The development of a multi-disciplinary educational programme in Biomedical Diagnostics - a novel approach.

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Abstract

This paper describes the development of a taught Master's course in Biomedical Diagnostics using a novel multi-disciplinary approach. This course, the first of its kind in Ireland, covers the science and technology underlying the development of medical diagnostic devices that detect early markers of diseases such as cancer. The ethical impact of these devices on society, the importance of scientific communication, relevant aspects of business entrepreneurial studies and the commercialisation of medical devices are also covered. The course consists of a mixture of theory, intensive laboratory practicals and independent research. The challenges faced in setting up and running the course are described, as well as some of the novel aspects and may provide valuable insight to those involved in the development of high level Masters courses.

1. Introduction

Traditionally science degree courses have tended to focus on one or more subject areas in order to develop expertise in biology, physics, chemistry or engineering or, more recently, in computing. Further specialisation may be necessary given the complexity of the subject and the rapid development of new areas. In biology, for example, there are now a huge number of specialisms emanating from the initial broad divisions of zoology and botany. Examples include microbiology, physiology, biochemistry, molecular biology, analytical science and environmental science and these in turn are often heavily dependent on a good knowledge of chemistry and physics (McCarthy, 2007). However, recent developments in a whole range of disciplines and technologies demand expertise in a number of additional areas (e.g. microfluidics and nanotechnology) not generally covered and the educational system is now facing a major challenge to address this problem. Successful new research programmes are now far more dependent on team-based approaches to tackle complex problems and team members need to have a good basic understanding of a number of disciplines, often far beyond their specific expertise, if they are to communicate effectively as a group and generate highly novel and ground-breaking solutions. The Faculty of Science & Health at Dublin City University, Ireland has a well established expertise in the development of highly original multi-disciplinary programmes for new degrees and educational initiatives (O' Kennedy et al., 2005; van Kampen et al., 2004; O' Kennedy, 1991). The Biomedical Diagnostics Institute (BDI) based at DCU has applied this approach to the development of a new programme in Biomedical Diagnostics.

The Biomedical Diagnostics Institute is a multi-disciplinary research institute focused on the development of next generation biomedical diagnostic devices (www.bdi.ie, February 2010). The integration of a range of scientific and engineering disciplines required for the development of these diagnostic devices is a key and unique feature of the BDI. The Institute has developed a collaborative research programme involving leading researchers from academic institutions, companies and the clinical environment.

The BDI has developed a taught M.Sc. in Biomedical Diagnostics, the first of its kind in Ireland. As part of the Education & Outreach programme, this course began in September 2006 and brings together biomedical and analytical science with communication skills, business creativity and ethics. This paper describes the development of the programme, course content, novel aspects and key challenges identified with the running of such a programme during the first three years.

2. Programme Demand

The BDI's M.Sc. in Biomedical Diagnostics was designed to address the needs of the Irish Diagnostics Industry and offers a unique graduate training programme merging academic training modules with industry insight and analysis. A Market Research Survey (March 2006) was carried out amongst those involved in the diagnostics field, including industries, academia and government agencies in Ireland to ascertain their views on the proposed programme. The M.Sc. was developed based on this feedback and the Irish National Competitiveness Councils' plans to develop an innovation intensive economy in Ireland by improving the quality of education in universities and fuelling the smart economy (Forfas and National Competitiveness Council, 2007). The programme is updated yearly to respond to the predicted future skills gap in the medical technology sector (Expert Group on Future Skills Needs, 2008).

3. Programme Overview

3.1 Aims

Overall, the programme aims to create

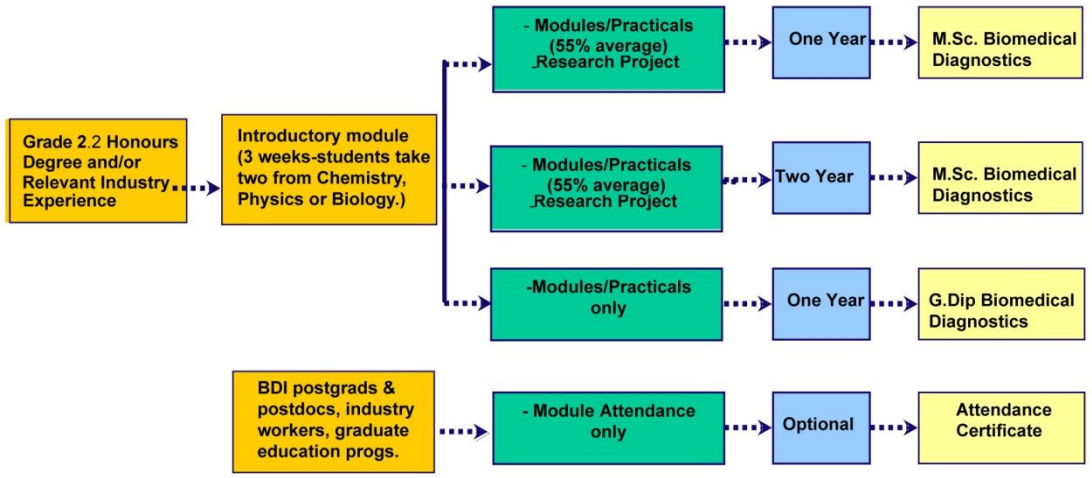
1. Highly trained individuals with multi-disciplinary expertise in key sciences related to diagnostics
2. Scientists with critical capacity, analytical and laboratory skills and flair to develop the highest quality research and to translate that knowledge into practical applications

3. Scientists skilled in key aspects of science communication and entrepreneurship as well as aware of the ethical aspects of their work

3.2 Programme Structure

The M.Sc. is delivered as a full-time programme over 12 months or part-time over 24 months. For entry to the course, students must have a minimum of a 2.2 Honours grade in a science or engineering degree (or equivalent) and/or relevant industry experience. For the M.Sc. programme, students are expected to complete all modules/practicals and achieve an average of 55%. They then must complete a substantial research project over the summer. Students may also exit with a graduate diploma after completing the modules/ practicals (see Figure 1 for the progression through the course). Individual (or 'stand-alone') modules are made available to BDI postgraduates and postdoctoral fellows, industry workers and graduate education programmes.

Figure 1: Progression through Masters (M.Sc.)/Graduate Diploma (G.Dip.) Biomedical Diagnostics course



3.3 Programme Content

The students taking this course have a variety of scientific and/or engineering backgrounds. Therefore, the introductory module is designed to ensure that they quickly achieve the necessary background and understanding in biology, chemistry and/or physics. The students then focus on specific modules in diagnostic sciences, such as Nanobiotechnology and Principles of Diagnostic Technology (see Table 1 for a full course description). Some of the more novel modules are explained in greater detail in section 5.

Table 1: Full Course description, including ECTS.

Semester 1 Autumn Semester		
Module Title	Brief Description	ECTS
Introductory Biology, Chemistry and Physics for Biomedical Diagnostics	Introductory 3 week course for students coming from various scientific backgrounds; students take two subjects out of three	7.5
Principles of Diagnostic Technology II	Immunology and immunoanalysis and applications in diagnostics	7.5
Genomes, Genes, Evolution and Heredity	Introduction to genetics and methods in biomedical research and industry	5
Innovation and Entrepreneurship for Scientists	Introduction to innovation and entrepreneurship in science and technology	2.5
Issues in Contemporary & Health Science	Exploration of scientific, moral, ethical and social issues arising from contemporary science and technology	5
Nanobiotechnology	Principles and practice of microfabrication techniques with a focus on applications in biomedical and biological research, includes group project	7.5
Semester 2 Spring Semester		
Principles of Diagnostic Technology I	Analytical Spectroscopy and the use of biophotonics in biomedicine	7.5
Advances in Diagnostics Technology	Lectures from visiting industrial and academic experts in the diagnostic field	5
Workshops	Four two day workshops: 1. Ethical principles & their applications for the Diagnostic Industry 2. Legislation & Regulations affecting Biomedical Diagnostics (including GMP training) 3. Research Commercialisation 4. Communication Skills for Researchers	7.5
Practical Techniques	Intensive practical course in key laboratory skills related to diagnostics	5
Semester 2 + Summer		
Research Project, Literature Review, Project Plan and Presentation	Substantial multi-disciplinary research project for student involving co-supervision.	30
TOTAL CREDITS		**90**

ECTS: European Credit Transfer and Accumulation System

4. Learning and Assessment Philosophy

Course assessment methodologies test key aspects of the students learning in line with the aims of the course.

This includes:

- in-class tests of specific knowledge and application of concepts
- problem-based written assignments and simulations
- team-centred research, analytical exercises and case studies
- project based research on a specific topic
- essays and paper critiques
- ‘in-class’ presentations
- terminal examinations
- exercises to develop innovation and creative approaches to solving specific problems.
- tests of practical ability to perform methodologies and statistically analyse results
- assessment of the recording of results, report writing and ability to comply with standard operating procedures.

Where appropriate, modules possess a significant element of continuous assessment that leads to the enhancement of technical/quantitative/analytical skills and transferable skills (e.g. organisational, communication etc.). Specific examples of novel learning and assessment are given in the next section.

5. Novel Aspects

The M.Sc. in Biomedical Diagnostics is novel in Ireland, a multi-disciplinary course in diagnostic technology hosted by a research institute within a university. The programme also has inputs from all the Schools at the Faculty of Science and Health at DCU, as well as the Business School, School of Communications and School of Nursing. The course has a number of novel aspects:

5.1 Co-ordinator

A full-time co-ordinator is designated to monitor the students closely. This co-ordinator is in contact with the students on at least a weekly basis and provides support for the students. The co-ordinator is the first point of contact if any problems arise.

5.2 Feedback

Two-way feedback is a key component of the programme and is emphasised from the very beginning. The students are given individual feedback on their assignments within the first three weeks so if necessary they can improve on any areas early on in the programme, particularly scientific writing and referencing. Initial feedback is given individually to students via e-mail or on-line; a small paragraph for each student early on in the course outlining suggestions for improvement has been cited as being most useful by all students who have participated in the course. Sample essays, presentations and answers to past exam questions are also made available on-line.

Individual feedback sessions with lecturers on the course are also held throughout the year, both to give feedback on the student's work and to hear any suggestions from the students. The course has been modified over the years based on student feedback, for example a new career development workshop was arranged for the students based on their insight.

5.3 Industry and Clinical Partners

The BDI has a number of industry and clinical partners from the diagnostics field who are world leaders in their area. As part of the Advances in Diagnostic Technology and Workshops module they are invited to speak to the students each year to give overviews of their companies and discuss with the students. These include both researchers in well-established companies and recent start-ups by entrepreneurs. Industry and Clinical researchers also have input into student's research projects.

5.4 Introductory module

The Introductory module is of utmost importance to the students as it is the first module encountered. It is an intensive three week course, in which students not only get an introduction to the subject, but also interact with their

classmates, meet BDI researchers for guest lectures and revise scientific writing and referencing. The module is delivered through intensive lectures but also through varied assignments such as

- writing short “literature-review” type essays on case studies in diagnostics to revise scientific writing and searching the scientific literature

-providing the students with chemical structures of interesting “mystery compounds” which they must search in chemical databases such Beilstein and Scifinder.

-Intensive calculations workshops, where students must work out a number of problems as if they were to carry out a lab, such as concentrations, dilutions or spectra of compounds. The lecturer is on hand to assist with this.

-carrying out on-line lab practicals from a variety of resources, such as the excellent on-line laboratories available from the Genetics Science Learning Center, University of Utah (http://learn.genetics.utah.edu/)

-discussing case studies of diagnostic devices, with demonstrations and hands-on activities if possible, including dissecting pregnancy tests to illustrate an example of a point-of-care device for example!

-Researchers from the BDI give short 20 minute lectures or lab tours on the final day

As well as the assignments, students are given a short in-class test at the end of each subject to assess their capability in the subject. They are also offered assistance throughout the year if needed and monitored at the feedback sessions. The format is successful as to date, all students coming from a particular scientific background have progresses in modules outside their field (e.g. physics students have been successful with advanced biology-based modules, etc.)

5.5 Nanobiotechnology

The Nanobiotechnology module is a multi-disciplinary module video-conferenced live from Cornell University that gives the students an opportunity to see guest lectures from world leaders in this field. As part of the assessment, a novel approach to project work is used. The students are arranged into groups and asked to theoretically create a diagnostic device or technique to solve a biological problem, using Nanobiotechnology. This can include making a device faster, using, lower sample volumes, cheaper or combining detection methods on a chip. As a group, they must complete a literature review and present a presentation on each aspect of their device/ method to BDI researchers. As well as becoming proficient in searching the scientific literature, the students must think creatively and work together as a team. Each member working on some aspect of the device or technique and combine research in biology, chemistry, physics and engineering to do this, as well as commercialisation and ethics. Examples of past projects include a point-of-care device for a specific strain of Methicillin-resistant Staphylococcus Aureus and a 3 in 1 point-of-care STD (Sexually transmitted disease) device.

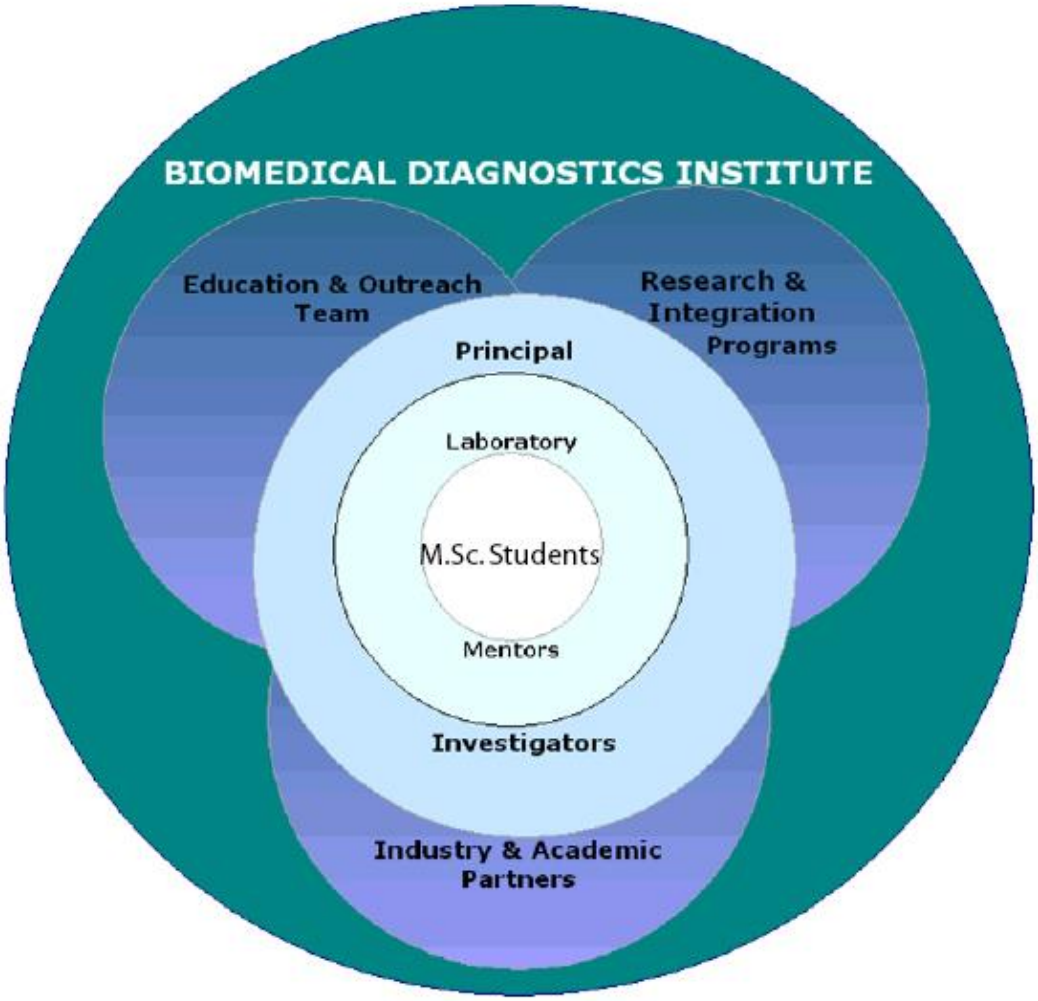
5.6 Research Project

The programme has advanced practicals underpinning the principles covered in the theoretical modules and ensuring that the students have the necessary lab expertise for the research project.

Students are placed with a research group within the BDI during their second semester and begin a literature review. They then work full-time on their project in the laboratory over the summer and complete a dissertation, presentation and poster on their work. The students are integrated fully into the BDI community for the duration of their project, attending bi-weekly community meetings etc. A key feature of the research projects is the integration of supervisors from different disciplines. The BDI itself is a unique academic-industry-clinical partnership and this is reflected in the projects. This enhances the multi-disciplinary nature of the projects and the working environments for the students. In a typical research project, a student would become familiar with a number of optical detection methods commonly used in physical laboratories as well as methods used in Biotechnology such as cell

culture and SDS-PAGE. Students also are given the opportunity to contribute to peer-reviewed papers or attend relevant conferences as part of the programme. The students are designated a PI and a mentor postdoc who supervises daily in the lab (See Fig. 2).

Fig. 2. Organisation of mentoring for M.Sc. Biomedical Diagnostics students



6. First experiences with the M.Sc. in Biomedical Diagnostics

Forty students are due to graduate from the course in November 2010. The students have a variety of nationalities and scientific backgrounds. Feedback from the students to date was generally very positive, with the following cited as the best features of the programme:

- The novelty of the material studied
- The multi-disciplinary nature of the course
- Interesting and varied research projects
- Access to lecturers from industry and clinical backgrounds
- Integration into the BDI community
- Small group facilitated discussion, learning and feedback
- A co-ordinator who acts as a first point of contact for any issues

Features of the course identified as requiring greater clarity included assessment for workshop-based modules as the format for assessment was different to that encountered at undergraduate level. Students also requested specific workshops on dissertation writing and career development, which were provided. Finally, some students displayed apprehension about conducting a research project outside the immediate field of their primary degree. However, this issue was overcome by having multi-disciplinary research projects underpinning the ethos of the programme. Key challenges identified are described in the Section 8.

7. Outcomes

7.1 Student destination

To date, graduates of the programme have continued their studies, with many studying for a PhD or medicine. Others have gained employment in ICT/Biotech sectors. Table 2 shows the current destination of past graduates of the course, as of Feb 2010.

Table 2: Current destination of M.Sc. Biomedical Diagnostics graduates 2007- 2009 (Data collected in February 2010)

Student destination (as of March 2010)	**Number of graduates (17 in total)**
PhD Studies (7) Dublin City University (within BDI) Royal College of Surgeons University College Dublin NUI, Maynooth	 3 1 2 1
Medical School	2
Employment in Diagnostics/ICT sectors	5
Gap Year	3

7.2 Papers and Presentations

Having a trained group of M.Sc. students working in the Biomedical Diagnostics Institute for 12 weeks each year has resulted in a number of excellent research outputs and moved research at the institute forward considerably.

The students have also contributed significantly to papers and have been as named authors on three peer-reviewed papers in international journals to date, with more planned for the future (Byrne, 2009; Nooney, 2009; Nooney, 2010). They have also contributed to many posters/ lectures presented at national and international conferences.

8. Operational Challenges

The running of this programme has identified key challenges that must be overcome for success.

1. Due to the intensive, multi-disciplinary nature of the programme, there is a need for careful and ongoing mentoring of students by the course coordinator and staff to ensure that they are fully engaged and that problems encountered are quickly resolved. It should be noted that a significant time commitment is required for this, particularly for the co-ordinator. This must be considered before developing such a programme.
2. The feedback mechanisms described can take considerable time and effort and are best suited to small classes but are found to be of greater benefit to the students and the co-ordinators/ lecturers in the long-term.
3. Students from many diverse backgrounds need to achieve a basic understanding of the key elements of chemistry, physics and biochemistry at a very early stage. This can be successfully achieved through an introductory module at the start of the programme. Subjects are selected based on the student's background. To date the introductory module has been successful in addressing this, as students have progressed well in modules outside their immediate area of expertise after the introductory course. Student performances in in-class tests and assignments have also qualified this.
4. Team work and the development of the appropriate associated skills needs to be a key element of the programme. In particular the Nanobiotechnology project emphasises this.
5. Case studies of a multi-disciplinary nature are essential and introducing these early on, in the introductory module, are useful.
6. Research projects must be designed to illustrate the need for a multi-disciplinary approach for successful problem solving. It should be noted that the provision of high-quality research projects within the institute

limits the amount of places on the programme, but provides highly-skilled graduates.

7. The close integration of research and training and the development of a collegiate learning community, with input from many visiting and ‘on-site’ researchers from academia and industry provide the ideal challenging and inspiring environment.

9. Conclusion

The biomedical diagnostics sector is currently one of the fastest growing fields in Ireland, with a predicted future skills gap in highly trained specialists in the area (Expert Group on Future Skills Needs, 2008; www.imda.ie, March 2010). Rapid changes in technology, particularly those associated with biomedical diagnostics, will require both continuous monitoring and subsequent updating of the programme. The strong links to research and the inputs of researchers and industry will ensure these are provided on an ongoing basis. We believe that this novel partnership approach provides the ideal platform to generate highly innovative and skilled multi-disciplinary graduates necessary for the successful development of diagnostics and diagnostic devices for the future.

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