienced by all students and a set of special study elective modules from which students are expected to choose a specified number according to their own interests and future career goals. Electives have two aims: to present novel content not included in the core modules and to include transferable research and professional skills for which no time is available in the core modules e.g., literature searches, presentation skills, data collection and analysis, patient interaction. These transferable skills should be the same for all modules so that although content may vary yet all students would develop transferable skills in a parallel fashion (Byrne, Lewis & Thompson, 1999). Electives present a formidable challenge to the BMPE as he 'competes' for students with other FHS disciplines. However they are also a great opportunity for the BMPE to interact with healthcare students, promote his discipline and introduce new ideas within the faculty.

6.3 CHALLENGES ARISING FROM HCP CURRICULAR DEVELOPMENTS

C6) The challenge of integrated curricula

Integrated curricula refers to a world-wide trend in which discipline-based curricula based on a pre-clinical and clinical dichotomy are replaced by a vertical integration of the pre-clinical and clinical sciences together with a horizontal merging of subjects that used to be taught in parallel. The objective is to ensure that pre-clinical sciences are taught in an applied manner and that clinical sciences become more scientific and evidence-based in their approach to clinical practice. At first this trend manifested itself in 'systems-based' curricula where students focus on one system of the body at a time with a team-teaching contribution from a mix of pre-clinical and clinical science educators. However the integrated approach has now been combined with the problem-based learning methodology where learning competences from pre-clinical, social, psychological and clinical sciences are embedded in progressively more complex patient case scenarios. Unfortunately there have been no significant published studies yet on ways that BMPE can be integrated with the other disciplines, however one can build on what other disciplines are doing (Carreras, 1997; Puri, 2002; Wendelberger, Burke, Haas, Jarenwattananon & Simpson, 1998; Rangachari, 1997). Successful integration requires inter-disciplinary collaborative strategies of curriculum development (Duthie, Simpson, Marcdante, Kerwin & Cohan, 2004).

C7) Interprofessional (also known as multiprofessional) learning

Interprofessional learning happens when students of various HCP learn together so that they can learn to work effectively, safely and efficiently together later on in their working lives. It is an attempt by HCP education leaders to bring about more understanding between the different HCP to help eradicate the problems highlighted in Section 5.3 (T3). It is also based on a recognition that modern healthcare can only be effective if carried out by multiprofessional teams. In multiprofessional learning, student teams go through the experiential learning cycle (planning, doing, observing and reflecting) in the context of increasingly more complex patient cases. Guiding principles for successful interprofessional learning can be found in the literature (D'Eon, 2004; Parsell and Bligh, 1998). It is our view that the biggest contribution to interprofessional education that can be given by the BMPE educator is to ensure that all HCP share a common terminology and understanding regarding the scientific, effective, safe and efficient use of medical devices and to be themselves role model team workers.

C8) The emphasis on healthcare ethics

'Ethics' is one of the present buzzwords in healthcare and healthcare education and every discipline is expected to contribute to the ethical formation of HCP students. In the case of the BMPE ethics make an appearance in discussions regarding medical devices e.g., patient and occupational safety in the use of medical devices, the ethics of the availability and non-availability of life-saving devices in different societies, health technology assessment, informed consent of volunteers in research studies which include the use of medical devices. Ethical issues in the use of medical devices should be an integral part of BMPE curricula for the HCP.

7 A ROLE DEVELOPMENT MODEL FOR THE BMPE EDUCATOR

7.1 OVERVIEW OF THE CHAPTER

This chapter presents the role development model for the BMPE educator. The model is based on an expanded form of the Briggs model of the academic which includes also the component roles of role model, change agent and guardian of professional proficiency standards (see Section 2.4), the proposed strategic planning model for role development in HE (Section 3.5), the results of the SWOT audit (Chapters 4 and 5) and the curricular challenges inventory (Chapter 6).

7.2 PARADIGMS GUIDING THE STRATEGIC PLANNING PROCESS

These have already been discussed in Section 3.6 and are repeated here verbatim for completeness:

> "The paradigms guiding the planning process were the open-systems and marketing paradigms. The open-systems model emphasizes that role development occurs within an environment and often as a response to changes in the environment. The marketing paradigm is a reminder that in current HE managerial systems BMPE services will only be requested (and in some countries bought and paid for) by HCP because they are seen as being of value *to them*"

7.3 CORE VALUES FOR THE BMPE EDUCATOR

Role holders will pursue role development within an environment that fosters the following core values:

a) Excellence: We consistently set, pursue and maintain the highest quality standards of curriculum research, development and delivery,

b) Respect: We respect the dignity, uniqueness and particular learning needs of every HCP and every student,

c) Professionalism: We work with expertise, commitment, integrity, fairness, reliability and flexibility, hence providing inspiration and role modeling opportunities to our students,

d) Service: We maintain positive relationships when fulfilling our duties with respect to the expectations of those HCP and students who request our services,

e) Teamwork: We recognize and consistently follow the principle that quality HCP education is intrinsically multi-disciplinary,

f) Lifelong learning: We affirm that in a knowledge-based society, leadership, excellence, professionalism and service are based on a process of lifelong learning.

7.4 SUMMARY OF SWOT THEMES FOR THE BMPE EDUCATOR ROLE

The following is a listing of the themes identified in the SWOT analysis for the BMPE educator role:

Strengths:

S1) Highly qualified academics
S2) High level of subject pride
S3) High esteem for BMPE amongst HCP
S4) Strong medical device competences
S5) Strong competences regarding safety with regard to *physical* agents
S6) Strong ICT competences
S7) Strong research competences

Weaknesses:

W1) Absence of a clear mission and role ambiguity
W2) Inappropriate role boundaries
W3) Absence of international networking
W4) Absence of harmonization of curricular content
W5) Absence of a unique name for the discipline
W6) Low awareness of importance of educational research
W7) Low client group base
W8) Insufficient reflection on core competences
W9) Low educator competences
W10) Small or absent departments
W11) Low strategic planning, marketing and publicizing competences
W12) Role conflict between the self-perceived role and the role expectations of the HCP
W13) Low competences in the social sciences and management
W14) Low awareness of the ethical and humanistic aspects of healthcare

Opportunities:

Political:
O1) EU goal of facilitating worker mobility within Europe: The European Higher Education Area and the internationalization of curricula
O2) Ensuring EU competitivity: The European Research Area and the need for new undergraduate programmes
O3) EU directives: medical devices and safety from *physical* agents

Economic:

O4) The escalating cost of health care: the efficient use of medical devices and health technology assessment
O5) EU Human resources requirements in the HCP sector: rising need for an expanded and better-educated HCP workforce

Social:
O6) Increased awareness of need for effectiveness standards in healthcare: evidence-based-healthcare and the effective use of medical devices
O7) Increased awareness of patient safety standards in healthcare: medical device safety and protection from *physical* agents
O8) The rise of the new HCP: HE based programmes, new HCP and expanded roles
O9) Increased regulation of the HCP: Professional standards of proficiency in medical device use
O10) Increased awareness of occupational safety issues: protection from *physical* health hazards in work-places

Technological - Scientific:
O11) The explosion in the number and sophistication of medical devices

Threats:

Political:
No threats arising from political factors have been identified.

Economic:
T1) The escalating cost of HE
T2) Low incentives for BMPE to join academia

Social:
T3) Resistance to multi-disciplinarity in HCP education

Technological - Scientific:
No threats arising from technological - scientific factors have been identified.

A condensed version of the results of the above SWOT audit have been published in the following article:

Caruana, C. J., & Plasek, J. (2006). A SWOT audit for the educator role of the biomedical physics academic within Faculties of Health Science in Europe. *Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2006. Modeling in Physics and Physics Education.* Amsterdam. ISBN: Not yet available.

A copy of the article can be found at the end of the dissertation.

7.5 SUMMARY OF CURRICULAR CHALLENGES

Challenges arising from general HE curricular developments:

C1) Emphasis on evidence-based educational practice
C2) The move to practice-oriented, outcome competences based curricula and new ways of determining content
C3) The problem-based-learning (PBL) methodology of curricular delivery
C4) The use of Information and Communication Technologies
C5) The challenge of electives: opportunities for promoting the disciplines

Challenges arising from HCP curricular developments:

C6) The challenge of integrated curricula
C7) Interprofessional learning
C8) The emphasis on healthcare ethics

7.6 PORTFOLIO ANALYSIS: CORE COMPETENCES OF THE BMPE ACADEMIC

Table 7.1 shows the results of the portfolio analysis used in the determination of core competences. The results in the table demonstrate clearly that the BMPE educator has a single yet encompassing and wide-ranging core competence which is the following:

"*The ability to identify, understand, apply, analyze, synthesize and evaluate the physics-engineering competences underpinning the scientific, effective, safe and efficient use of present and future medical and biophysical devices and the ability to set up learning opportunities for others to acquire these competences*".

In this context 'scientific' refers to the use of devices in research situations whilst 'effective' means ensuring that the medical device attains the intended healthcare purpose for which it is being used. 'Safe' refers to the avoidance of unnecessary risk to patients and the total elimination or reduction to acceptable levels of risks from *physical agents associated with medical devices* to users, colleagues and others through appropriate user protocols, environmental control and personal protective equipment. 'Physical agents' refers to ionizing radiation, mechanical, electrical, acoustic, ultrasonic, magnetic, electromagnetic, high temperatures, optical, ultraviolet, infrared, and laser sources of risk. 'Efficient' refers to the extent that purpose is achieved at minimum device use time.

The results of the portfolio analysis clearly indicate that the major expectations from the HCP with respect to the BMPE educator at present are based on medical devices and safety from physical agents associated with these devices. These two areas are the key strategic opportunities for the role. We propose that this competence fulfills the requirements for a core competence. For a competence to be considered as core both questions in Table 7.1 must have affirmative answers when applied to the competence (see Section 3.10). This competence is highly unique to the role and no other roles within the FHS can compete with the BMPE academic in this domain of expertise (S4 and S5). Provided role holders develop this competence to a high level, transfer to other roles within the FHS would be extremely difficult. This is in direct contrast to other BMPE competences like physiological, biomolecular and cellular physics which can be (and have been in some cases) taken over by physiology or multi-disciplinary biomolecular science departments (W8). This competence already offers access to several HCP client groups and the number is expected to increase further owing to the expansion in the use of medical devices as the HCP develop further their own professional roles (O3 to O11). The emphasis on *future* devices is important - it implies that as existing devices are developed and new devices emerge the BMPE is in a very strong position to expand his role particularly to those devices that are based on physics principles which are new to biomedicine. This competence is seen as valuable by various client groups (S4 and S5). The importance of this core competence is further confirmed by the fact that in the great majority of the FHS surveyed, the overall number of ECTS units in the medical device and safety content areas vastly outstrips that of other BMPE content areas. The few exceptions are medical curricular programmes within faculties of medicine in which BMPE departments conduct research in biomolecular and cellular science. In these cases the BMPE programme was approximately equally divided between medical devices/safety and biomolecular/cellular science.

BMPE Content Area	Difficult to transfer to another role?	Offers access to client groups at entry level?	Core competence?	Comments
General non-applied physics	Yes	No	No	Definitely on the way out at EU level - all HCP expect physics *applied* to the biomedical field. Still unfortunately present in some FHS, but definitely puts HCP students off physics.
Biomolecular and cellular science (not including biophysical devices which are considered separately)	No	Yes	No	Biomolecular and cellular science knowledge is taught by several FHS roles across the EU (BMPE, physiology, biochemistry, biomolecular science, cellular science) and would often be better served by new very multi-disciplinary specializations (e.g., biomolecular and cellular science departments).
Physical biochemistry	No	No	No	Physical biochemistry is taught by several departments across the EU (BMPE, physiology, biochemistry, biomolecular and cellular science) and would often be better served by other specializations (e.g., biochemistry).
Biophysical devices	Yes	Yes	Yes	Although biophysical devices are often used by other specializations (biochemistry, physiology, biomolecular

				and cellular science) these specializations often seek BMPE advice when seeking to extend the use of such devices used in their department.
Biomechanics	No	No	No	Undergraduate biomechanics is sometimes partly taught by BMPE but often taught by physiologists or anatomists. As little mathematics is required at this level it is easily transferred to other roles. For this reason we do not consider that biomechanics at undergraduate level is a core-competence for the BMPE even though the area has a strong physics basis. The situation may be different at *postgraduate research* level where advanced modeling competences may be necessary. BMPE are very strong in such competences. *One should mention that the teaching of devices associated with biomechanics (e.g., force platforms) is often serviced by BMPE.*
Cardiovascular haemodynamics	No	Yes	No	Also serviced by physiology, and hence not a core competence.
Biophysics of perception	No	Yes	No	Biophysics of perception included also in physiology so is not a BMPE core competence. *However BMPE should consider that the necessary biophysics of perception which is required for the effective and safe use of microscopy and vision assisting devices also falls within their remit.*
Electrophysiology	No	Yes	No	Mostly serviced by physiology. Though there is a contribution also by some BMPE in some FHS. However it is a case of role overlap and should be avoided. *However such topics should be included in BMPE as a prelude to the teaching of associated devices.*
Signal-processing	Yes	Yes	Yes	Definitely a core competence for the BMPE and an increasingly important one.
Physiological measurement devices	Yes	Yes	Yes	Definitely a core competence for the BMPE and again an increasingly important one. One of the major journals in BMPE is 'Physiological Measurement' (Institute of Physics – UK). A new healthcare profession called Clinical Physiological Measurement is being offered in some FHS and

				therefore this is definitely a growth area.
Microscopy (including modern microscopy devices)	Yes	Yes	Yes	A traditional core competence for BMPE. The scope has been considerably widened with more modern forms of microscopy (e.g., atomic force microscopy).
Biomedical laboratory devices	Yes	Yes	Yes	Although biomedical laboratory devices are used by many non-BMPE specializations (biochemistry, physiology, biomolecular and, cellular science) these often work in collaboration with BMPE and seek BMPE advice particularly when extending the use of the devices used in their department.
Laser based biomedical devices	Yes	Yes	Yes	Definitely a core competence for the BMPE and an increasingly important one.
Rehabilitation devices	Yes	Yes	Yes	Another increasingly important core competence for the BMPE.
Biomedical imaging devices	Yes	Yes	Yes	A traditional core competence for BMPE. Radiology is now a vertical strand in undergraduate medicine and being included in the curricula of many HCP (e.g., physiotherapy, podiatry, nursing). Definitely a growth area.
Radiotherapy devices	Yes	Yes	Yes	A traditional core competence for BMPE. The presence of a radiotherapy physicist is also required in clinical radiotherapy departments by EC Directive 97/43//Euratom.
Electrotherapy devices	Yes	Yes	Yes	The increasing use of these devices in physiotherapy indicates a growth area.
Safety (ionizing radiation protection and dosimetry)	Yes	Yes	Yes	A traditional core competence for BMPE. Radiation protection training is a legal requirement of EC Directives 96/29/Euratom and 97/43//Euratom for those HCP coming into contact or using radiation sources.
Safety (physical agents other than ionizing radiation)	Yes	Yes	Yes	An emerging core competence for the BMPE. As the emphasis on patient and occupational safety increases lawmakers are realizing that safety issues should not be limited to ionizing radiation only but expanded to other medical devices (e.g., electrotherapy devices, medical laser devices).

Other (modeling, cybernetics and others)	depends on topic	No	No	These are often minor topics sometimes found in BMPE curricula. However the demand is invariably low at undergraduate level.

Table 7.1: A portfolio analysis for the BMPE educator.

7.7 BENCHMARKING THEMES

In this section we list good practices of other healthcare science disciplinary groups which should be emulated by the general BMPE educator community:

a) The formulation and publicizing of a clear mission statement (W1, W11),
b) The establishment of a single unifying name for the department (W5),
c) The establishment of a Journal of Biomedical Physics-Engineering Education (W6),
d)The establishment of an international research group specifically targeting BMPE education (W3, W6).

7.8 KEY ‘MARKET-FORCES

The key forecasted ‘market forces’ for the BMPE educator in the FHS milieu are:

a) The EU Tuning initiative and the harmonization of curricula (O1),
b) The emphasis on practice-oriented, competence-based-curricula (C2),
c) The insistence on horizontally and vertically well-integrated curricula (C6),
d) The move to research based curriculum development (C1),
e) The emphasis on effectiveness, safety and efficiency in healthcare (O3, O4, O6, O7, O9, O10),
f) The emphasis on ethical values in healthcare (C8),
g) The rapid expansion in number and sophistication of medical devices (O3, O4, O7, O9, O11).

7.9 A STRATEGIC MISSION STATEMENT (ROLE DEFINITION) FOR THE BMPE EDUCATOR

We propose that the mission statement for the BMPE educator role should be:

“BMPE educators will make a decisive contribution to quality healthcare professional education through the pursuit of practice-oriented curriculum research, development and delivery in the physics-engineering competences necessary for the scientific, effective, safe, ethical and efficient use of biomedical devices and the supervision of student research involving such devices. We will be guided in our efforts by our values of Excellence, Respect, Professionalism, Service, Teamwork and Lifelong Learning”

We have used the term ‘biomedical devices’ as opposed to the strictly legal term ‘medical devices’ to include both medical devices as defined in the EC Directives and also devices used in the biophysics research field which have not yet made it to routine healthcare use and which are at this moment more prominent in basic science research (e.g., fluorescence imaging, x-ray diffraction, electron-misroscopy). One must keep in mind that devices used in fundamental biophysical science research today are the clinical medical devices of tomorrow. The mission also implicitly includes the human body biophysics competences complementary to BMPE device competences (e.g., electrophysiological physics when teaching electrophysiological devices).

This is a role definition which includes core competences and client groups as required of a mission statement (See Section 3.13), is unambiguous (addresses W1), defines appropriate boundaries for the role (addresses W2), addresses the low importance presently given to educational research (addresses W6), widens the client base to all HCP (addresses W7), highlights the importance of the development of educational competences (addresses W9), ensures role complementarity and avoids unnecessary role overlap with other faculty roles (addresses W8). It is a mission that links BMPE to a daily ongoing concern of all HCP. Perception of relevance of content is therefore assured.

This mission must be active within all the component roles of the BMPE academic (see Section 2.4) as all component roles impinge on the educator role:

a) As an expert the BMPE academic has a duty to:

i. Communicate to his students an appreciation of the unique contribution that BMPE makes to the development of quality healthcare,
ii. Pass on important values that underpin the BMPE discipline which would be of value to the HCP student in his practice,
iii. Use relevant information from specialist BMPE, healthcare and HCP literature regarding medical devices and their clinical uses for his teaching,
iv. Communicate his vision of developments in biomedical device technology to his students,
v. Survey, evaluate and continuously update an inventory of biomedical device related educational resources.

b) As an educator the BMPE academic has a duty to:

i. Identify and apply existing pedagogical knowledge which can be utilized to facilitate biomedical device learning,
ii. Provide information and sources of information to students regarding biomedical devices,
iii. Develop curricula and courses which address the special learning needs of FHS students in their endeavours to develop into scientifically-oriented, effective, safe, ethical and efficient users of medical devices,
iv. Develop learning resources and share these resources with colleagues across Europe,
v. Supervise HCP student research which involves significant use of biomedical devices,
vi. Mentor HCP students who would like to move to specializations within their profession which require a high level of biomedical device expertise.

c) As a researcher the BMPE academic has a duty to actively develop the evidence and research base for quality education in the use of biomedical devices.

d) As a team-worker the BMPE educator has a duty to:

   i. Realize that biomedical device education is intrinsically multi-disciplinary and that though his role is fundamental in this area the scientific, effective, safe, ethical and efficient use of biomedical devices by students requires the inputs of other faculty roles,
   ii. Ensure that his biomedical device curricula integrate well both horizontally and vertically with those of other disciplines in the FHS,
   iii. Ensure that his biomedical device curricula dovetail successfully with the overarching organizational educational goals of the FHS.

e) As a manager the BMPE educator has a duty to:

   i. Plan, organize, administer and monitor effective educational programmes set up by his department to ensure biomedical device learning outcomes which are satisfactory to all stakeholders,
   ii. Manage biomedical device learning resources so that they would be available to all students as required by the various HCP programmes,
   iii. Ensure that quality information regarding educational programmes offered by the department is communicated to HCP educational leaders within the FHS,
   iv. Publicize the role of the BMPE profession within the FHS and university.

f) As a consultant the BMPE academic has a duty to use his experiences of BMPE practice within the community to enhance his teaching.

g) As an agent of change the BMPE academic has a duty to encourage his students to work towards increased quality and safe healthcare within their future work-places through the professional application of their biomedical device competences.

h) As a guardian of professional standards of proficiency the BMPE academic has a duty to:

   i. Insist on professional standards of proficiency in the use of medical devices,
   ii. Reflect in an ongoing manner on his own standards of educator proficiency,
   iii. Develop and use forms of student assessment that ensure rigorous and fair summative assessment of students in biomedical device competences.

i) As lifelong learner the BMPE academic has a duty to:

   i. Keep his expertise in biomedical devices current,

ii. Keep himself updated with new legislation (EU, national and local) impinging on the use of medical devices,
iii. Keep himself updated with developments in the biomedical device market,
iv. Keep himself updated with educational developments and research that would impact his role as biomedical device educator.

j) As a role model the BMPE academic has a duty to:

i. Provide a continuous example of the professional manner in which biomedical devices should be utilized,
ii. Provide a continuous example of the professional manner in which the role of academic educator should be practiced.

7.10 A VISION STATEMENT FOR THE ROLE

The following ideal future state description expresses the proposed vision state for the BMPE educator role in the FHS:

"The BMPE educator will be recognized by HCP leaders across Europe as the academic of first call in the biomedical devices education domain, perceived to be providing a practice-oriented, competence-based, well-integrated, research-based, internationally harmonized, ethically moderated, contribution to the education and research endeavours of HCP students".

7.11 GAP ANALYSIS

The following gap analysis discusses the discrepancy between the desired future state descriptors of the role as promoted in the vision statement and the actual present state of the role as elicited from the SWOT audit.

With regard to the future state descriptions set out in the vision statement, the SWOT audit clearly indicates that the following gaps exist and need to be addressed:

a) The BMPE educator is not at present recognized by HCP leaders across Europe as the academic of first call in the biomedical devices education domain.

   This mainly is the result of role ambiguity (W1) and the fact that the role is not well-known (W11). BMPE involvement in HCP education varies widely from one state to another and even within states (W2, W4, W7). In the traditional strongholds of radiography and radiation therapy BMPE educators are regarded by HCP as possessing strong biomedical device competences (S4 and S5) but weak educator competences (W9)

b) The BMPE contribution to HCP education in Europe is far from satisfactory.

   The number of HCP client professions seeking the services of the BMPE educator is low and in most states mainly confined to radiation therapists, radiographers and medicine. In a few countries there is also a basic contribution to physiotherapy and audiology programmes. Contribution to nursing is practically non-existent (W7).

c) Very few BMPE curricula are practice-oriented, competence-based and research based (W2, W6).

d) International harmonization of curricular content is practically non-existent (W4).

e) Horizontal and vertical integration of the BMPE contribution is not satisfactory.

   In the case of radiography and radiation therapy the contribution of the BMPE is often appropriately spread both horizontally and vertically throughout the curriculum, however in the case of medicine and dentistry it is mostly confined to the initial pre-clinical stages (W7). The BMPE contribution should come into play whenever students meet new biomedical devices - particularly non-trivial devices which require higher levels of BMPE device competences for scientific, effective, safe and efficient use.

f) Ethical and humanistic considerations are not being given sufficient attention (W14).

g) The BMPE educator is not involved as much as he should be in student research involving biomedical devices (W2).

7.12 STRATEGIES AND TACTICS FOR GAP REDUCTION

Suggested general gap reduction strategies and explicit actions for the above gap analysis themes are:

a) The BMPE educator is not at present recognized by HCP leaders across Europe as the academic of first call in the biomedical devices education domain.

   Strategy 1: Specialization

   i. Focus on and concentrate resources on core biomedical device competences as articulated in the proposed mission statement,
   ii. Disseminate and publicize the new mission statement among the international BMPE and HCP community,
   iii. Practice role complementarity with respect to other faculty disciplines and role distancing from non-core competence subject areas which are either not in demand or can be substituted easily by other roles (e.g., basic non-applied physics, physics for physiology, physical biochemistry, biomolecular and cellular science),
   iv. A curriculum development model must be urgently designed and disseminated throughout the international BMPE community - a curriculum which would reflect the proposed mission statement,
   v. Be a proactive advocate for the scientific, effective, safe, ethical and efficient use of biomedical devices within the FHS,
   vi. Include the proposed mission statement in websites, departmental stationery etc.,

vii. Promote the BMPE profession based on pride in BMPE past, present and projected future medical device achievements,

viii. Promote oneself as a medical device consultant both internally within the FHS and in the community.

Strategy 2: Innovation

i. Set up clinically oriented biomedical device physics - engineering based Bachelor and Master programmes within the faculty. This is particularly crucial where a BMPE department does not exist as it would justify the setting up of such a department,

ii. Include a Medical Device Management module within multidisciplinary Health Services Management programmes offered by the FHS,

iii. Develop the concept of a 'biomedical device skills laboratory',

iv. Hold public lectures on clinical and home use medical devices.

Strategy 3: Merger

i. Set up joint biomedical physics-engineering departments (including Medical Physics, Biophysics, Biomedical Physics, Clinical Physics, Radiological Physics, Imaging Physics, Medical Engineering, Biomedical Engineering, Bioengineering, and Medical Technology) where these are still separate to ensure a strong BMPE department. These disciplines can easily work together under the guidance of the proposed mission statement and in fact there is much more that unites than separates the disciplines. There are already departments in which physicists and engineers work together (e.g., CZ). In some countries biomedical physicists and engineers are members of a single unified professional society (e.g., Institute of Physics and Engineering in Medicine, UK). The separation between biomedical physicists and engineers is more a remnant of historical accident than anything tangible. It is also essential to specify a single EU wide name for the department (W5).

b) The BMPE contribution to HCP education in Europe is far from satisfactory.

Strategy 1: Diversification

i. BMPE educators must be encouraged to move away from limiting their role to imaging and radiation therapy devices and involve themselves in the teaching of all biomedical devices,

ii. Research must be conducted in conjunction with new HCP to produce documents regarding the extension of the role to other professions e.g., by identifying unsatisfied and unarticulated learning needs (e.g., safety, quality control of devices, health technology assessment),

iii. Existing exemplars of good curricular practice outside of the traditional imaging-radiotherapy themes should be disseminated.

Strategy 2: Strengthen weak strategic planning, marketing and publicizing competences

i. Set up courses at EFOMP and GIREP conferences specifically for educators entitled ‘Developing the BMPE Educator Role within the FHS’
ii. Develop materials to guide and help BMPE educators market their services to HCP groups.

c) Very few BMPE curricula are practice-oriented, competence-based and research based

Strategy 1: Develop weak resources

i. Create curriculum development models that are practice-oriented, competence-based and research-based for the perusal of role practitioners,
ii. Set up BMPE competence inventories for specific HCP in collaboration with HCP groups,
iii. Disseminate educational research presented in national and international BMPE meetings,
iv. Set up discipline-specific training materials to improve the educator competences of role holders,

d) International harmonization of curricular content is practically non-existent

Strategy 1: Develop weak organization

i. Set up a European research group of BMPE educators within EFOMP and GIREP which would participate actively in Tuning programmes for the various HCP (W3, O1),
ii. Set up a European email group specifically for BMPE educators,
iii. Set up a dedicated website linked to the EFOMP site,
iv. Ensure BMPE education research is given its due importance at EFOMP conferences,
v. Set up a Journal of BMPE Education.

e) Horizontal and vertical integration of the BMPE contribution is not satisfactory.

Strategy 1: Innovation

i. Set up optional units regarding biomedical devices for the clinical stages of the HCP curricula. Some suggestions:
   The safe use medical devices in the clinical areas,
   Medical device management for HCP,
   EU directives regarding medical devices,
   Making best use of a medical device manual,
   Research using biomedical devices.

Strategy 2: Develop weak resources

i. Research, develop and disseminate resources for the integration of biomedical device education within the clinical stages of the HCP curricula.

f) Ethical and humanistic considerations are not being given sufficient attention

Strategy: Develop weak resources

i. Research, develop and disseminate appropriate curricular resources, for the inclusion of ethical and humanistic considerations within BMPE curricula for the HCP.

g) The BMPE educator is not involved as much as he should be in student research involving biomedical devices.

Strategy 1: Innovation

i. Study the literature of the HCP to identify suitable biomedical device based projects which can be followed in collaboration with HCP supervisors,
ii. Hold research workshops with other HCP to identify interdepartmental biomedical device and educational research and collaboration.

7.13 FROM MISSION STATEMENT TO LEARNING OUTCOME COMPETENCES

A mission statement is of little value unless it is translated into a more tangible form with a high degree of usability. A way of doing this is to produce a *Biomedical Physics - Engineering Elements-of-Competence Inventory for Healthcare Professional Users of Biomedical Devices* which can be used to guide role holders in curriculum development. No such competence inventory has yet been published. Abbey and Shepherd (1992) suggested a basic model for the general use of medical devices. However their suggestions were too general, too biased towards nursing, and includes very little physics-engineering. No attempt was made at developing a specific learning outcomes competences framework. This means that the model is of little practical use in the everyday educational arena. The model's main strong point is the emphasis on a systems approach to device use, in the sense that appropriate device use is the result of a combination of device, user, patient, facility and environmental factors. A scrutiny of the literature revealed that there has been no further attempt to develop the original model neither by the original authors nor by others, nor have there been any attempts to apply the model to curriculum development for specific HCP. The absence of research into a well-developed and structured biomedical device education model has resulted in a medley of syllabi with little organization and functional value (W6). We consider that this issue needs to be addressed with urgency if the BMPE educator is to play any role in the European Higher Educational Area's Tuning progamme and not to miss out on the opportunities that this programme is offering (See Gap (a) Strategy 1 Action (iv) and Gap (d) Strategy 1, Action (i) above). This part of the thesis attempts to fill this void. We first present a practice-based structured inventory of generic (here meaning device independent) BMPE competences to guide role holders in the determination of syllabus content. The inventory is designed to ensure that BMPE learning encompasses both the physicist's rigorous approach to devices and the practice-oriented competence requirements of the HCP. It would also help in avoiding the extremes of superficiality or unnecessary physics detail which often afflict BMPE education for the HCP. This inventory is then placed within a curriculum development model which can be used to develop appropriate syllabus content for any HCP.

7.14 A GENERIC (DEVICE-INDEPENDENT) BIOMEDICAL PHYSICS - ENGINEERING ELEMENTS-OF-COMPETENCE INVENTORY FOR HCP USERS OF BIOMEDICAL DEVICES

This section presents the Generic Biomedical Physics - Engineering Elements-of-Competence Inventory for Healthcare Professional Users of Biomedical Devices. The inventory can be found at the end of this chapter and is a much-improved and elaborated version of a version published by us in an article earlier in the study and which can be found in the following publication:

Caruana, C. J., & Plasek, J. (2004). Generic learning objectives in the domain of medical device physics. *Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2004, Teaching and learning physics in new contexts.* Ostrava, Czech Republic. ISBN 80-7042-378-1. pp 69-70.

A copy of the article can be found at the end of the dissertation.

The first column of the table lists the statements of the elements-of-competence. The second column contains explanatory notes. These explanatory notes were added after feedback from HCP during Tuning conferences attended by the author. The order of the elements-of-competence is meant to guide sequencing during curriculum delivery. The structure of the inventory and choice of the included elements-of-competence were guided by the following principles:

a) The inventory will be a pragmatic tool to guide curriculum development across all HE cycles and all HCP.

b) Owing to the increasing pressures on the curriculum, only those BMPE elements-of-competence specifically required by the clinical and research contexts will be included (Frey, Dixon & Hendee, 2002).

c) Owing to the need of employability of First Cycle graduates, elements-of-competence necessary for effective and safe performance in the clinical context will be included at lower levels (see for example, Flinton & Simpson, 1996).

d) The design will acknowledge that the role of many HCP today encompasses the use of a widening range of devices, but that the level of competence for particular devices within particular cycles varies from one country to the other and indeed from one university to another (see for example, International Society of Radiographers and Radiological Technologists, 2003).

e) The competences will be formulated in a way to promote a consistent and harmonized use of terminology across devices and across professions - this will guarantee an integrated approach to biomedical devices, a more rapid acquisition of equivalent competences across devices (cross-device transferability of competences) and the avoidance of communication errors in multi-professional teams.

f) The competences will be couched in precise, scientific and up-to-date terminology.

g) The inventory will be formulated to allow for future role and scientific developments (Ludvigsson, 1999) - in particular, as the number of biomedical devices is changing rapidly, the inventory will be devised in a way such that it would be applicable to future devices. It has been reported that changes in device technology would have the highest impact on the roles of certain HCP (Williams & Berry, 1999).

h) The inventory will not be over-prescriptive to prevent educator and student disempowerment with respect to curriculum content (Grundy, 1987 cited in Rees, 2004), allow for diversity as required by Tuning and permit the development of native solutions to local curricular targets.

The above guiding principles point to the need for a *multi-level* inventory consisting of *device-independent* elements-of-competence statements. Our inventory therefore was stratified into five levels, L1 to L5, where L5 represents the highest level of educational and professional achievement. A higher level assumes acquisition of elements-of-competence at lower levels. The aim of the device-independent nature of the elements-of-competence is to circumvent the perennial curriculum development problems of future coverage (in this context meaning trying to predict what devices students may need to learn about in the future) and early obsolescence as conventional devices are replaced by newer ones (Ludvigsson, 1999; Kell & van Deursen, 2000). Such a framework would also permit and promote flexible curriculum development, yet be robust and structured enough to guide curriculum development in a systematic manner.

The operational descriptions of the levels are shown in Table 7.2. The descriptions are based on a pragmatic and judicious blend of cognitive, experiential, and career-progression paradigms that incorporates aspects of the proposed cycle descriptors of the European Higher Education Area (Bologna Working Group on Qualifications Frameworks, 2005), the Bloom, Gagne and Marzano taxonomies (Bloom, Engelhart, Furst, Hill & Kratwohl, 1956; Gagne, 1977; Marzano, 2001), Benner's Novice-to-Expert model (Benner, 1984) and the Knowledge and Skills Framework of the National Health service - UK (Department of Health UK, 2004) most of which have been extensively cited in the literature. These frameworks offer complementary perspectives on competence and it was considered beneficial to mesh their better aspects into a single set of level descriptors. The benefits of integrating such stratification paradigms in the case of professional education in general have been discussed in the literature and ensures a level structure that would be acceptable to educationalists, professional bodies and employers alike (Yielder, 2004). The levels were formulated to make them directly applicable to the biomedical device context as discipline-specific level descriptors have been found to be more suitable at the operational level, particularly in HCP education where students learn a wide range of disciplines (Rees, 2004).

As the scope of this thesis is delimited to entry level programmes, our initial intention was to produce an inventory of elements-of-competence at levels leading up to entry level only. However at Tuning conferences we were repeatedly asked by HCP to extend the inventory to *all* HE Tuning cycles. In our inventory therefore, levels L1 to L3 generally correspond to First Cycle level, L4 to Second Cycle programmes and L5 for the Doctoral level. However the flexible nature of the inventory makes it possible for a particular programme to include devices at different levels according to European and local requirements. As an example Table 7.3 shows a suggested European programme for First Level Diagnostic Radiography programmes for Europe based on the inventory.

Level	**Level Description**
L1	Competences necessary and sufficient for an appreciation of the clinical capabilities of a biomedical device, an awareness of risks to patient, self, colleagues and others from use of the device and for the effective and safe utilization of the device with test-objects or in simulated studies in a skills-lab context. Cognitive processes are mainly at knowledge retrieval and comprehension levels.
L2	Competences necessary and sufficient for supervised effective and safe use of a biomedical device with patients, under written protocol, scope-of-practice restricted to studies that are basic, routine and predictable. Cognitive processes are mainly at knowledge retrieval and comprehension levels.
L3	Competences necessary and sufficient for minimally supervised effective and safe use of a biomedical device with patients, under written protocol, scope widened to include studies that are complex or somewhat non-predictable. Supervised research using the device at a basic level. Cognitive processes are mainly at the analytic and knowledge-utilization levels.
L4	Competences necessary and sufficient for a fully autonomous effective, safe and economic use of a biomedical device at the forefront of professional practice, comprehensive scope-of-practice in a wide variety of clinical contexts including studies that are complex and unusual, contingency preparedness, device management, allocation of resources, development of existing protocols and audits of practice, all totally guided by a best-evidence and ethical approach. Basic technology assessment and implementation of research studies in relation to new clinical applications of the device. Cognitive processes are mainly at the metacognitive and self-system thinking levels.
L5	Competences necessary and sufficient for a complete utilization of the scientific knowledge base underpinning the effective, safe and economical use of a biomedical device in the clinical and research contexts including clinical service development, comprehensive technology assessment and the conceptualization, design and implementation of new device applications and user protocols. Cognitive processes are mainly at the metacognitive and self-system thinking levels.

Table 7.2: Operational descriptions of the competence levels used in structuring the inventory.

Imaging Modality	L1	L2	L3	L4	L5	Notes
General projection radiography	C	C	C			Film and/or digital sensor
Mammography	C	C	C			Film and/or digital sensor
Dental radiography	C	C	C			Film and/or digital sensor
General fluoroscopy	C	C	C			Image intensifier and/or digital sensor
Angiography	C					Image intensifier and/or digital sensor
Interventional fluoroscopy	C					Image intensifier and/or digital sensor
CT	C	C	OP			Sequential and/or multislice-spiral.
USI	C	C	OP			Including Doppler
MRI	C	C	OP			
RNI (planar)	C	C	OP			
SPECT	C					
PET	C					
Bone densitometry	C					

Table 7. 3: Use of the competence inventory for setting possible minimum BMPE First Cycle competences for Europe (C = core compulsory programme, OP = optional electives).

7.15 USE OF THE INVENTORY FOR SETTING UP OF THE LEARNING OUTCOMES AND SYLLABUS CONTENT COMPONENT OF UNIT DESCRIPTIONS

To produce learning outcomes for a particular unit description, BMPE educators should translate the generic elements-of-competence in the inventory to more device specific elements-of-competence formulated according to the scope of practice of the particular HCP. These device-specific elements-of competence can then be used to determine syllabus content. Syllabus content is defined as a detailing of the topics to be covered and skills to be mastered to support the particular elements-of-competence. We have illustrated these uses of the inventory by applying it to the determination of the elements-of-competence and syllabus content for a learning unit on computerized tomography (CT) scanners for Diagnostic Radiographers (EUR, 1999; European Commission, 1998b; Kalender, 2000; Institute of Physics and Engineering in Medicine, 2005 and 2003; International Commission on Radiological Protection, 2001). One can in a similar manner determine content for any other present or future biomedical device.

7.16 A GENERIC (HCP - INDEPENDENT) CURRICULUM DEVELOPMENT MODEL FOR THE BMPE ACADEMIC IN THE FHS

The curriculum development model we are proposing for the BMPE educator is based on the proposed role development model, the total quality service approach to curriculum design as proposed by Divoky and Taylor (1996) (based on client HCP requirements, quality measurements and on-going design improvements) and the Harden curriculum development model as outlined in section 2.4. The process is generic in the sense that it can be applied to device curriculum development for any biomedical device and any HCP. The model is designed to give direction only as ultimately curriculum development needs to be tailored to the local situation.

The main steps of the curriculum development process we are proposing are:

a) Research the educational needs of the particular client HCP to ensure relevancy of content

   Identify those HCP programme outcome competences which include a significant number of biomedical device elements-of-competence falling within the remit of the BMPE educator as expressed in the mission statement. Although many research methodologies are possible, perhaps the most reliable and credible technique is document analysis. Published documents are often the results of exhaustive well-conducted research studies and wide consultations among various stakeholders and hence have the advantage of relevance and of being relatively free from individual biases and opinions. Documents also have the practical advantages of being condensed, easy to use, readily available and inexpensive (McKernan, 1996, p. 149). Other methodologies that have been used e.g., surveys and focus groups are often less credible as results are usually too biased according to the background and commitments of the particular persons involved (Sanson-Fisher & Rolfe, 2000). They are also very time-consuming, can be very expensive and often entail logistical problems. We recommend an analysis of the particular HCP educational and role development literature and any relevant EU, national and local legislation associated with the devices. Well-written documents written by specialized task-groups and educational and role development research articles in the literature of the particular HCP are ideal sources of competence data. Such documents should be analyzed from a functional analysis perspective (Bench, Crowe, Day, Jones & Wilebore, 2003; Blackmore, 1999; Storey, 1998). If such documentation is not yet available (as is often the case at the time of writing with the new HCP) other techniques would have to be used (Sanson-Fisher & Rolfe, 2000). We suggest that the Tuning First Cycle outcome competences inventory for the particular HCP would be the first document to analyze if this is available (only the nursing document has at present reached a state of development which makes it suitable for use), followed by local HCP educational programme benchmark statements and legal requirements. The outcome of this step in the process would be a proposal for the consideration of the HCP consisting of a list of devices and an estimate of the competence level required for each device as illustrated by us in the case of Diagnostic Radiography above (Table 7.3).

b) Send your proposals to HCP programme leaders (European, National or local according to context) asking for feedback. The outcome of this step in the process would be an assessment of the level of HCP satisfaction with the proposals.

c) Revise your proposals according to feedback and iterate if necessary. The outcome of this step in the process would be a multi-disciplinary team constructed and approved document.

d) Use the Generic Biomedical Physics - Engineering Elements-of-Competence Inventory for Healthcare Professional Users of Biomedical Devices to identify the BMPE elements-of-competence learning needs of the particular HCP for each device.

e) Construct a syllabus specific to each particular device. The outcome of this step in the process is a syllabus for each biomedical device used by the particular profession.

f) Pool common cross-device syllabus content to avoid repetition and save on curriculum time. Consider also pooling across HCP disciplines as this would create opportunities for shared learning opportunities for HCP (C7) as well as improving efficiency by freeing unnecessary teaching time which can be used for alternative academic activities.

g) Identify local FHS preferred methods of content organization (outcome based, discipline based, theme centered, problem centered, case based etc.), determine desired weighting of breadth and depth, sequencing of content, methods for curriculum delivery (lecture based, small group based, tutor led, student led, team teaching, ICT, independent learning) and student assessment methods (Leggat, 1998).

h) Collect curriculum delivery resources and evaluate them in terms of suitability.

i) Set *measurable* programme quality indicators. Here it is important to point out that the concept of quality in education is problematic and requires considerable reflection to ensure that suitable measures are adopted (Ashcroft & Foreman-Peck, 1996).

j) Evaluate the programme via the quality indicator measurements and modify the design for continuous quality improvement.

7.17 USING THE CURRICULUM DEVELOPMENT MODEL FOR PRODUCING BMPE CURRICULAR CONTENT FOR SPECIFIC HCP

In this section we demonstrate the use of certain aspects of the curriculum development model for producing BMPE curricular content for specific HCP in Europe. We have chosen the professions of Diagnostic Radiography, Medicine and Nursing for illustrating the process. Diagnostic Radiography was chosen as it is perhaps the most device-intensive of the HCP and because of its historical ties to BMPE. A major effort went into the development of content for Diagnostic Radiography because we considered the project as setting the prototype standard model for content determination - a standard which could then be used for other HCP. The level of satisfaction of content developed was assessed at the European level directly by Diagnostic Radiography progamme leaders at a meeting of HENRE (Higher Education Network for Radiography in Europe) - the Tuning group for Radiography in Europe. The resulting inventory has been published in the article:

Caruana, C. J., & Plasek, J. (2006). An inventory of biomedical imaging physics elements-of-competence for diagnostic radiography education in Europe. *Radiography* (Elsevier), 12(3), 189-202. doi:10.1016/j.radi.2005.07.005

A copy of the article can be found at the end of the dissertation.

The article describes in detail the whole process of the development of the inventory. In fact this was the first (and to date the only) research article in Diagnostic Radiography education that came out of the HENRE Tuning group. The involvement of the author of this thesis in HENRE has resulted in a confirmation of the importance of BMPE education for the radiography profession.

Medicine was chosen as it is an example of an HCP profession in which the BMPE component is in decline owing to the absence of curriculum research on the part of BMPE educators. The following two articles were published regarding BMPE education for medicine.

Caruana, C. J., & Plasek, J. (2005). A systematic review of the biomedical physics component within undergraduate medical curricula in Europe. *Proceedings of the 14th International Conference of Medical Physics, Nuremberg, 2005*. *Biomedizinische Technik* Vol 50 Supplementary vol.1 Part 2. ISSN 0939-4990 pp. 931-932

Caruana, C. J, & Plasek, J. (2005). A biomedical physics elements-of-competence inventory for undergraduate medical education in Europe. *Proceedings of the 14th International Conference of Medical Physics, Nuremberg, 2005*. *Biomedizinische Technik* Vol 50 Supplementary vol.1 Part 1. ISSN 0939-4990 pp. 31-32.

A copy of both articles can be found at the end of the dissertation.

The first article presents the results of a systematic review of the BMPE component within undergraduate medical curricula in Europe as preparatory work for the second article which describes the use of aspects of the above curriculum development model for the setting up of a BMPE elements-of-competence inventory for undergraduate medical education in Europe.

Nursing was chosen as notwithstanding the fact that it is by far the largest of the HCP groups it has been given the least attention by BMPE educators. Moreover it was the first regulated profession to be included in Tuning. The involvement of the author of this thesis on the Nursing Tuning group has led to the insertion of the terms ‘medical devices’ and ‘physics’ within the list of First Cycle Tuning Nursing competences for Europe.

A proposed BMPE elements-of-competence inventory for Nursing based on the above curriculum development model can be found in the following article:

Caruana, C. J., & Plasek, J. (2006). An initial biomedical physics elements-of-competence inventory for First Cycle nursing educational programmes in Europe *Proceedings of the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP) Conference 2006. Modeling in Physics and Physics Education.* Amsterdam, Netherlands. ISBN Not yet available.

A copy of the article can be found at the end of the dissertation.

A much simplified version has been incorporated in the following Tuning document:

Caruana, C. J. (2004). Basic biomedical device physics elements-of-competences for nursing. Incorporated in the Tuning document *Summary of Outcomes - Nursing.* Accessible from the Tuning Educational Structures in Europe website at: http://tuning.unideusto.org/tuningeu/index.php?option=content&task=view&id=112&Itemid=139#competences

A Generic (device-independent) BMPE Elements-of-Competence Inventory for Healthcare Professional Users of Biomedical Devices

A Generic (device-independent) BMPE Elements-of-Competence Inventory for Healthcare Professional Users of Biomedical Devices			
Element-of-Competence	**Notes on Element-of-Competence**	**Element-of-Competence Applied to a CT-scanner**	**Illustrative Syllabus Content Supporting the Particular CT-Scanner Element-of-Competence**
Level 1	Level 1	Level 1	Level 1
Describe the purpose of the device in terms of the physical properties, structure or function of the human tissues, systems, fluids, organs etc which the biomedical device seeks to measure, correct, replace etc including any variables impacting the value of these properties.	Remember a device can have more than one purpose - which purposes are relevant to the particular healthcare profession?	Describe a CT scanner as a device for the measurement and imaging of the linear attenuation coefficient of patient voxels and including the variables impacting the value of the measured attenuation coefficient.	Definition of linear attenuation coefficient. Slice (conventional CT) or volume (multislice-spiral CT) measurements. Conversion of attenuation coefficient to CT number scale. Tissue contrast as difference in CT-number of tissues. Dependence of CT-number on voxel electron density (atom density and atomic number) and beam energy (effects of choice of kV and beam filtration).
List and explain the target clinical outcomes relevant to clinical effectiveness when using the device (in terms of appropriate quality criteria).	The word ‘target’ emphasizes an outcomes based approach to device use.	List and explain the target clinical imaging outcomes which are relevant to diagnostic effectiveness when using CT (in terms of the image quality criteria).	Image quality criteria used when using CT: the meaning of visualization, reproduction and visually sharp reproduction of anatomical structures and details of interest.

List and explain the target safety outcomes when using the device (in terms of safety criteria in relation to patient, user, colleagues and others) anticipated when using the device with respect to physical health hazards	'Physical health hazards' include ionizing radiation, mechanical, electrical, acoustic, ultrasonic, magnetic, electromagnetic hazards and elevated body temperatures.	List and explain the target safety outcomes (in terms of safety criteria in relation to patient, user, colleagues and others) anticipated when using CT with respect to physical health hazards.	Target safety criteria with respect to the patient e.g., doses at or below diagnostic reference levels, no damage to eyes from localization lasers, avoidance of electric hazards Target safety criteria with respect to the user are: near-zero occupational dose, avoidance of electric shock hazards.
List and operationally define suitable device performance indicators appropriate for users of the device and their relation to target clinical outcome quality or safety criteria.	A performance indicator is a measurable objective quantity that presents an indication of the extent to which a device is performing as it should, when compared to agreed standards. Performance indicators are associated with one or more quality or safety criteria. In the case of instruments include basic instrument science concepts: accuracy, noise, uncertainty, precision, calibration, etc. However concepts should be restricted to those relevant to the clinical situation.	List and operationally define suitable CT performance indicators appropriate for users and their relation to target image quality or safety criteria.	CT performance indicators associated with image quality criteria e.g., spatial resolution in scan plane (line pairs sufficient), spatial resolution in the direction of axis of rotation (nominal slice thickness for sequential CT, line-pairs for multislice-spiral), pixel noise (standard deviation of pixel CT numbers in a water phantom image), contrast resolution, CT-number uncertainty, homogeneity (uniformity), absence of artifacts and distortion. Performance indicators associated with patient dose criteria are: weighted CTDI, DLP. Relationships between performance indicators and image quality or safety criteria e.g., spatial resolution and sharpness, noise and reproduction of small detail, DLP and patient effective dose. Include instrument science concepts as applied to CT.

Describe and explain the general structure and functioning of the device including user controls and settings.	Use schematic and flow diagrams to aid understanding of how different parts are related to the overall functioning of the device, user controls and settings. Include only details necessary for the clinical situation, in particular avoid circuit diagrams. These are rarely necessary and tend to be off-putting to healthcare professionals. Emphasize that user controls and settings are often manufacturer, model and purchase options specific (include post-purchase modifications).	Describe and explain the general structure and functioning of a CT scanner including user controls and settings for both image acquisition and reconstruction.	CT-scanner as a measuring instrument: structure in terms of sensor, signal-processor and output-device. Details such as generations of CT scanners and reconstruction algorithms are not required. Meaning of z-interpolation in spiral-CT. Scan parameters for sequential CT. For spiral-multislice CT include also pitch and replace scan increment by reconstruction increment. Advantages of retrospective choice of image position, scan increment and slice thickness in spiral.
Explain design variables of the device which impact performance indicators (and hence outcome quality or safety criteria) at a level appropriate for users	Consider each performance indicator in turn and list the device design variables that impact the particular performance indicator. Concentrate on those variables that can be	Explain CT-scanner design variables which impact device performance indicators (and hence image quality or safety criteria) at a level appropriate for users	Examples: The main device design variables which impact spatial resolution in the scan plane are focal spot size, focus to detector distance, minimum focus to isocentre distance, maximum reconstruction matrix size and minimum reconstruction field-of-view size (relationship to minimum measurable

	controlled by the user.		patient voxel size, zoom facility), number of projections per rotation, availability of image filters, detector spacing.
Explain limitations and artifacts of the device and their impact on performance indicators (and hence outcome quality or safety criteria) at a level appropriate for users.	Artifacts are defined as systematic inaccuracies between the actual output outcomes of the device and the target outcomes.	Explain limitations and artifacts of a CT-scanner and their impact on performance indicators (and hence outcome quality criteria) at a level appropriate for users	Examples of limitations of CT: subjects of non-circular cross-section, finite speed of rotation etc. Types of CT artifacts: streaking, shading, ring and distortion artifacts. Origin of CT artifacts: physical processes, patient related, scanner and software imperfections. Effects of limitations and artifacts of CT on quality related performance indicators and hence image quality criteria.
Explain the physical principles underpinning the utilization of protective accessories and apparel and appropriate facility design for patients, staff and others when the device is in use.	Protective accessories and apparel fall under Council Directive 89/686/EEC	Explain the physical principles underpinning the use of protective barriers, accessories and apparel in a CT facility. CT facility design features for radiation protection.	Various instances from practice of use of accessories and apparel for patients, staff and others when using CT. CT room and barrier design.
List and explain use protocol design variables (including appropriate device settings, use of protective accessories and apparel) which impact performance indicators (and hence clinical outcome quality or safety criteria) at a level appropriate for users	From a device perspective protocols are designed to ensure that device performance indicators are not impacted negatively, to reduce the effects of the limitations of the device and eliminate or reduce	List and explain the protocol design variables (including appropriate device settings, use of protective barriers, accessories and apparel) which impact CT performance indicators (and hence image quality or safety criteria) at a level appropriate for users.	Example: the main protocol design variables which impact spatial resolution in the scan plane are focus to isocentre distance, application of high pass image filters, reconstruction matrix size, reconstruction field-of-view size, use of zoom, application of bolus around patient to improve cross-sectional shape. Attempts to increase scan plane spatial

	risk to all concerned. It is important to realize that attempts to improve one performance indicator may lead to degradation of another and/or an increase in risk.		resolution by reducing the reconstruction field of view or increasing the reconstruction matrix size will lead to an increase in pixel noise and lowering of contrast resolution which may necessitate an increase in mA and hence DLP. Similarly, use of high-frequency filters for increasing spatial resolution (sharpening filters) will increase visibility of pixel noise.
Demonstrates ability to apply commonly used post-utilization procedures for enhancing clinical outcome quality or safety.		Demonstrates ability to apply commonly used CT image processing and post-processing procedures for image enhancement	Magnification, zooming, windowing, choice of image filters as specified in protocols.
Explain user options for at least one commercially available device	Explain with the help of the user manual so that students become familiar with reading manuals. Important to emphasize that controls and settings are often manufacturer, model and purchase option specific (including post-purchase modific.).	Explain user options for the available CT-scanner.	Scan parameters for CT can be found in the literature. Include any special parameters available on the particular scanner (for example gantry tilt angle, partial scan).
Discuss qualitatively risk-benefit issues.		Discuss qualitatively risk-benefit issues when using CT.	CT as a high dose technique. Special care in justification and optimization is necessary particularly for women of child-bearing age and children.

Compare at a basic level the device with devices of similar function in terms of clinical effectiveness and safety.	Emphasize the complementary nature of devices.	Compare a CT-scanner with MRI and ultrasound in terms of effectiveness and safety.	Discuss in particular the complementary nature of CT and MRI.
Level 2	Level 2	Level 2	Level 2
Demonstrates performance of L1 competences at a level that would ensure understanding of and strict adherence to protocols.	Including any calculations necessary to adjust the protocol to particular client groups.	Demonstrates performance of L1 competences at a level that would ensure understanding of and strict adherence to protocols.	For example adjustments of mA in pediatrics.
Lists and explains the physical basis of any contraindications in the use of the device		Absence of absolute contraindications in the use of CT.	Although there are no absolute contraindications for CT (compare MRI), however great care is required in justification when it comes to pregnant patients and children. Where possible alternative non-ionizing modalities should be used.
Demonstrates knowledge of EU and National legislation, recommendations, regulations and documentation regarding the use of the device.		Demonstrates knowledge of EU and National legislation, recommendations, regulations and documentation regarding the use of CT.	Good references on radiation protection and dosimetry considerations in CT can be found in ICRP documents.
Demonstrates understanding of the physical principles underpinning the effective and safe use of any ancillary biomedical devices.	Imaging software is considered as a device ancillary to imaging devices. Which devices are considered as ancillary is determined locally.	Demonstrates understanding of the physical principles underpinning the effective and safe use of ancillary medical devices used in CT.	For example contrast media injectors, ionization chambers for CTDI measurement, ECG for gated studies.

Demonstrates safe disposal of non-reusable biomedical devices.	For example contaminated vials and syringes.	Demonstrates safe disposal of non-reusable ancillary medical devices used in CT.	Disposal of non-reusable ancillary medical devices used in CT (e.g., contrast media injector syringes).
Demonstrates awareness that a device should be checked before use (daily quality control), cared for during use and left in a condition for subsequent use by self or others.	Daily quality control is the systematic 'constancy testing' of performance indicators prior to use.	Demonstrates awareness that a CT-scanner should be checked before use (daily quality control), cared for during use and left in a condition for subsequent use by self or others.	Recommended daily quality control tests for CT can be found in the references.
Describes the impact on performance indicators arising from device malfunction, inappropriate protocol, device misuse, patient factors, facility design, environmental factors and combination of such factors including any artifacts arising from these within their scope of practice and local procedures for reporting such malfunctions.	Patient factors include anatomical (e.g., patient size) physiological (e.g., skin dryness) and psychological (e.g., anxiety) factors. Facility design factors include inadequate power points, power failures, room size and design, equipment layout, protection barriers and light fittings. Environmental factors include heat, dust, smoke, ionizing radiation, electromagnetic interference and other devices in the room.	Describes the impact on CT performance indicators arising from device malfunction, inappropriate protocol and device misuse including any artifacts arising from these within their scope of practice and local procedures for reporting such malfunctions.	Good discussions on artifacts in CT can be found in the references. Effects of inappropriate protocol on image quality and patient doses when using CT.

Demonstrates ability to measure or calculate recommended indicators of risk and compare to established risk reference levels.		Demonstrates ability to measure or calculate recommended indicators of risk in CT (weighted CTDI, DLP) and compare to established diagnostic reference levels.	Methods for measurement of weighted CTDI and calculation of DLP can be found in the references.
Level 3	Level 3	Level 3	Level 3
Demonstrates performance of L1 and L2 competences at a level that would require minimum supervision when using the biomedical imaging device with patients, scope of practice widened to include studies that are complex or somewhat non-predictable.	Which studies are considered ‘complex’ and ‘somewhat non-predictable’ will be determined locally. The necessary extensions in the elements-of-competence for such cases are derived by competence analysis.	Demonstrates performance of L1 and L2 competences at a level that would require minimum supervision when using a CT-scanner with patients, scope of practice widened to include studies that are complex or somewhat non-predictable.	Which studies are considered ‘complex’ and ‘somewhat non-predictable’ for CT will be determined locally. The necessary extensions in the elements-of-competence for such cases are derived by competence analysis.
Explain the physical mechanism underpinning procedures which would extend the functionality of the device.		Explain the physical mechanism of tissue contrast enhancement by CT contrast media.	Iodine based CT contrast media. Attenuation coefficient of contrast media.
Demonstrates skill in basic routine preventive maintenance and more advanced quality control appropriate for users	Weekly and monthly QC.	Demonstrates skill in basic routine preventive maintenance and weekly and monthly QC protocols appropriate for users	Quality control test for CT can be found in the references.
Demonstrates understanding of and ability to follow written contingency	Explain the set of contingency procedures	Demonstrates understanding of and ability to follow written	Explain the set of contingency procedures for CT used in the actual practice setting.

procedures	used in the actual practice setting. Evaluate and critically compare with others from literature.	CT contingency procedures	Evaluate and critically compare local procedures with others from the literature.
Level 4	Level 4	Level 4	Level 4
Demonstrates L1 to L3 competences at a level expected of a user at the forefront of professional practice.		Demonstrates L1 to L3 competences at a level expected of a user at the forefront of professional practice.	
Ability to formulate procurement plans for the device in terms of performance indicators and associated specifications required by the clinical needs.	Evaluation and comparison of performance indicators and associated parameters from different manufacturers.	Ability to formulate procurement plans for a CT-scanner in terms of performance indicators and associated specifications required by the clinical needs.	Evaluation reports of CT scanners can be purchased or downloaded freely from the internet.
Demonstrates advanced skills in preventive maintenance and quality control of the device appropriate for users.		Demonstrates advanced skills in preventive maintenance and quality control of the device appropriate for users.	Quality control of CT can be found in the references.
Ability to identify and correct causes of below target quality and safety criteria.	It is not necessary to include correction of causes requiring advanced physics-engineering expertise.	Ability to identify and correct causes of below target image quality and safety criteria when using CT.	
Demonstrates physics-engineering knowledge utilization in adjusting protocols to the needs of particular		Demonstrates physics knowledge utilization in adjusting CT protocols to the	

clients in studies which are complex, unusual, beyond-protocol and non-predictable.		needs of particular clients in studies which are complex, unusual, beyond-protocol and non-predictable.	
Demonstrates ability to conduct risk assessment and develop contingency procedures.	Both patient and occupational risk. Creating a culture of safety.	Demonstrates ability to conduct risk assessment and develop contingency procedures for CT.	
Applies physics-engineering knowledge to carry out advanced applications of the device.		Applies physics-engineering knowledge to carry out advanced CT applications.	CT angiography, interventional, endoscopy, multiplanar reformatting, 3D reconstruction etc.
Applies physics-engineering knowledge to manage any device data archiving and communication systems.		Applies physics-engineering knowledge to manage to manage image archiving and communication systems	In particular show examples of the effects of different levels of compression on CT images.
Ability to liaise with biomedical physicists-engineers in the development of clinical services (device and risk management, clinical outcome quality improvement, clinical audits)	Procurement, installation, acceptance testing of new devices, evaluate device specifications, QC protocol development etc	Ability to liaise with biomedical physicists-engineers in the development of CT services (device and dose management, image quality improvement, clinical audits)	
Applies physics-engineering knowledge and demonstrates the scientific attitude necessary for full effective, safe and economical use of the device in the coordination and implementation of clinical and research programmes.	The emphasis here is on a complete *scientific* attitude to devices. How can one get the most out of this device yet still keep risk to acceptable levels?	Applies physics-engineering knowledge and demonstrates the scientific attitude necessary for full effective, safe and economical use of CT in the coordination and implement of clinical and research prog.	

Level 5	Level 5	Level 5	Level 5
Demonstrates understanding of the underpinning physics - engineering (including the supporting mathematical) knowledge necessary to envisage *new* clinical and research applications for the device and be able to liase fully with biomedical physics-engineering professionals in the development of these applications.	Basics of the mathematics for a high level of understanding of device, quality control etc with emphasis on those aspects required for the particular research project. Research papers including CT physics-engineering should be critically analyzed.	Demonstrates understanding of the underpinning physics - eng. (including the supporting math.) knowledge necessary to envisage *new* clinical and research applications for CT and be able to liase fully with biomedical physics-engineering professionals in the development of these applications.	Basics of mathematics of image reconstruction and processing in CT (image reconstruction from projections, Radon transformation, convolution integral, image transforms, image filters etc).
Ability to recognize ethical and economic issues regarding the device in research and service development initiatives.	e.g., quant. risk-benefit analysis, equitable use of resources, importance of making full use of the capabilities of a device, EU risk classes of medical devices.	Ability to recognize ethical and economic issues regarding CT in research and service development initiatives.	CT is a high dose procedure. Guidance on exposures in biomedical research can be found in the references. Owing to the high doses CT is in the higher risk classes defined by the Medical Devices Directive.
Ability to recognize technical and ethical deficiencies in documentation and legislation regarding the device.	Available documentation and legislation should be critically analyzed.	Ability to recognize technical and ethical deficiencies in documentation and legislation regarding CT-scanners.	
Apply physics-engineering knowledge to the technical aspects of a healthcare technology assessment report for the device.		Apply physics knowledge to the technical aspects of a healthcare technology assessment report for CT.	A health technology assessment for CT (though limited to dose considerations only) can be found in the references.

Please address any feedback regarding the above inventory to Carmel J Caruana (carmel.j.caruana@um.edu.mt). All suggestions that are adopted will be acknowledged in future versions of the inventory.

8 CONCLUSIONS, REFLECTIONS, LIMITATIONS AND RECOMMENDATIONS

8.1 OVERVIEW OF THE CHAPTER

This chapter presents a summary of the main conclusions from the study, followed by reflections on the study, a discussion of the limitations of the study and recommendations for future research.

8.2 SUMMARY OF CONCLUSIONS

The following are the main conclusions of the study:

a) Although the role of BMPE educator is exercised in most FHS in Europe, has intrinsic strengths which can be exploited, and several instances of good practice exist, the role has been generally weakened by neglect from role holders who have not practiced proper role balance amongst their various academic roles - in particular the educator role has not been given its due importance as a result of an over-emphasis on the discipline research role.

b) However, the opportunities for the role are tremendous and should role holders rise to the occasion a good future for the role is assured. This thesis has indicated the way forward through the setting up of strategic role development and curriculum development models based on evidence and not mere opinion or speculation. We have also demonstrated that high quality, practice-oriented curriculum development is possible through concrete examples by producing elements-of-competence inventories for specific HCP.

8.3 REFLECTIONS ON THE STUDY

On the nature of the study

This thesis is quite unique in the sense that the literature does not give other instances in which a discipline specific academic role has been studied in such detail. We have found no other instance in which role, organizational and strategic planning theories were used to produce a role development model specifically for a disciplinary academic role. Yet if the standing of academic roles within society in general and if the quality of HE are to improve, each disciplinary role must make an honest appraisal of its actual and future contribution to student learning.

On the dissemination and implementation of the proposed strategy

Strategic plans are set up to be disseminated and implemented and not to remain on paper. The strategic plan is the end of one phase of the process and the start of another.

Specific, attainable, measurable objectives should be set up within the ambit of the plan and prioritized according to the context (European, national or local).

On the time-limited applicability of strategic plans

Every strategic plan is designed for a specified future period and would need to be revised periodically as a consequence of changes in the external environment. Although we have taken great pains to propose models and strategies which are quite robust, we do recommended that this strategic plan be revised periodically owing to the rapid changes in healthcare and HE in Europe.

8.4 LIMITATIONS OF THE STUDY

Research design limitations

The methodological limitations of the study arise from limitations of the main research design frameworks used. Practitioner research has the major advantage that it is carried out by ‘insider’ researchers who would have a very good working knowledge of the research context. However, it has been criticized as being biased in favour of the profession carrying out the research. We have minimized this bias by including both BMPE academics and educational leaders of the HCP in our research and by using extensively the literature of the HCP. Qualitative research has been critized for its use of non-representative non-random samples. However this type of criticism arises from a misconception of the purposes of qualitative research. Qualitative research is more interested in uncovering the range of themes relevant to an issue than the number of people holding a particular thematic point of view. This is particularly relevant in strategy studies where often it is the ‘outliers’ and ‘early adopters’ who produce the new ideas. The SWOT audit methodology has often been criticized as producing long lists of vaguely described SWOT factors which are not used in the subsequent strategy formulation (Hill & Westbrook, 1997). We have taken great pains to avoid these pitfalls by focusing on the SWOT themes most relevant to the purposes of the study and ensuring that these were used in the subsequent formulation of the role development model.

The absence of a political model of the FHS

Universities are highly political systems - the internal politics of the FHS would have an impact on what changes are possible. However it is our belief that in the present circumstances client-oriented strategies are more significant than political strategies and the marketing paradigm is becoming increasingly the dominant paradigm in HE planning. It is our belief that an entity that that renders itself useful to its clients will thrive, whilst one that renders itself irrelevant to its clients will cause its own existence to be unsustainable no matter its political clout. However an appended political model would definitely be an improvement to the strategic model (Harrison, 2005, p. 126).

The absence of a change model

No model has been proposed for managing the changes envisaged by the strategy both within the profession and within the FHS. Barriers to acceptability and implementability of strategic plans need to be studied before this can be done. Local organizational culture is of course a determining factor and there is no guarantee that a successful realization in one milieu would imply a similar outcome in another. Change in medical education has been discussed by Harden (1998) and a model of change in medical education has been carried out by Gale and Grant (1997).

8.5 RECOMMENDATIONS FOR FUTURE RESEARCH

The following are some suggestions for future research. The list is no means exhaustive as so little has been done to date. The field of BMPE educational research can be very fertile indeed and filled with opportunities.

A competency model for the BMPE educator in the FHS

This research would address questions of the type: “What competences should a BMPE educator have or need to acquire in order to be effective and efficient when practicing in a FHS?”, “What level and type of pedagogical, sociological, psychological and ethical knowledge is required in addition to the physics-engineering knowledge?”, “What level of interaction with the clinical milieu is required to ensure ongoing curricular relevance?” and “How can we prepare future BMPE educators so that the mistakes of the past will not be repeated?”. Another issue is that of specialisation. As the breadth of device information and research published in academic journals, conference proceedings and on healthcare oriented and device manufacturers’ websites mushrooms a point is being reached where keeping up with developments has become difficult. Specialisation is becoming necessary as no BMPE educator can possibly keep up with medical device development in all fields of healthcare. Several strategies are available for developing such competency models (Marelli, Tondora & Hoge, 2005; Markus, Cooper-Thomas & Allpress, 2005).

BMPE elements-of-competence inventories for other HCP

The BMPE elements-of-competence inventories we have formulated are limited to Diagnostic Radiographers, Physicians and Nurses. Further research needs to be carried out to produce inventories for other HCP. Radiation Therapists and Physiotherapists who are both intensive device users immediately come to mind. Moreover as HCP develop their roles these inventories would need to be amended and as new HCP roles crop up new inventories formulated.

Curricular challenges facing the BMPE educator

The curricular challenges inventorized in Chapter 6 need to be studied in a systematic manner. Each challenge presents opportunities for educational research as so little has been done.

Development of BMPE education resources

The educational resources available for BMPE educators are extremely limited and most of the little that exists is directed towards imaging or radiation therapy and targeted to BMPE. Here it would be opportune to mention the efforts of Tabakov and collaborators (Aitken & Tabakov, 2005; Tabakov, 2005; Tabakov, Roberts, Jonsson, Ljungberg, Lewis, Wirestam, et al. 2005) who have produced award-winning educational multimedia packages for teaching medical imaging and radiation therapy. However these multimedia packages are aimed at medical physicists and engineers. It would be interesting to know to what extent these can be adapted for use in the teaching of Diagnostic Radiographers, Radiation Therapists and other HCP. There are also quite extensive multimedia for mainstream physics and engineering some of which might be suitably adapted for use in HCP education (Altherr, Wagner, Eckert, & Jodl, 2004).

Applying mainstream physics education research to BMPE education

Although much mainstream physics research is dedicated to pre-university levels, there is much that can be adapted to HE. Work on physics concept formation, concept mapping, physics misconceptions, laboratory work and educational evaluation would be particularly relevant. However it has also been pointed out that HE requires methods of research that are somewhat different from those used in conventional pre-HE educational research (Stierer & Antoniou, 2004).

The issue of mathematics

The well-known problem of low levels of competency in mathematics among HCP is continuously with us. Sabin (2001) has produced a critical review in the case of nursing - however the same findings can be easily applied to most HCP. The issue is seriously limiting the range and depth of content that can be included in BMPE curricula and the research opportunities available to HCP students. Research needs to be carried out to find ways of incorporating mathematical background in BMPE curricula without compromising the amount of time dedicated to physics-engineering.

Humanistic and ethical aspects of biomedical devices

BMPE educators owing to their highly technical background have to constantly remind themselves that they are physical scientists working in a multidisciplinary milieu which is charged with humanistic and ethical issues (Murphy, 2001 & 2006; Vos & Williams, 2000). Research needs to be carried out to determine how BMPE elements-of-competence inventories and curriculum delivery needs to be adjusted to such sensibilities.

8.6 CONCLUSION

In this study we have provided BMPE educators in the FHS with role development and curriculum development frameworks which they can utilize to enrich their role. We now challenge all European BMPE educators to critically question their current practices, construct the conditions for change where such change is necessary and foster national and international cooperation in the field.

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