Analysis of M-level modules in interdisciplinary nanotechnology education

May 2009

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Editors Note

When developing a new course of study there is always a great deal of soul-searching about what should, or should not, be contained in the course. This is especially so in an area of technology that is truly multi-disciplinary and developing rapidly into new thematic areas such as Nanotechnology. This document provides a snap shot as to what various institutions across Europe have elected to teach at post-graduate level under a large, and exciting, variety of Nanotechnology Masters qualifications. It shows that there are courses teaching programme devoted to physics at the nanoscale, courses that can develop an entrepreneur and courses that are focused on using Nanotechnology for the betterment of mankind through the development of medical or energy harvesting devices. In essence this document contains the key information of what modules are seamlessly pieced together to generate a Nanotechnology Masters.

S Dunn - May 2009

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1. Introduction

The convergence of knowledge from natural sciences, engineering and humanities discipline characterises the knowledge disseminated in nanoscience and nanotechnology educational programmes. The vast knowledge area represented by the field presents significant challenges in the design, development, and delivery of educational programmes both at the bachelor and master level. The study aims to provide educators preparing new educational programmes at the masters level (M-level), those engaged in continual improvement of programmes and professional bodies engaging in accreditation, with an overview of current practices and methods collectively applied by higher education establishment. The understanding of the knowledge dissemination practice was developed through core knowledge being imparted, the learning outcome achieved and assessment methods.

The objective of the study was to identify, the core knowledge that is being imparted to students within the current MSc courses. The module content is drawn from knowledge of different disciplines; physics, chemistry, biology, engineering, management, philosophy, and social studies. This was achieved by segmenting the collection of modules and identifying discipline orientation for the scientific and technical knowledge content. Information was processed to relate the nature of the module in the program. The aim was also to identify the preferred assessment method of learning outcomes and the credits assigned to the modules. The methodology used for segmenting the modules has been presented in the subsequent section.

The scope of the modules analyse was limited to programmes whose information is included in the Institute of Nanotechnology education database. The Universities whose program information is available in the database can be accessed from Appendix E. These programmes are delivered by Universities based in Europe. They are mainly full time educational programmes taught largely in English. Further information about the programmes is mentioned in section 3. The focus of knowledge is on Natural Sciences oriented modules, and Engineering oriented modules. Ethical, Legal, Societal and Communication modules, along with Management and Innovation modules have also been covered as supplementary education. The subsequent sections relate the distribution of knowledge in the various disciplines to the assessment methods, credit allocation and the nature of module.

2. Methodology

The data set used in the analysis of the modules was obtained from the data provided by educational programmes. The methodology used was to segment the modules based on the discipline orientation of the modules. Four main segments were identified Natural Sciences; Engineering; Ethical, Legal, Societal and Communication (ELSC); Management and Innovation. The module segments and the number of modules are shown in Table 1 below.

Table 1 - First module segmentation and total number of modules

Module Segmentation	Number of Modules
Natural Sciences oriented Modules	180
Engineering Modules	57
ELSC	12
Management and Innovation	9
Total	258

The criterion used was the ratio of Physics, Chemistry, Biology, Engineering and other subject's knowledge as indicated by course directors in the circulated information template. In the Natural Science segment, all modules with a cumulative percentage composition of more than 50% were included. In the case of a 50% split between natural science and engineering, the department providing the education was used as a decision criteria. For engineering modules, the criterion used was more than 50% content of the module being relevant to Engineering and the department providing the education.

Natural Sciences and Engineering modules were further segmented. For Natural Science, the second level differentiation used was '*Single Discipline Natural Science*' module, '*Pure Natural Science*' module and '*Interdisciplinary with Natural Science*' orientation. Where ratios were not defined the data was excluded. These 11 modules had a Material Science orientation with a focus on enterprise. The '*Single Discipline Natural Science'* modules were those, with 100% knowledge content allocated to Physics, Chemistry or Biology. '*Pure Natural Science*' modules were those that were that had knowledge content from Physics, Chemistry and Biology in the module content. Interdisciplinary modules were those which had majority content from Natural Science but also had knowledge content from engineering discipline.

Table 2 – Natural Sciences second level module segmentation

Natural Science second level differentiation	Number of Modules
Single Natural Sciences Discipline	24
Pure Natural Science	27
Interdisciplinary	118
Modules with Ratios not defined	11
Total	180

The Engineering modules were segmented into those that are completely focused on Engineering or had some natural science knowledge included. The modules on engineering were identified to have 100% knowledge content drawn from the discipline. The Interdisciplinary modules with engineering orientation contained modules with up to 50% content from natural sciences. Table 3 below gives the number of modules in the two second level segmentation of Engineering modules.

Table 3 - Engineering modules second level segmentation

Engineering Second level differentiation	Number of Modules
Engineering focused	24
Interdisciplinary	33
Total	57

The assessment of learning outcomes was further categorised into examination based or coursework based. A number of mixed methods were mentioned in the coursework assessment of modules. These were based on essays, practical tests, group projects, individual projects, thesis, viva-voce, problem sheets, reports, technical papers, poster presentation, and laboratory session. The percentage of assessment of learning outcome for each module was identified by the course directors. Credits of learning outcome for each of the levels of module differentiation have been graphically represented. These have been categorised by UK Universities or the ECTS credits for modules offered by Universities based in other European countries.

3. Programme information

This section provides information about the programmes and the education offered by these programmes. The majority of the programmes provide a Masters of Science degree followed by Masters of Research and Masters of Philosophy as shown in Figure 1.

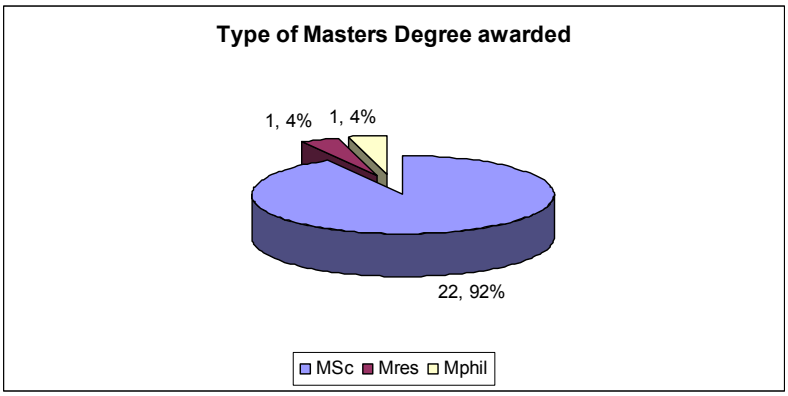

Figure 1 - Type of Degree awarded

19 programmes reported to provide full time learning in one year while 5 other programmes delivered in two years. In addition 6 programmes provide the same learning outcome as a part-time study in two years. This is shown in figure 2 below.

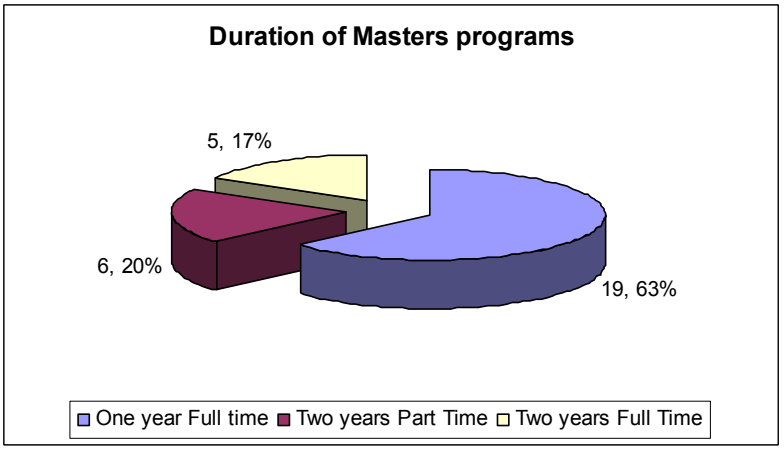

Figure 2 - Duration of Masters Programmes

The primary mode of education was found to be full time with 20 programmes offering interdisciplinary curriculum , 9 programmes offering part time education, 1 program offering online while another offering distance education as shown in figure 3.

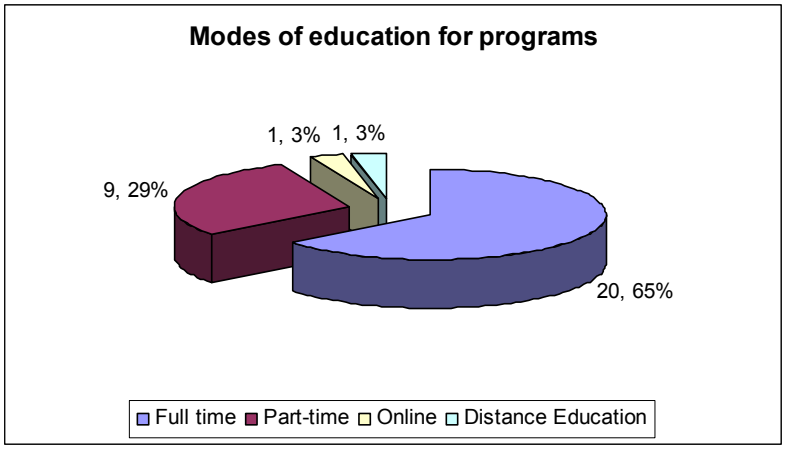

Figure 3 - Mode of education for programmes

The data used was from programmes in different educational systems across Europe. The majority of programmes are delivered by Universities based in the UK (14 programmes) while the remaining are in other European Countries; 4 programmes are based in Netherlands, 2 in Belgium, 1 each in Sweden, Spain, Italy, Ireland, and France as shown in figure 4. The main language of instruction is English. 22 (92%) programmes offer the curriculum in English, 1 with combined English and Spanish, and another in French and English. 83% of the programmes whose module data was analyzed provided grants to students for education while others do not.

4. Natural Sciences Discipline orientation

This section provides a visual representation of modules with a Natural Science orientation. Data has been organized into Single Natural Science Discipline modules, Pure Natural Science Discipline modules, and Interdisciplinary Natural Sciences module. A list of modules is available from Appendix A.

4.1 Single Natural Science Discipline

58% of single natural science discipline modules (24) were optional for the different programmes as shown in Figure 4.

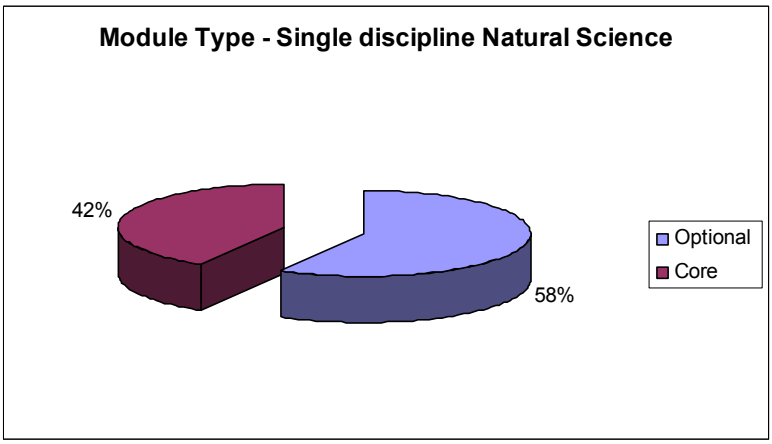

Figure 4 - Single Discipline Natural Sciences module type

A majority of single natural science discipline module were physics oriented (17), followed by chemistry (4) and biology (3) as shown in Figure 5. The entire content in these modules was drawn from a single natural science discipline.

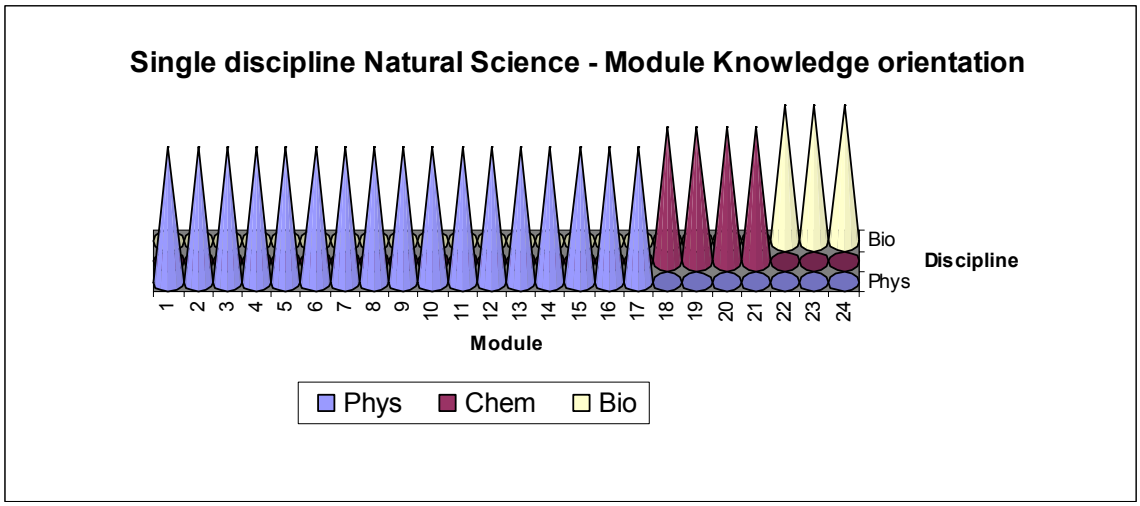

Figure 5 - Single discipline Natural Science - Module Knowledge orientation

A majority (15) of single discipline natural science modules were assessed for learning outcomes through examinations, while only 2 were completely assessed through coursework. An area chart of learning outcomes is shown in figure 6.

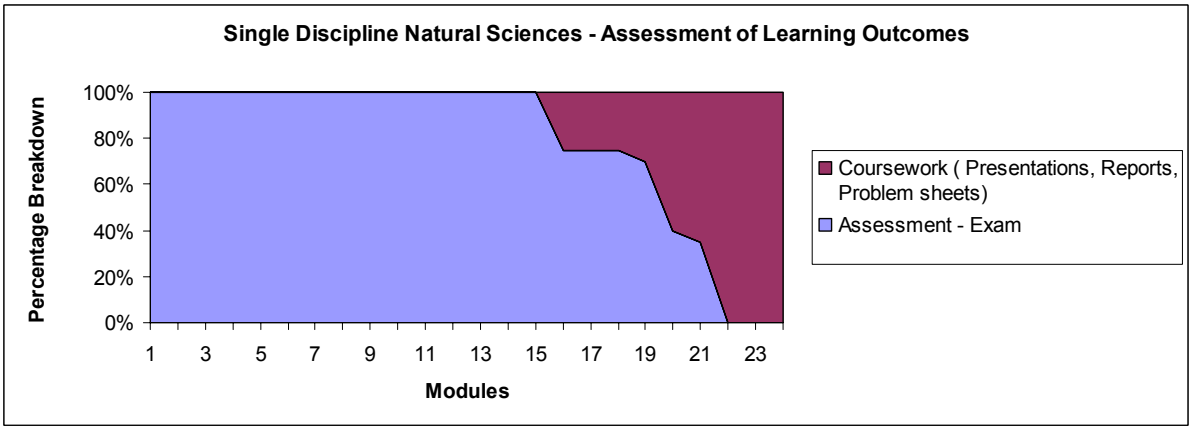

Figure 6 - Single Discipline Natural Science modules - Assessment of learning outcomes

A maximum of 12 credits and a minimum of 8 credits were assigned for single discipline natural sciences modules by UK Universities as shown in figure 7.

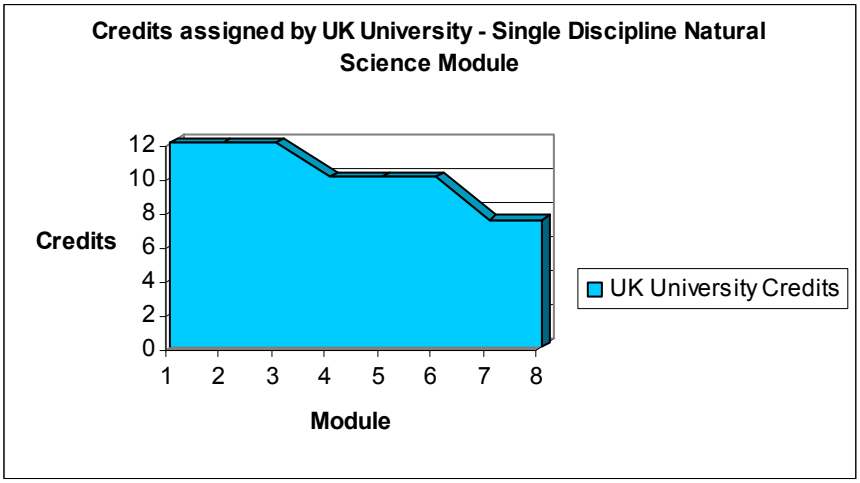

Figure 7 - Credits assigned by UK Universities for Single Natural Sciences Discipline

A maximum of 6 credits and a minimum of 3 credits were assigned by other Universities in Europe for learning outcomes demonstrated in single discipline natural sciences modules. The ECTS weights for each module are shown in figure 8.

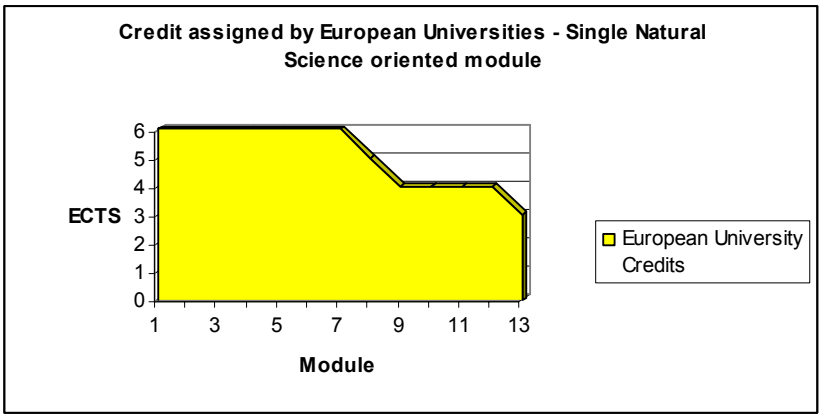

Figure 8 - Credits assigned by European Universities for Single Natural Science module

4.2 Pure Natural Science Discipline Modules

Pure Natural sciences modules were those that draw upon knowledge from Physics, Chemistry and Biology into the knowledge imparted through the modules. 73% of the modules in this segment were core modules as shown in figure 9.

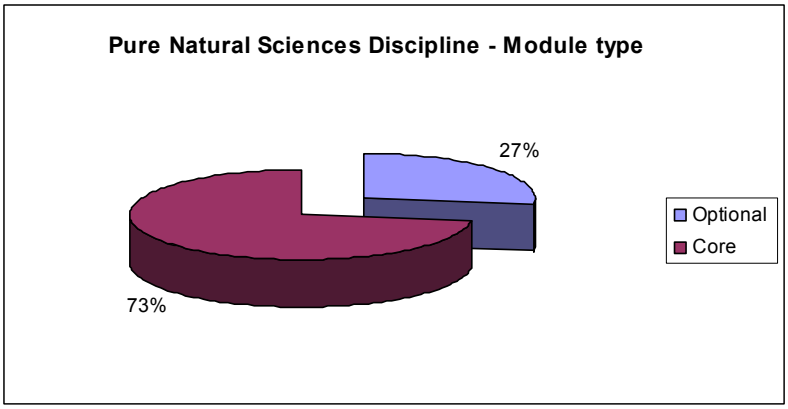

Figure 9 - Pure Natural Science Discipline: Module type

Pure Natural Sciences module knowledge content was observed to be evenly spread across, Physics, Chemistry and Biology. Physics knowledge was more evenly spread out across the different disciplines (18), while biology had higher content for 7 modules followed by chemistry for 5 and physics for 4 modules. The percentage distribution is shown in figure 10 shown.

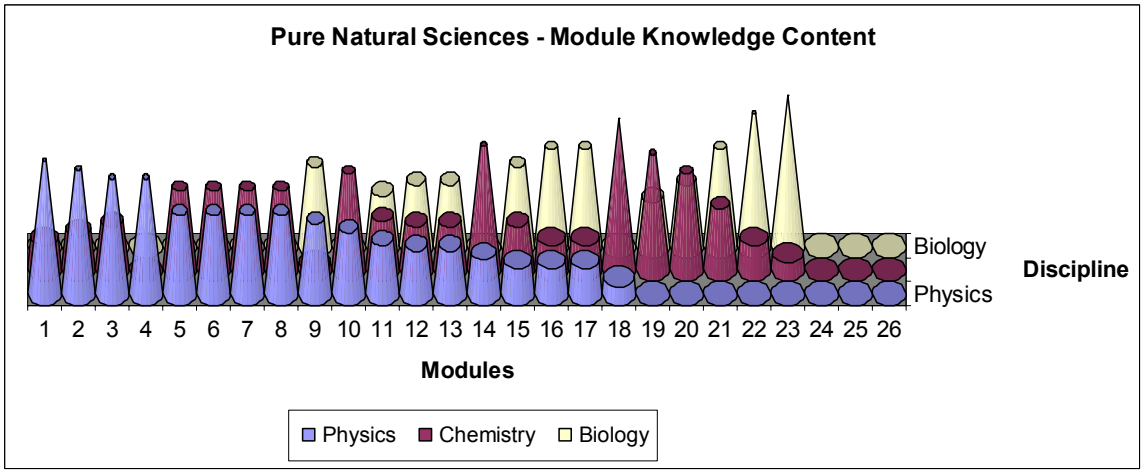

Figure 10 - Pure Natural Science modules knowledge content

The preferred assessment of learning outcomes for the modules was both examination and coursework based (10), followed by coursework assessment for 9 modules and completely examination assessment for 7 modules. An area chart representing the assessment of learning outcomes is shown in figure 11. The figure demonstrates a preference for single mode of assessment over mixed modes for pure natural sciences disciplines.

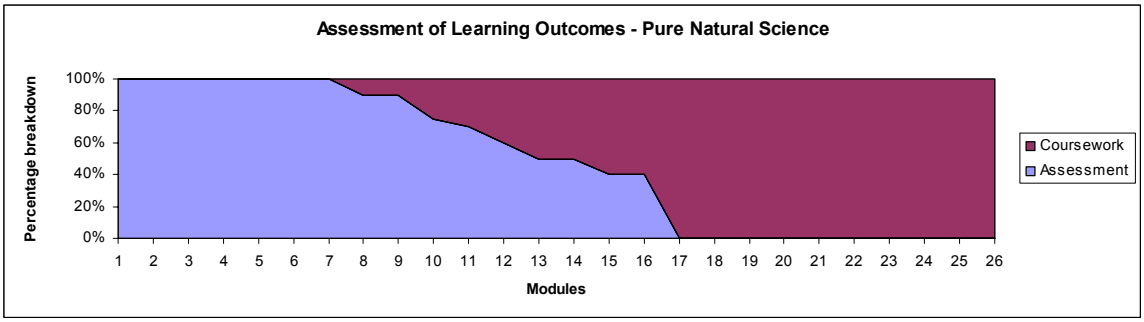

Figure 11 - Assessment of learning outcomes: Pure Natural Science modules

Modules with pure natural sciences knowledge content were assigned a maximum of 25 credits and a minimum of 7.5 credits by programmes based in the UK. This is shown graphically in figure 12.

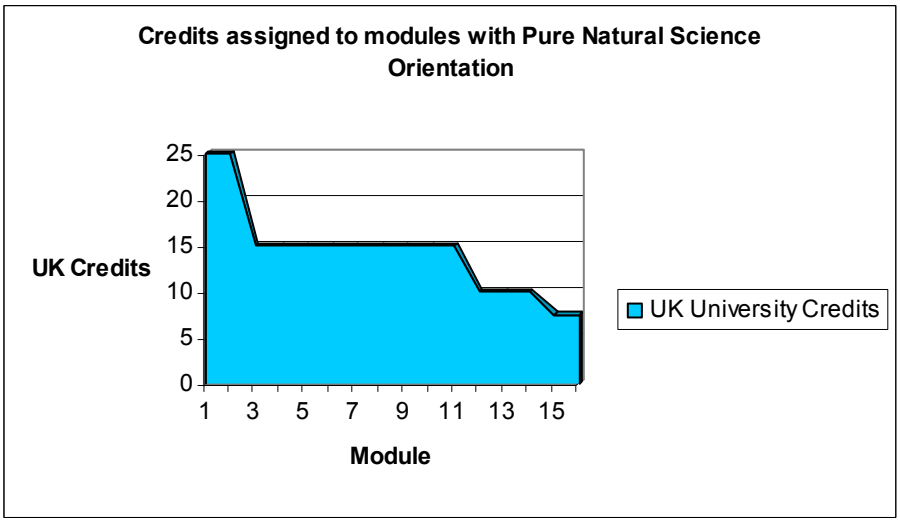

Figure 12 - Credits assigned by UK Universities: Pure Natural Science oriented modules

A maximum of 6 EC credits and a minimum of 3 EC credits were assigned to pure natural science modules by programmes outside the UK. The credits assigned are shown in figure 13.

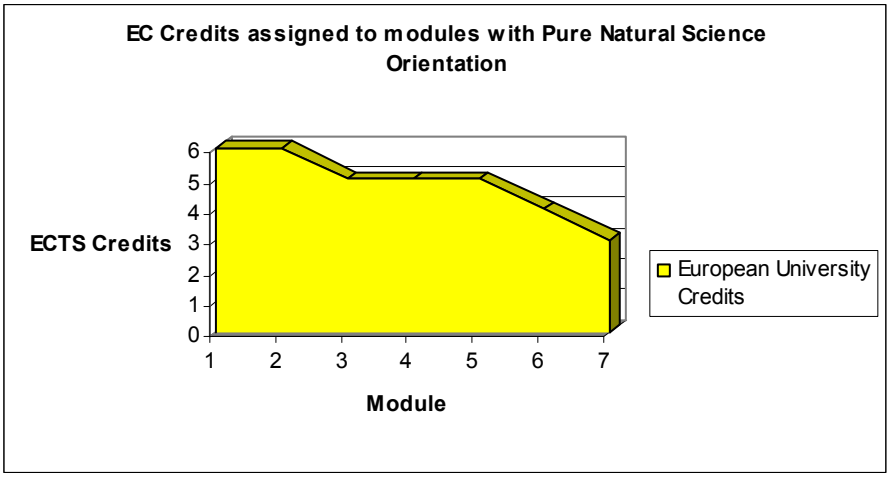

Figure 13 - EC Credits assigned to modules by European Universities : Pure Natural Science orientation

4.3 Natural Science oriented Interdisciplinary modules

Natural Science oriented Interdisciplinary modules form the bulk of the natural sciences modules imparted collectively by the educational programmes. 81% of the 118 modules were core modules in the various programmes. 19% of the total modules were considered optional, as shown in the figure 14.

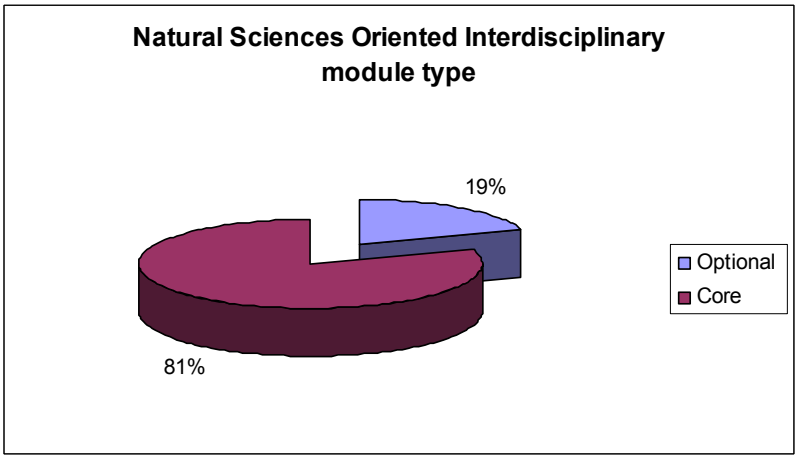

Figure 14 - Natural Sciences oriented Interdisciplinary module type

The interdisciplinary modules were further classified as general, physics oriented, chemistry oriented or biology oriented. The classification of orientation was based on percentage of

knowledge content for physics, chemistry and biology which was higher than the other discipline in the module. A fraction of the knowledge content was drawn upon from the engineering discipline. The largest fraction of modules were general interdisciplinary modules (47%), followed by physics oriented (36%), chemistry oriented (11%), and biology oriented (6%) as shown in figure 15.

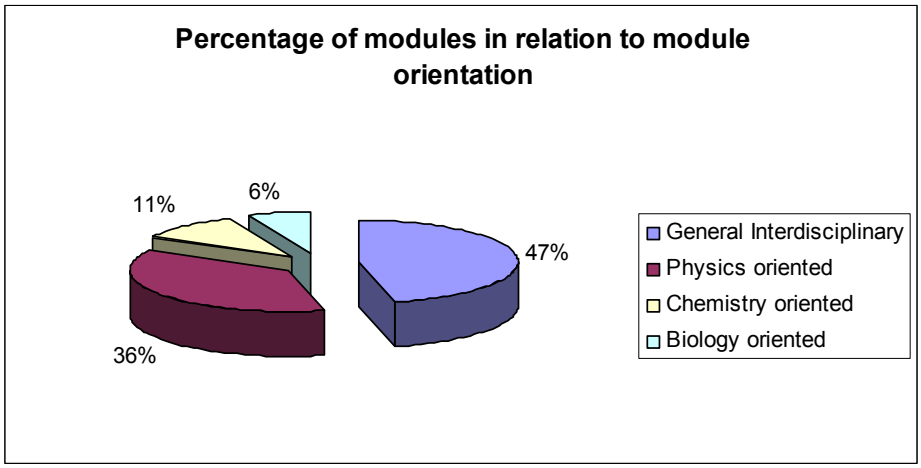

Figure 15 - Percentage breakdown of Natural Science modules in relation to orientation

The physics oriented modules (40) had between 50-90% content derived from the knowledge discipline. Others disciplines with fractional representation were, chemistry, biology, and engineering as shown in figure 16 below. The graphical representation gives a view of physics oriented modules that have drawn knowledge content from the different disciplines.

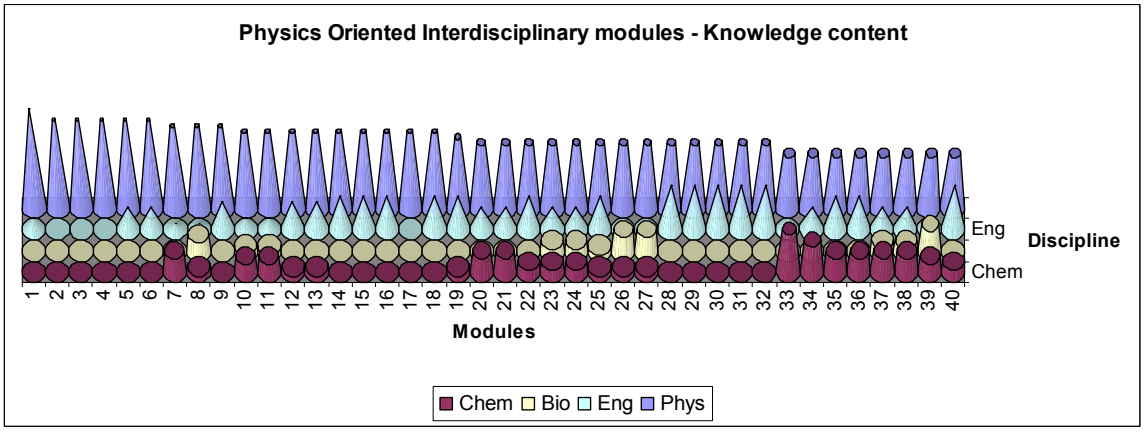

Figure 16 - Physics oriented Interdisciplinary modules: Distribution of Knowledge content

There were 12 modules with chemistry discipline orientation. The content range ranged from 50 - 80% chemistry discipline knowledge as shown in figure 17. The graphical representation shows that the supplementary knowledge is drawn upon from physics discipline for these modules.

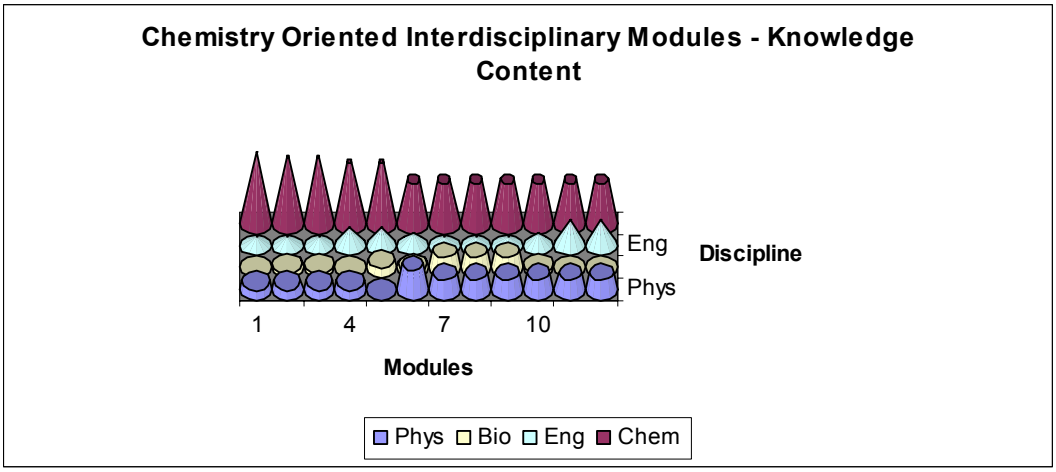

Figure 17 - Chemistry oriented Interdisciplinary module: Distribution of Knowledge content

The biology orientated modules (7) has a knowledge content ranging from 50 – 90 % of content drawn from the discipline as shown in figure 18 below. Physics and chemistry knowledge were supplementary for the biology oriented modules.

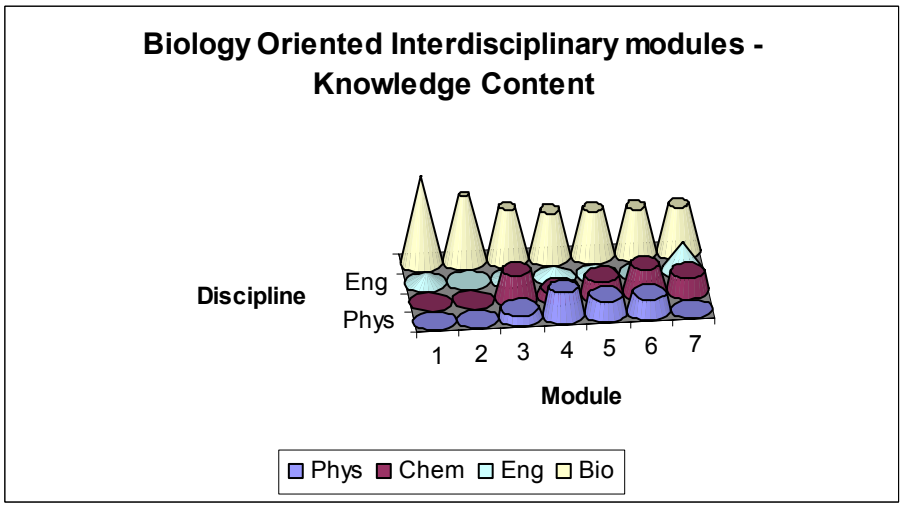

Figure 18 - Biology oriented interdisciplinary modules: Distribution of Knowledge content

The general interdisciplinary modules formed the largest part of the natural sciences. There are 51 modules in this category. 10 of these modules had knowledge content evenly divided between physics (50%) and engineering (50%). The remaining modules have content from the different discipline was evenly spread in the knowledge imparted. The knowledge distribution is shown in figure 19. The wide distribution of knowledge source from disciplines in such interdisciplinary modules presents challenges for design, development, delivery and assessment of educational content.

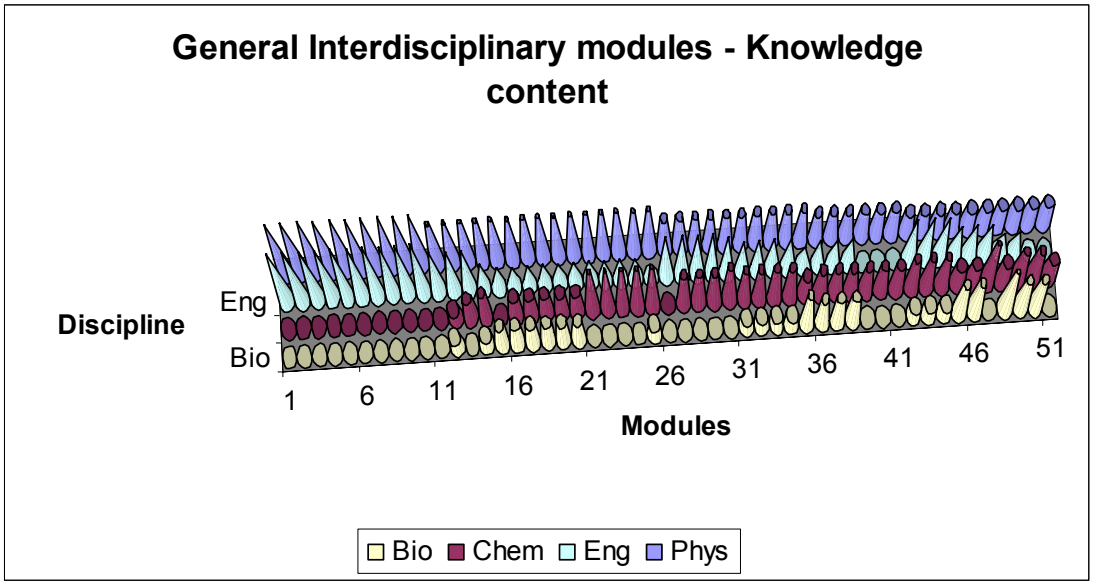

Figure 19 - General Interdisciplinary modules: Distribution of Knowledge Content

The assessment of learning outcomes for general interdisciplinary modules is shown in figure 20 below. The most preferred method for assessment was observed as a combination of examination and coursework (46). This was followed closely by modules (44) completely assessed for the learning outcomes through examination. 28 modules completely assessed learning outcomes only through coursework.

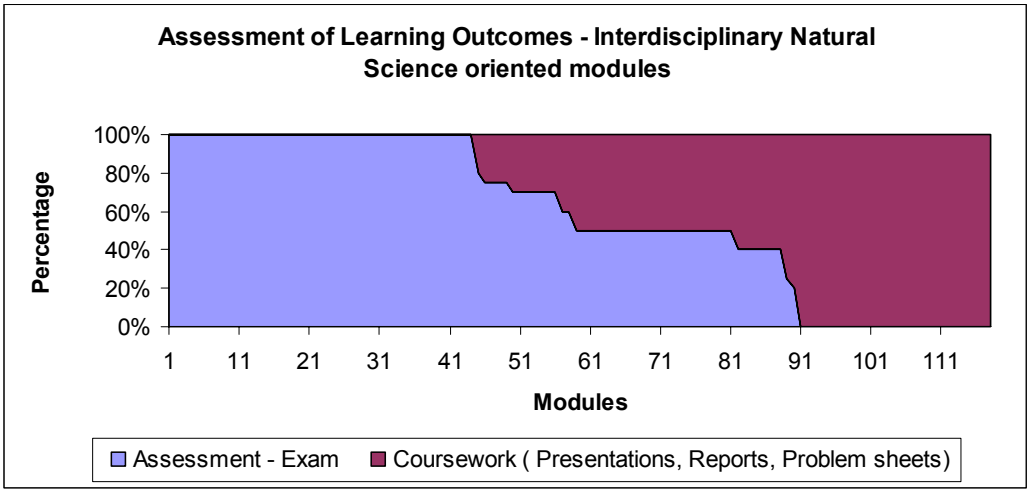

Figure 20 - Assessment of learning outcomes: Interdisciplinary natural science oriented modules

The credits assigned to natural science oriented interdisciplinary modules, by UK Universities range from 60 credits to 5 credits. This is shown in figure 21. It is notable to mention, that two modules with 60 credits assigned to learning outcomes are dissertation projects.

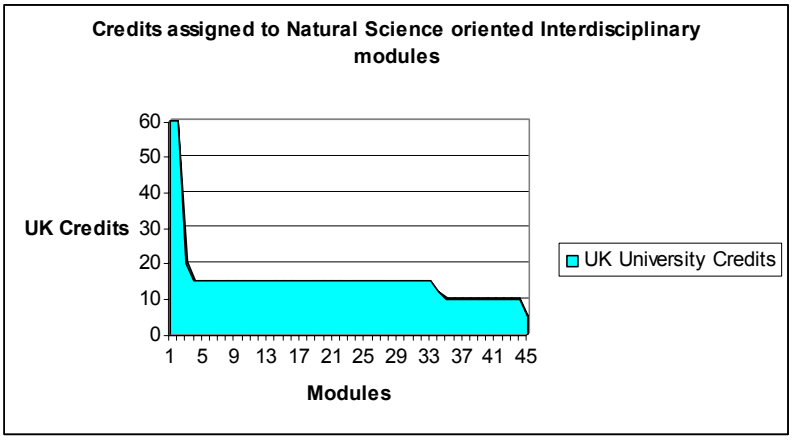

Figure 21 - Credits assigned to Natural Science oriented interdisciplinary modules: UK Universities

Credits assigned by European Universities to learning outcomes vary from 48 credits to 2.5 credits as shown in figure 22. It should be noted that three modules with relatively high credit allocation were mentioned to be thesis or research projects.

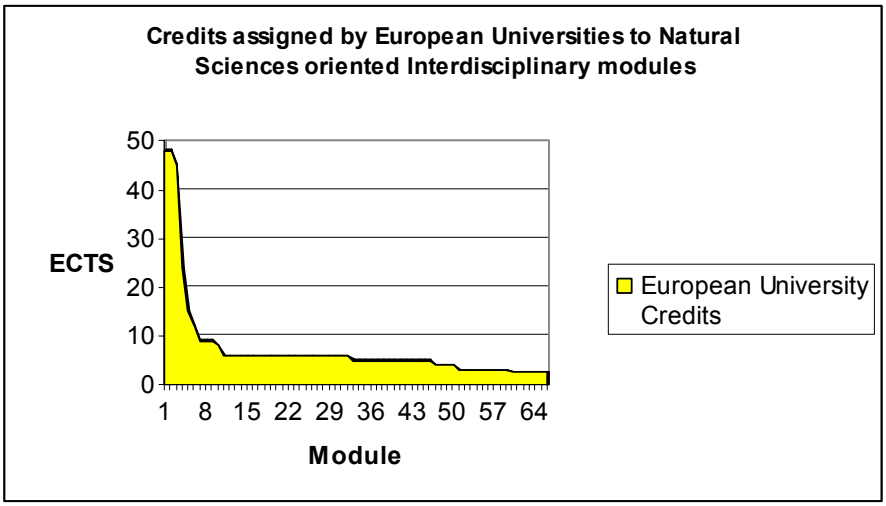

Figure 22 - Credits assigned to Natural Sciences oriented Interdisciplinary modules: European Universities

5. Engineering Discipline Modules

The following section is focused on interdisciplinary modules that have majority content drawn from the Engineering discipline knowledge. The modules have been segmented into modules completely drawn from the Engineering discipline, and those that have a fraction of knowledge content included from the natural sciences discipline. A list of modules is available from Appendix B.

5.1 Engineering Modules

A majority of 24 Engineering modules are core modules (83%), while a smaller fraction are optional (17%) as shown in the figure 23. These modules were indicated as 100% Engineering content, ranging from Electrical, Electronics Manufacturing Engineering.

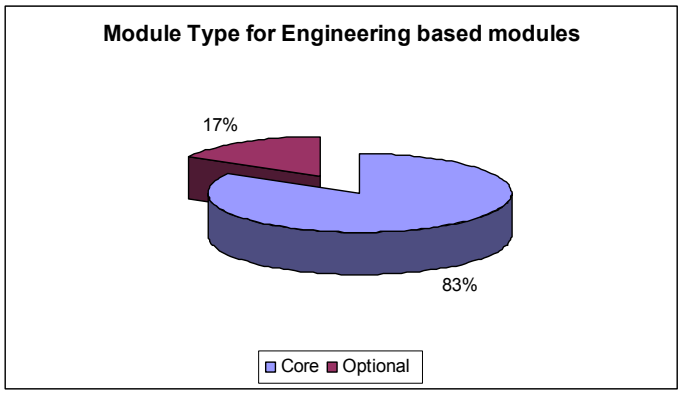

Figure 23 - Type of Engineering based modules

The assessment of learning outcomes for engineering modules was mainly done through coursework (12), followed by combined course work (6) and examination, and complete examination (6). A graphical representation of course work is shown in the figure 24.

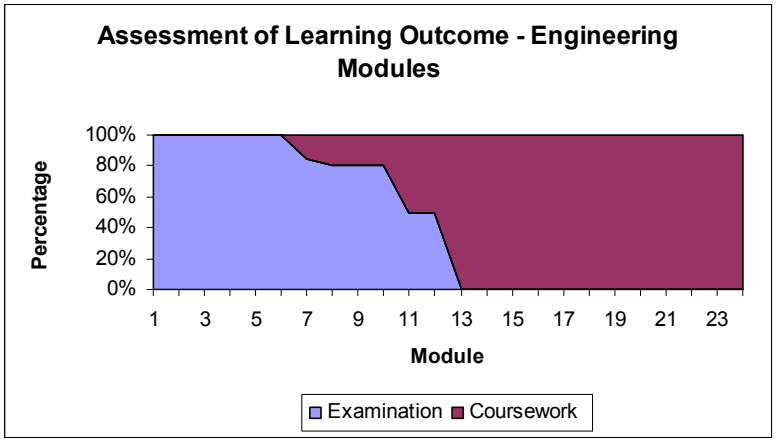

Figure 24 - Assessment of learning outcomes: Engineering modules

The credits assigned by UK Universities to Engineering modules ranged from 60 to 7.5 credits. This is shown graphically in figure 25. It is notable to mention that three modules in this segment of modules are research projects. There was only one module taught by a European program identified completely as Engineering. The module was assigned 11 credits (ECTS).

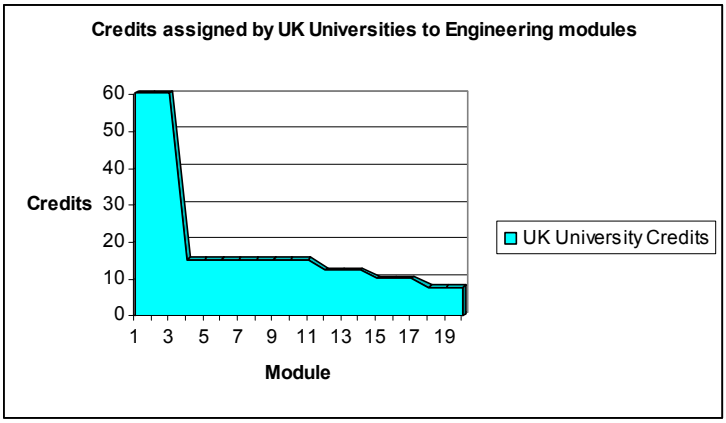

Figure 25 - Credits assigned by UK Universities to Engineering modules

5.2 Interdisciplinary modules oriented towards Engineering

A majority of the 33 interdisciplinary modules oriented towards Engineering, were considered to be core within the curriculum (64%). The remaining 36% modules were optional as shown in the figure 26.

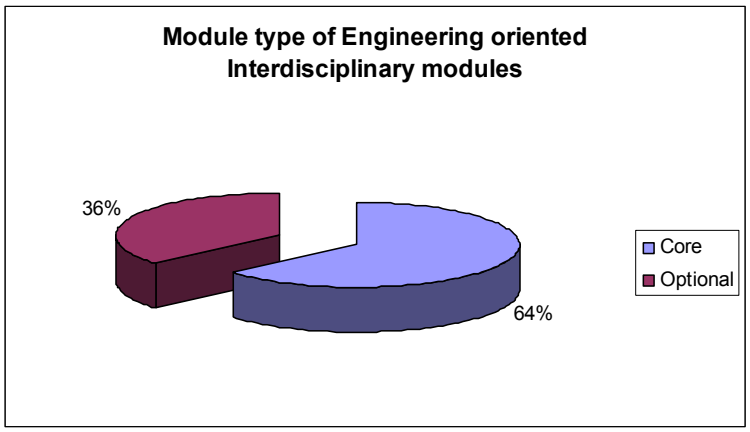

Figure 26 - Type of engineering oriented Interdisciplinary module

The knowledge content for engineering oriented Interdisciplinary modules, ranged from 50 – 80%. The second most complimentary discipline for education in module content was physics while limited knowledge content was drawn from the biology discipline. A graphical representation is shown in the figure 27. It is important to note that modules 25-30 indicated, Mathematics as an important part of the content. Modules 31-33 indicated Materials and Electronics as the main knowledge content while they were based in Engineering Departments. Other modules had also indicated Materials knowledge as an important constituent. It is notable to mention that limited knowledge was drawn from biology discipline was included in this categorisation of modules.

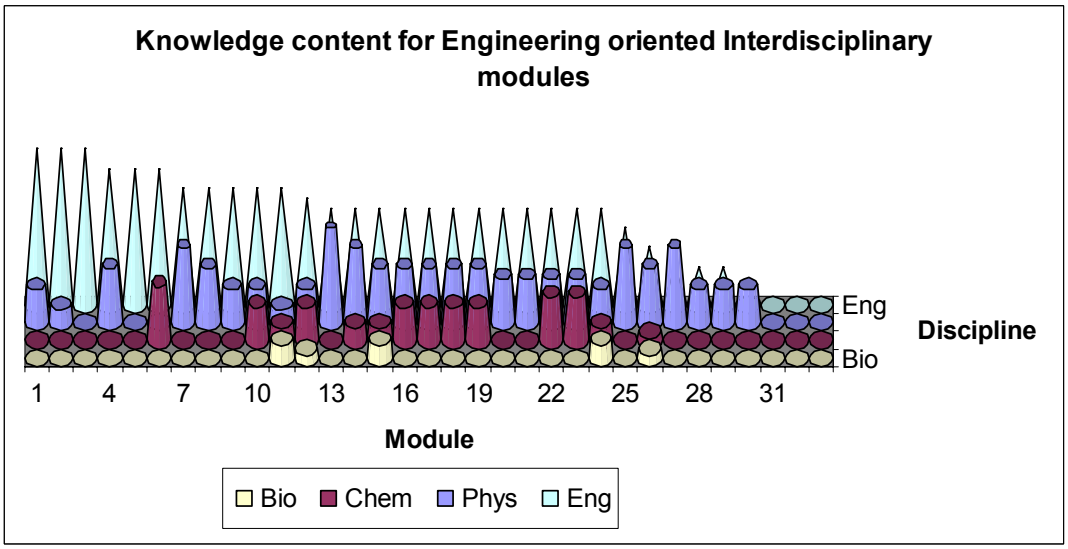

Figure 27 - Engineering oriented Interdisciplinary modules: Distribution of Knowledge content

The assessment of learning outcomes for engineering oriented interdisciplinary modules is shown in figure 28. The main method assessing learning outcomes was either coursework (13) or examination (11) based. Only 9 modules had taken varied degrees of examination or coursework based approaches.

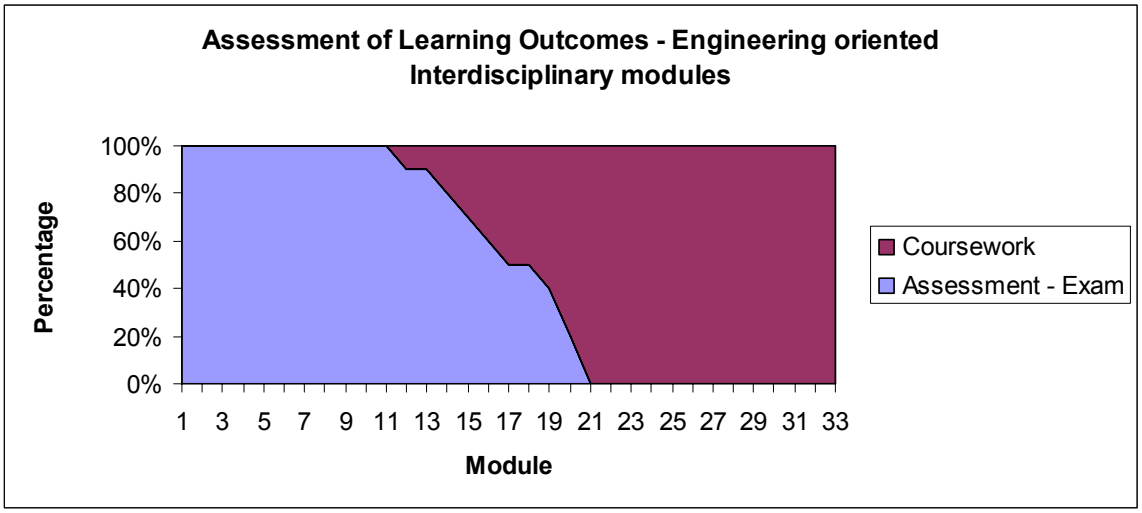

Figure 28 - Assessment of Learning Outcomes: Engineering oriented Interdisciplinary modules

The credits assigned by UK Universities to Engineering oriented Interdisciplinary modules ranged from 80 – 4.5 credits, as shown in figure 29. Two modules with 80 and 40 credits assigned were identified as individual or group projects.

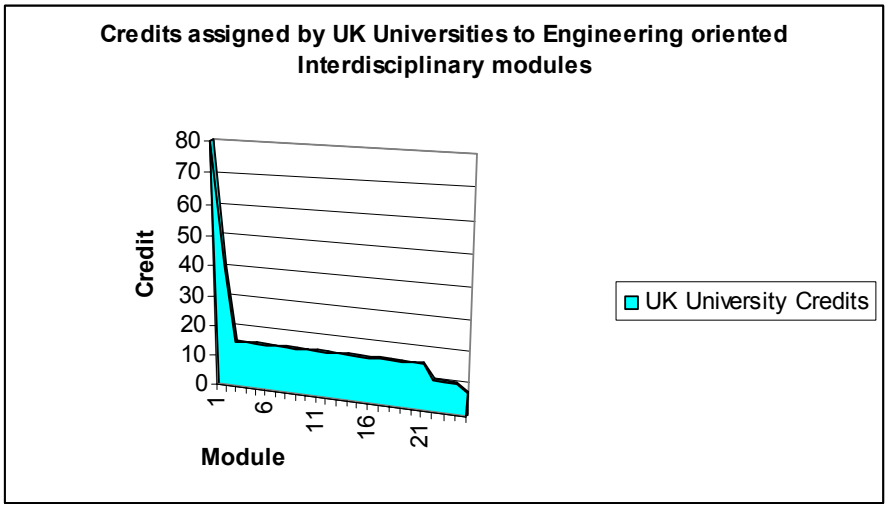

Figure 29 - Credits assigned by UK Universities: Engineering oriented Interdisciplinary modules

The Credits assigned by other European programmes to Engineering oriented Interdisciplinary modules, ranged from 6 – 2.5 credits. The ECTS for 8 modules is shown in figure 30.

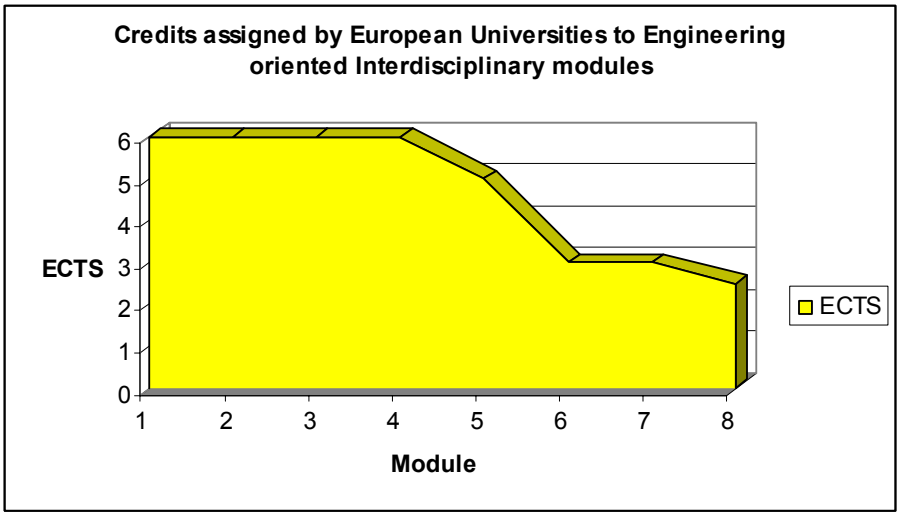

Figure 30 - Credits assigned by European Universities: Engineering oriented Interdisciplinary modules

6. Ethical Legal Societal and Communication

Ethical, Legal, Societal and Communication (ELSC) modules have been included as supplements to education provided by masters' level programmes. A majority of the 12 modules taught in different programmes were considered mandatory (92%). A list of the modules is available from Appendix D. The discipline knowledge distribution can be seen from the figure 31. Modules 1-9 were focused primary on ethical, legal societal and communication knowledge. Modules 10-12 focused on communication, also drew upon knowledge from technical and business disciplines.

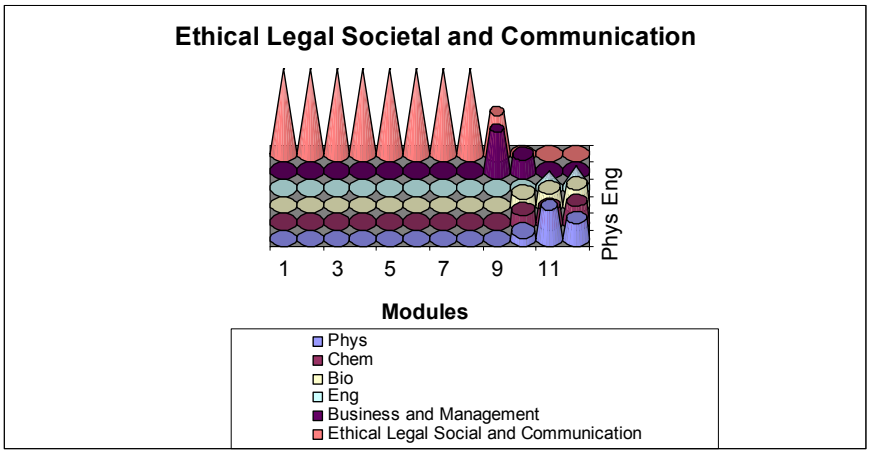

Figure 31 – ELSC modules: Distribution of Knowledge Content

The main form of assessment of learning outcomes ELSC modules was through coursework (6), followed by examinations (4) and a combination of the two methods (2). This is shown graphically in figure 32.

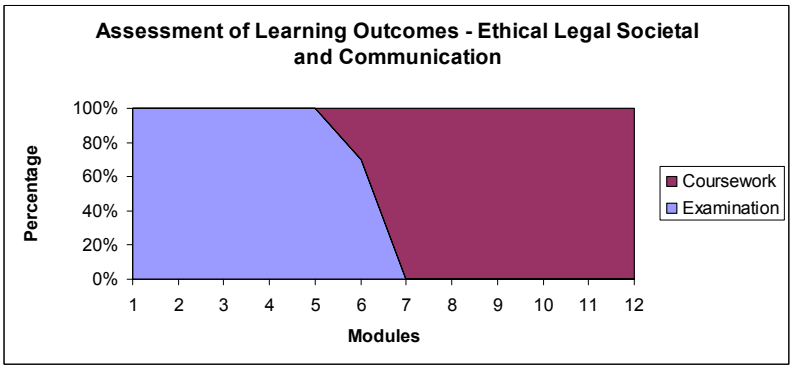

Figure 32 - Assessment of learning outcomes: ELSC modules

The UK Universities were observed to have assigned 15-10 credits to the 3 ELSC modules analysed in the study. European Universities assigned between 4 -2.5 credits to 7 ELSC modules as assessed from the database.

7. Management and Innovation

Management and Innovation modules are taught either as supplementary modules in programmes or form an important part of the program. A majority of the 9 modules are core (78%) for the curriculum. The distribution of knowledge content is shown in the figure 33 for the management and innovation modules. Module 5 was identified as an industrial internship, while module 9 was given the title of an innovation.

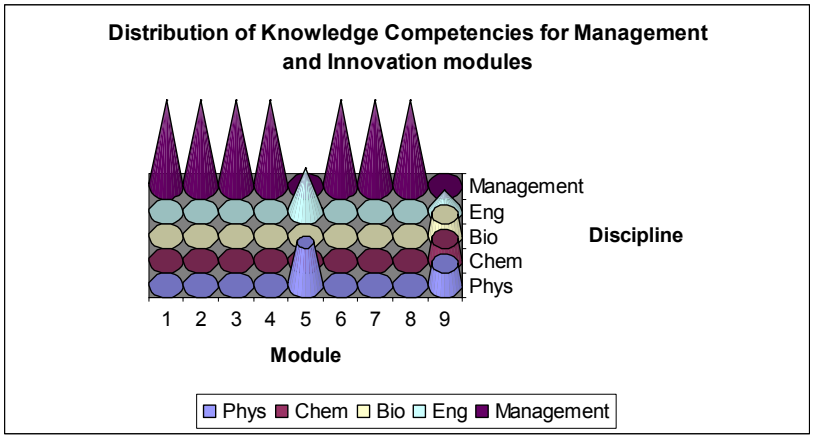

Figure 33 - Management and Innovation modules: Distribution of knowledge content

The assessment of learning outcomes for management and innovation modules, are shown in the figure 34. The main method of assessment of learning outcomes was through coursework (6). Two modules were focused on assessing learning outcomes through examinations, while one had a mixed method for assessment.

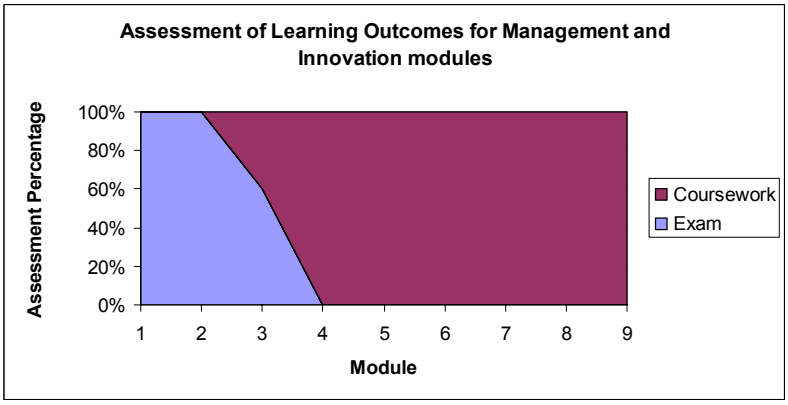

Figure 34 - Assessment of learning outcomes: Management and Innovation modules

The credits assigned to learning outcomes by UK programmes range from a minimum of 5 credits to a maximum of 15 credits for the 5 management and innovation modules analysed. The credits assigned to learning outcomes, by European programmes, range from a minimum of 2.5 credits to a maximum of 30 credits for the 3 modules included in the collective. It is notable to mention here that 30 credits were assigned by a programme for internship in industry.

8. Concluding remark and recommendations for further work

The study was focused on developing a shared understanding and communicating the best practice adopted by educational programmes in imparting nanoscience and technology education at M-level. The methodology aimed to segment modules based on the discipline knowledge relating the orientation to the content of modules. The segmenting of educational modules was done into natural sciences, engineering, ELSC and Management related knowledge. The distribution of knowledge from wide and disciplines was analysed and related to type of module, learning outcome demonstrated, preferred assessment method and credits assigned to each module. The work is expected to be beneficial for both educators and assessors of educational programmes. The limitation of the report lies in the availability of data from all the existing educational programmes in nanoscience and nanotechnology at M-level in Europe.

Recommendations for work in this area include preparing a map of the knowledge common to Natural Sciences, Engineering, ELSC and Management modules as robust guidelines for determining threshold levels of knowledge demonstrated by learning outcomes in an educational programme.

Appendix A – List of Natural Sciences oriented modules

A.1 Single Discipline oriented Natural Science Modules

Table 4 provides a list of module titles drawn from single discipline of natural sciences. These are being delivered by Universities as core and optional modules.

Table 4 – List of Modules for Single Discipline Natural Sciences modules

	Single Discipline Natural Sciences Discipline module
1	Advanced Quantum Mechanics
2	Advanced Solid State Physics
3	Advanced Statistical Mechanics
4	Bionanotechnology
5	Chemical nanocharacterization
6	Chemical Nanotechnology
7	Cosmology
8	Diffraction and imaging techniques
9	Electron microscopy
10	Elementary Particles
11	Fundamentals of Quantum Mechanics
12	Nanochemistry
13	Nanophotonics
14	Nanophysics
15	Nanoscale Physics & Technology
16	Nanoscale Simulation
17	Path integrals and applications
18	Physics of low-dimensional systems
19	Practical: Characterization Procedures of Nanomaterials
20	Practical: Gene expression under heat chock conditions
21	Quantum Transport
22	Self-assembly and Bottom-up Approaches to Nanostructure
23	Spectroscopic techniques

24	Superconductivity and super fluidity

A.2 Pure Natural Science oriented modules

Table 5 below gives a list of titles drawn from Natural Sciences discipline. These are being delivered as core and optional modules by various Universities.

Table 5 – List of Pure Natural Sciences Discipline modules

	Pure Natural Science Discipline
1	Advanced Materials Characterisation
2	Biophotonics and bioimaging
3	Physical concepts in bionanotechnology
4	Nanotoxicology
5	Bionanomaterials
6	Electronic and Optical Devices
7	Smart Materials
8	Fundamental Science of nanotechnology
9	Fundamental Characterisation for Nanotechnology
10	Nanoparticles
11	Thin Layers
12	Surface Modification
13	Advanced Module
14	Bionanotechnology
15	Advanced Biophysics
16	Nanoscience: fundamentals and applications
17	Chemical Synthesis of Nanoparticles
18	Fundamentals of Molecular Biology, Genetics
19	Interactions between Biological and Non-Biological Devices
20	Nanodevices in Medicine, Pharmacy, and Biology
21	Characterization techniques for nanostructures
22	Quantum chemistry
23	Quantum Physics and Chemistry
24	Biochemistry at the Nanoscale

25	Characterization of (bio)molecular assemblies, nanomaterials, interfaces
26	Top-down Approaches to Nanostructure Fabrication
27	Electron Optic & X-ray Techniques

A3. Interdisciplinary modules oriented towards Natural Sciences

Table 6 provides a list of interdisciplinary modules oriented towards natural sciences. The list provides the title of module being delivered at various Institutions through nanoscience and technology educational programmes.

Table 6 – List of Interdisciplinary modules oriented towards Natural Sciences

	Interdisciplinary modules oriented towards Natural Sciences
1	Advanced Electrodynamics
2	Advanced Experimental Methods
3	Advanced Wave Propagation
4	Atomic Force Microscopy
5	Bio-captors and bio-chips
6	Bio-fluid Mechanics
7	Biomaterials
8	Biomimicry
9	Biomolecular Motors
10	Bionanotechnology
11	Biophysical Methods For Medicinal Chemistry
12	Biophysics
13	Biophysics at the Nanoscale
14	Biosensors
15	Chaotic Processes
16	Characterization Procedures of Nanomaterials
17	Characterization techniques II (microscopy TEM,SEM,AFM,STM)
18	Computational Biophysics
19	Computational nanophysics
20	Computer modelling and simulation
21	Continuum Physics

22	Elaboration of Nano-objects
23	Electronic and Photonic Molecular Materials and Devices
24	Fabrication and characterization of nanostructures I
25	Fabrication and characterization of nanostructures II
26	Frontiers of Nanotechnology
27	Functional Materials
28	Further Microengineering
29	Generic methodologies for bionanotechnology
30	Generic methodologies for nanotechnology
31	Inorganic semiconductor nanostructures
32	International Masters Course on Computational Physics
33	Internship
34	Internship in industry
35	Internship/Research project
36	Introduction to Nanotechnology
37	Lab practise experiments in biology and in near field microscopy
38	Lab training
39	Macro molecules at interfaces and structured organic films
40	Master thesis Applied Physics
41	Master thesis NanoScience
42	Master thesis project
43	Mesoscopic Physics
44	Micro fluidics
45	Microsystems technology I
46	Molecular Electronics
47	Molecular engineering of supramolecules, nanomaterials and interfaces
48	Nano Magnetism and spintronics
49	Nano structures of semiconductor
50	Nanobiotechnology
51	Nano-electronics
52	Nanoelectronics and Devices
53	Nanofluidics
54	Nanomanufacturing nanoprocessing: the top down approach
55	Nanomechanics

56	Nano-optics
57	Nanooptics and Biophotonics
58	Nanoparticles as Therapeutic Drug Carriers and Diagnostics
59	Nanoparticulate materials
60	Nanophotonics
61	Nanoscale magnetic materials and devices
62	Nanoscale phenomena
63	Nanoscale Structures and Devices
64	Nanoscience and Nanomaterials
65	Nanoscience Literature and Communication Skills
66	Nanoscience primer
67	Nanoscience Research Project
68	Nanotechnologically Modified Biomaterials
69	Nanotechnology
70	Nanotechnology I
71	Nanotechnology II
72	Partial Differential Equations 1
73	Physical Characterisation of Nanostructures
74	Physical Synthesis of Nanoparticles
75	Physics of materials
76	Physics of micro and nano electronics
77	Physics of Nano structures
78	Physics of Nanomaterials
79	Physics of semiconductor nanodevices
80	Practical lab course
81	Probing at the Nanoscale
82	Processing & properties of inorganic nanomaterials
83	Processing Ceramics and Composites and their Applications
84	Processing Coatings and their Applications
85	Project computer simulation techniques
86	Quantum electronics and quantum optics
87	Research Project
88	Screening Methods in Biology, Chip Technologies
89	Self-assembling nanostructured molecular materials and devices
90	Single Molecule Biophysics: Theory and Practice

91	Single Molecule Optics
92	Soft Nanotechnology
93	Spectroscopy and Lasers
94	Superconductivity and magnetism: spintronics and supertonics
95	Supra and Macromolecular Chemistry
96	Supramolecular Chemistry
97	Surface physics
98	Surface Science
99	Topics in nanophysics and nanotechnology

Appendix B – List of Engineering Oriented modules

B.1 Engineering oriented modules

Table 7 below provides a list of Engineering oriented modules delivered by educational programmes.

Table 7 - List of engineering modules

	Engineering oriented modules
1	Application to industry
2	BioMEMS
3	Business Process Reengineering
4	Carbon Based Electronics
5	Computer Aided Design
6	Fundamentals of Microengineering for Biotechnology
7	Laser Microengineering
8	MEMs Design
9	MEMS Design
10	Micro- and Nano-electromechanical systems
11	Modelling of Microsystems
12	MSc Project
13	Nanofabrication techniques
14	Project Foundations and Management Tools
15	Project Outline and Investigation
16	Quality, Value and TQM
17	Rapid Prototyping
18	Research Methods
19	Research Skills
20	RF and MMIC Design
21	RF Electronics

B.2 Interdisciplinary oriented Engineering modules

The table 8 below shows the titles of Interdisciplinary modules in Engineering imparted by educational Institutions.

Table 8 - List of Interdisciplinary modules

	Interdisciplinary modules from the Engineering Discipline Modules
1	Advanced Sensors
2	Biodisponibility and therapeutic efficiency
3	Characterization techniques I (spectroscopy SIMS,XPS,FTIR)
4	Complex Analysis
5	Design for Manufacture and Reliability Testing
6	Elaboration techniques (crystal growth, lithography)
7	Foundation in Microsystems & Nanotechnology
8	Group project
9	Hard Lithography
10	Individual project
11	Introduction to Nanotechnology
12	Micro and Nanotechnology
13	Microengineering
14	Microsystems Design
15	Microsystems technology II
16	Microwave engineering principles
17	Modelling and Design
18	Nanoparticle and thin film technology
19	Nanostructures, nanopatterning and nanomechanics
20	Next Generation Silicon Technologies
21	Numerical Analysis
22	Optoelectronics
23	Partial Differential Equations 2
24	Programming and Interfacing
25	Quantum Computing

26	RF and Optical MEMS
27	RF systems and Circuits
28	Scanning-probe microscopy
29	Semi-conductor Device Fabrication
30	Silicon Device and Technology
31	Soft Lithography

Appendix C - List of management and innovation modules

The table 9 below shows a list of management and innovation modules. The most notable one in the list are those classified as Management of Technology and Innovation, and Management of Technology based enterprise taught at Cambridge University. They comprise of intensive modular content spanning across a number of management themes relevant to nanotechnology.

Table 9 – List of Management and Innovation modules

	Management and Innovation modules
1	General Management
2	Innovation
3	Internship in Industry
4	Management
5	Management of Innovation and Technology
6	Management of the Technology Based Enterprise
7	The Business of Microsystems Engineering
8	The High Technology Entrepreneurial Venture
9	The Scientific Entrepreneur: Starting Your Own Pharmaceutical Or Biotech Company

Appendix D – List of Ethical, Legal, Societal and Communication modules

The list of ethical, legal, societal and communication modules have been listed in Table 10 below.

Table 10 -List of Ethical, Legal, Societal and Communication modules

	Ethical, Legal, Social and Communication modules
1	Communications skills for engineers
2	Conference
3	English and business
4	English or interdisciplinary
5	Ethics
6	Journal Club
7	Paper and presentation
8	Science Communication in Media, Business and Research
9	Societal and Ethical Dimensions of Nano and Biotechnology
10	The Ethical and Societal Dynamics of Nanotechnology
11	Wider Context of Nanotechnology
12	Workshops

Appendix E – List of Universities

The table 11 below gives a list of University programmes across UK and Europe. The educational programme data has been used for the analysis in the study. The information was gathered using a template produced in 2006. The data field for this template was agreed by a consortium of Universities providing educational programmes and representatives from Industry. In the time subsequent to the data being provided, the educational programmes have evolved and changed along the course.

Table 11–University programme data used

	University
1	Bangor University, UK
2	Cranfield University, UK
3	Leiden University, UK
4	Delft University of Technology, the Netherlands
5	Double diploma of two out of four institutions - Chalmers Tekniska Högskola (Chalmers), Göteborg, Sweden Delft University of Technology (TUD) & University of Leiden (UL), The Netherlands Technische Universität Dresden (TU Dresden), Germany Katholieke Universiteit Leuven (K.U.Leuven),Belgium
6	Heriot-Watt University, UK
7	Lancaster University, UK
8	Universit Joseph Fourier - Grenoble, UK
9	Universities of Padua, Venice & Verona, Italy
10	University College Dublin, Ireland
11	University of Antwerp, Belgium
12	University of Barcelona and Rovira & Virgili University, Spain
13	University of Cambridge, UK

14	University of Kaiserslautern, Germany
15	University of Leeds or Sheffield University, UK
16	University of Liverpool, UK
17	University of Nottingham, UK
18	University of Oxford, UK
19	University of Surrey, UK
20	University of Twente, UK
21	University of Wales Swansea, UK