

Marie Curie Reintegration Award (2010)

SMART MAG SOLUTIONS

Final Report

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University College Cork, Ireland

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Scope

The purpose of this final report is to document the impact of the Marie Curie Reintegration Award entitled “Smart Mag Solutions” on the reintegration of Dr. Padraig Cantillon-Murphy in his current institution, University College Cork, Ireland. The report has two main sections corresponding to the impact of the Marie Curie award on the awardee’s (1) scholarly and research activity, and (2) teaching activity, as supported through the award. The summary of the funding support’s impact is included in the following section.

Summary of Reintegration

Through the support of the award, the awardee has now established a well-supported and sustainable research group within the School of Engineering at University College Cork. The Biomedical Design Research Group is an interdisciplinary research group which seeks to develop novel biomedical devices and systems for applications in surgery and endoscopy. The group now supports three graduate students and a number of inter-related taught masters students who contribute to the group’s research outputs. The group’s first PhD student graduated in 2014 (K O’Donoghue).

With the support of the award, the group has become established internationally as a leading centre in the development of novel user-centred solutions for surgery and endoscopy, as indicated in the PI’s invitation to assume a visiting appointment at Imperial College London and the group’s inclusion in an upcoming Marie Curie ITN proposal led by the University of Leeds.

In addition, the group’s work has led to over 20 peer-reviewed publications across both technical and clinical journals, conferences, and workshops. This includes an invited review of the role of magnets in gastrointestinal therapy for Gastrointestinal Endoscopy (IF 4.9). The group’s published work cuts across the areas of medical device design and testing, medical imaging and endoscopic navigation. The group’s work has led to a number of pending European patent applications as well as published outputs. In addition, the group’s work has positively impacted the PI’s teaching activities and this is reflected by an upcoming publication in the International Journal of Engineering Education. The group is healthily supported by a combination of exchequer (Irish Health Research Board, Enterprise Ireland) and European funding (Erasmus) which has been enabled by the launchpad of Marie Curie support. The PI is now permanently established at UCC School of Engineering and, as well as leading successful research activities, has assumed leadership positions within the university, including First Year Programme Director for Engineering at UCC. In summary, the Smart Mag Solutions award has proven the key enabler to establishing the awardee has a researcher of high international calibre in an important research area for Europe.

1. Scholarly Publications

1.1 Peer-reviewed Journals

"Low cost super-Nyquist asynchronous demodulation for use in EM tracking systems", K. O'Donoghue and **P. Cantillon-Murphy**, IEEE Transactions on Instrumentation and Measurement, doi: 10.1109/TIM.2014.2343431, Oct 2014.

"Planar magnetic shielding for use with EM tracking systems" , K. O'Donoghue and **P. Cantillon-Murphy**, IEEE Transactions on Magnetics, doi: 10.1109/TMAG.2014.2352344, Oct 2014.

"Catheter position tracking system using planar magnetics and closed loop current control," K. O'Donoghue, D. Eustace, J. Griffiths, M. O'Shea, T. Power and **P. Cantillon-Murphy**, IEEE Transactions on Magnetics, 50(7), 1-9, July 2014.

"Design, Development and Evaluation of an Inflatable Retractor for Atraumatic Retraction in Laparoscopic Colectomy". C O'Shea, D. Kelliher, E. Andrews, M. Ó Riordáin, M O' Shea, T. Power, **P. Cantillon-Murphy**. Annals of Biomedical Engineering, doi: 10.1007/s10439-014-1029-1. July 2014

"Electropermanent Magnetic Anchoring for Surgery and Endoscopy" J. Tugwell, P. Brennan, C. O'Shea, K. O'Donoghue, T. Power, M. O'Shea, J. Griffiths, R.A. Cahill, **P. Cantillon-Murphy**, IEEE Transactions on Biomedical Engineering, doi: 10.1109/TBME.2014.2366032. Oct 2014.

"Magnetic compression in gastrointestinal and bilioenteric anastomosis: how much force?" T. Lambe, M.G. O'Riordain, R.A. Cahill, and **P. Cantillon-Murphy**, Surgical Innovation, 21(1), 65-73, Feb 2014.

"Convergence and translation: attitudes to inter-professional learning and teaching of creative problem-solving among medical and engineering students and staff" H. Spoelstra, S. Stoyanov, L. Burgoyne, D. Bennett, C. Sweeney, H. Drachsler, K. Vanderperren, S. Van Huffel, J. McSweeney, G. Shorten, S. O'Flynn S, **P. Cantillon-Murphy**, C. O Tuathaigh. BMC Medical Education. 14, 14, January 2014.

"Addressing biomedical problems through interdisciplinary learning: a feasibility study," **P. Cantillon-Murphy**, J. McSweeney, C. O'Tuathaigh, L. Burgoyne, S. O'Flynn and G. Shorten, International Journal of Engineering Education, in press, Dec 2014.

"Magnets for Therapy in the Gastrointestinal Tract," **P. Cantillon-Murphy**, T. Cundy, N. Patel, G-Z. Yang, A. Darzi, J. Teare, Gastrointestinal Endoscopy, in press, Dec 2014.

"Optimizing CT parameters for open-source airway," Segmentation, Pietro Nardelli, K.A. Khan, A. Corvo, N. Moore, M.J. Murphy, M. Twomey, O. J. O'Connor, M.M. Maher, M. P. Kennedy, R. San José Estépar, and **P. Cantillon-Murphy**, IEEE Transactions on Medical Imaging, under review, Dec 2014.

"Self-deployed Magnetic Polygons: Design, Construction and Application". R. McEvoy, M. McMenamin, G. Ha, J. Lang, and **P. Cantillon-Murphy**, IEEE Transactions on Magnetics, 39, 496 – 505, Jan 2013.

"Deflection modeling of permanent magnet spherical chains in the presence of external magnetic fields," K. O'Donoghue and **P. Cantillon-Murphy**, Journal of Magnetism and Magnetic Materials, 343, 251–256, Feb 2013.

"Magnetic pancreaticobiliary stents and retrieval system: obviating the need for repeat endoscopy (with video)," M. Ryou, **P. Cantillon-Murphy** et al., Gastrointestinal Endoscopy, 75, 888-892, April 2012.

"Smart Self-Assembling MagnetS for ENdoscopy (SAMSEN) for transoral endoscopic creation of immediate gastrojejunostomy (with video)," M. Ryou, **P. Cantillon-Murphy** et al., *Gastrointestinal Endoscopy*, 73, 353-359, February 2011.

"A Magnetic Retrieval System for Stents in the Pancreatobiliary Tree," **P. Cantillon-Murphy**, M. Ryou, C.C. Thompson and J. Lang, *IEEE Transactions on Biomedical Engineering*, 57, 2018-2025, July 2010.

"A Magnetic Retrieval System for Pancreaticobiliary Stents: Obviating the Need for Second Endoscopy," M. Ryou, **P. Cantillon-Murphy**, J. Lang, and C.C. Thompson, *Gastrointestinal Endoscopy*, 71, AB134, 2010.

"Transoral Endoscopic Creation of Immediate Cholecysto-Gastrostomy Using Smart Self-Assembling Magnets via Endoscopic Needle (SAMSEN) ," M. Ryou, **P. Cantillon-Murphy**, J. Lang, and C.C. Thompson, *Gastrointestinal Endoscopy*, 71, AB242, 2010.

"Heating in the MRI environment due to superparamagnetic fluid suspensions in a rotating magnetic field," **P. Cantillon-Murphy**, L.L. Wald, M. Zahn and E. Adalsteinsson, *Journal of Magnetism and Magnetics*, 322, 727-733, March 2010.

"Proposing Magnetic Nanoparticle Hyperthermia in Low-Field MRI," **P. Cantillon-Murphy**, L.L. Wald and E. Adalsteinsson, *Concepts in Magnetic Resonance, Part A*, 36A, 36-47, 2010.

1.2 Peer-reviewed Conferences

K. O'Donoghue, A. Corvó, P. Nardelli, C. O'Shea, K. A. Khan, M. Kennedy and **P. Cantillon-Murphy**, "Evaluation of a novel tracking system in a breathing lung model", 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Chicago, Illinois, USA, August 26-30, 2014 (oral presentation).

K. O'Donoghue, A. Corvó, P. Nardelli, C. O'Shea, K. A. Khan, M. Kennedy and **P. Cantillon-Murphy**, "Evaluation of a novel EM tracking system in a breathing lung model", The Hamlyn Symposium on Medical Robotics, London, United Kingdom, July 12-15, 2014.

C. O'Shea, P. Lee, and **P. Cantillon-Murphy**, "Design and development of a visual syringe for epidural entry," 11th IASTED International Conference on Biomedical Engineering (BioMed 2014), Zurich, Switzerland, June 23 - 25, 2014 (oral presentation).

K. O'Donoghue, and **P. Cantillon-Murphy**, "A low cost system for 3D position and orientation sensing," The Hamlyn Symposium on Medical Robotics, London, United Kingdom, June 22-25, 2013 (oral presentation).

P. Nardelli, R. San Jose Estepar, **P. Cantillon-Murphy**, "Semi-automated airway segmentation of 0.64mm lung CT using 3D Slicer". 27th International Congress on Computer Assisted Radiology and Surgery (CARS 2013), Heidelberg, Germany. June 26-29, 2013 (oral presentation).

D. Hogan, M. Healy, J. Griffiths, T. Power, M. O'Shea, K. O'Donoghue, M. Kennedy, and **P. Cantillon-Murphy**. "Two-dimensional Magnetic Catheter Navigation with Applications in Endoscopy". 24th International Conference of the Society for Medical Innovation and Technology (SMIT), Barcelona, Spain. September 20-22, 2012 (*oral presentation*)

C. O Lionaird, S.P. Walsh, L. Barry, M. Buckley, J. Griffiths, T. Power, M. O'Shea, K. O'Donoghue, F. Carpi, and **P. Cantillon-Murphy**. "An Optimised Electromagnetic System for Endoscopic Capsule Propulsion: Report on a Benchtop Feasibility Study." SMIT 2012, Barcelona, Spain. September 20-22, 2012 (*oral presentation*)

P. Cantillon-Murphy, T. Lambe and D. Cronin, "A Magnetic Coupling to Improve Placement of Gastroenteral Feeding Tubes," BIODEVICES 2012, Vilamoura, Portugal, February 1-4, 2012 (*oral presentation*)

P. Cantillon-Murphy, "When doctors and engineers talk," TEDxUCC, University College Cork, Ireland, October 27, 2011.

M. Ryou, **P Cantillon-Murphy**, D. Azagury, S. Sheikh, G. Ha, M. Ryan, J. Lang, C.C. Thompson. "Transoral Endoscopic Creation of Immediate Gastrojejunostomy Using Self Assembling Magnets via Endoscopic Needle (SAMSEN)", AGA Distinguished Abstract Plenary at Digestive Disease Week, May 2010.

M. Ryou, **P Cantillon-Murphy**, D. Azagury, S. Sheikh, G. Ha, M. Ryan, J. Lang, C.C. Thompson. "Transoral Endoscopic Creation of Immediate Cholecysto-Gastrostomy Using Smart Self-Assembling magnets via Endoscopic Needle (SAMSEN)", Digestive Disease Week, May 2010.

M. Ryou, **P Cantillon-Murphy**, M. Ryan, J. Lang, C.C. Thompson. "A Magnetic Retrieval System for Pancreaticobiliary Stents: Obviating the Need for Second Endoscopy ," Digestive Disease Week, May 2010.

1.3 Other Publications

C. O'Shea, **P. Cantillon-Murphy** et al., "An inflatable laparoscopic retractor for atraumatic retraction in abdominal surgery," European Patent Application EP12198842.2, Dec 2012.

P. Cantillon-Murphy, D. Cronin, "A magnetic coupling to improve placement of gastroenteral feeding tubes and colostomy tubes", European Patent Application EP11193758.7, Dec 2011.

P. Cantillon-Murphy, "A Method and Apparatus for Combining Magnetic Nanoparticle Hyperthermia with MRI for Cancer Therapy" U.S. Patent Application No. 61/179,256. May 2009.

J. McWeeney, M. Ryou, **P. Cantillon-Murphy**, J. Lang and C.C. Thompson, "Methods and Apparatus for Magnet-Induced Compression Anastomosis Between Adjacent Organs," U.S. Patent Application Nos. 61/118,571 Oct 2008 and 61/292,313, January 2010.

D. Azagury, **P. Cantillon-Murphy**, J.H. Lang, M. Ryou, C.C. Thompson, "Description of Magnetic Self Assembly and Self Expansion for Magnetic Compression Anastomosis and One-step Endoscopic Access," U.S. Patent Application No. 61/308,680. Feb 2010.

K. O'Donoghue, D. Hogan, M. Healy, and **P. Cantillon-Murphy**, "Magnetic Catheter Steering in Human Bronchoscopy: an initial feasibility study," Smart Cathetersation (SCath) Workshop on Advanced Technology in Minimally Invasive Surgery (*invited paper*), Madrid, July 2012.

K. O'Donoghue, S. Winters, and **P. Cantillon-Murphy**, "A 2D Magnetically Guided Catheter for Minimally Invasive Procedures," Smart Cathetersation (SCath) Workshop on Advanced Technology in Minimally Invasive Surgery (*invited paper*), Graz, July 2011.

1.4 Research Awards and Fellowships

UCC College of Science, Engineering and Food Science –Best lecturer, runner-up (2014)

UCC Pfizer Prize for Innovation through Teamwork – (2013)

Cleveland Clinic/Enterprise Ireland award for clinical innovation – *with Dr. Peter Lee* (2012)

UCC Academic Rising Star (2012)

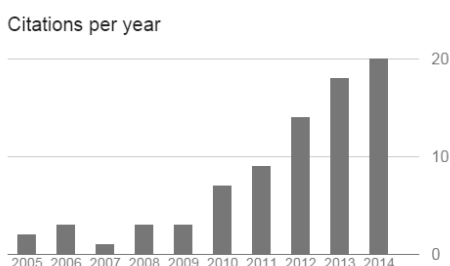
UCC Invention of the Year (2012)

Marie Curie Reintegration Award Final Report
IRCSET Ph.D. Scholarship [Kilian O'Donoghue] (2011)
HRB Summer Scholarship [Tadhg Lambe]
HRB Watts Medal for Outstanding Undergraduate Research [Tadhg Lambe], runner-up (2011)
FP7 Marie Curie Fellow (2010-2014)
MIT Whitaker Fellow (2007-2008)
MIT-Deshpande Center Grant Recipient (2005)
University Scholar at University College Cork (1999-2003)
Intel Corporation Scholar (2002)

1.5 Citation and review data

The following data is provided by Google Scholar¹.

Citation indices	All	Since 2009
Citations	81	72
h-index	5	5
i10-index	3	2



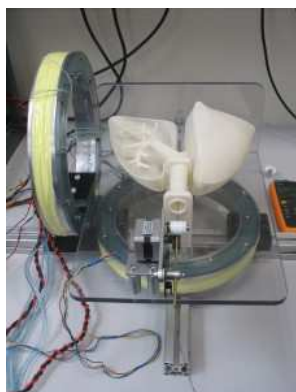
2. Research Supervision

2.1 Doctoral Research

2.1.1 Three-dimensional magnetic navigation for endoscopic applications

Students: Kilian O'Donoghue (2011-2014), Alex Jaeger (2014-), David Eustace (2013-2014).

Funded by the Irish Research Council (2011-2014) and the Marie Curie Reintegration Award entitled 'Smart Mag Solutions'² (2010-2014)



Research Summary: An electromagnet is a magnet which is controlled by an electrical current. The UCC Bioelectromagnetics group³ uses electromagnets to move and control small permanent magnetic devices. These devices are small enough to be deployed in minimally-invasive surgical environments, like through the portals used in cardiovascular stent placement and interventional radiology. Steering and guiding minimally-invasive devices like catheters and cameras using electromagnetic fields may give the physician better diagnostic capabilities than hand control alone. The group looks to couple our electromagnetic guidance system with patients' scans so that the physician can easily locate his real-time position in vivo with an *a priori* MRI, CT or x-ray image.

Figure 1. An early bench-top prototype used to demonstrate feasibility of magnetic steering for clinical applications.

Research Aims:

- To design and build a 3D magnetic coil array to map catheter position in the clinical space
- To investigate the integration of magnetic and/or mechanical steering with position sensing
- To test and validate the magnetic catheter in the pre-clinical and clinical settings

Collaborators: Cork University Hospital Department of Respiratory Medicine
Cork University Hospital Department of Radiology

Outputs to date: Four peer-review journal papers, three peer-review conference paper, and two invited workshop papers.

¹ <http://scholar.google.com/citations?user=nsOhTG0AAAAJ&hl=en>

² http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCIN=11618578

³ <http://bioelectromagnetics.ucc.ie>

2.1.2 Virtual bronchoscopy and navigation using open source tools

Student: Pietro Nardelli (2013-2016), Alberto Corvo (2014), Riccardo Volpi (2015).

Funded by the HRB Clinical Research Awards in Patient-Oriented Research (2012-2016)

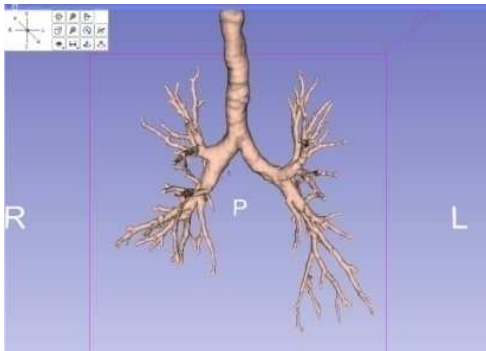


Figure 2. Shown here is an example of segmentation results using 0.64mm clinical CT data at UCC.

Research Summary: Computed Tomography (CT) is the gold standard for lung imaging and will remain so in the near and medium term. However, manual analysis of CT images to detect diseases can be a very tedious. Thus, a 3D reconstruction of the airway tree may hugely help the physician to assess pathological conditions. To this end, segmentation of the airway is essential. The Biomedical design research group is working with collaborators at Harvard Medical School⁴ and MD Anderson Cancer Center, as well as local clinicians, to develop a simple and reliable algorithm which can segment the airway tree of the lung starting from high-resolution low-dose CT using the open-source 3D Slicer platform. As part of this work, UCC doctoral student, Pietro Nardelli, will spend six months at the Surgical Planning Laboratory at Harvard in 2013.

Research Aims:

- To design and develop an open-source virtual bronchoscopy platform for research use
- To implement the platform using the Slicer 3D⁵ environment
- To test and validate the magnetic catheter in the pre-clinical and clinical settings

Collaborators: UCC Department of Radiology

Cork University Hospital Department of Respiratory Medicine

Cork University Hospital Department of Radiology

The Surgical Planning Laboratory at Harvard Medical School

The MD Anderson Cancer Centre at University of Texas, Houston

Outputs to date: M.Eng. thesis (University of Genoa, see 2.3.1), one peer-reviewed journal paper and one conference paper.

2.2 Masters (MEngSc) Research

2.2.1 An inflatable laparoscopic retractor for atraumatic abdominal surgery

Student: Conor O'Shea (2012-13)

Funded by Enterprise Ireland (2012-13)

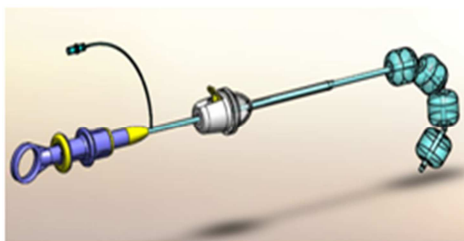


Figure 3. The SecuRetract device is an easily-deployed inflatable arm which can manoeuvre the small bowel *in vivo*.

Research Summary: A key impediment in laparoscopic abdominal surgery is small bowel obstruction. The intestine (small bowel) tends to fall into the operating field impairing surgical visibility and access. As visibility and space within the pelvic cavity are of vital importance, the problem of the bowel falling into this space can be quite detrimental to the ease and success of these procedures. The Bioelectromagnetics group seeks to overcome these difficulties with a stand-alone, inflatable device which is laparoscopically deployed and which can prevent the bowel from interfering with abdominal surgery. The device can be adjusted or manoeuvred as required to retain the bowel without interfering with the operating space. Our interdisciplinary team consists of surgeons, regulatory experts and business professionals, in developing a device which can be the solution to small bowel retraction difficulties.

⁴ <http://www.spl.harvard.edu>

⁵ <http://www.slicer.org>

UCC Department of Surgery
Cork University Hospital Department of Surgery
Mercy University Hospital Department of Surgery
Open Innovation Partners, Cork (*regulatory expertise*)
Creagh Medical, Ballinasloe, Co. Galway (*medical device manufacturer*)
Mr. John McSweeney (*business consultant and entrepreneur*)

Outputs to date: One EPO patent application, one peer-reviewed journal paper and two peer-reviewed conference papers.

2.3 Erasmus Research

The Department of Electrical and Electronic Engineering has a long history of supervising research as part of Erasmus masters requirements for European partner universities. The group has engaged with the University of Genoa in particular to this end.

2.3.1 Semi-automated airway segmentation of 0.64mm lung CT using 3D Slicer

Pietro Nardelli, Genoa (2011), Alberto Corvo (2013), Riccardo Volpi (2014)

Funded by FP7 Erasmus Exchange Programme (UCC / University of Genoa)

Research Summary: This work represents the proof-of-concept validation for the doctoral proposal outlined in 2.1.2 and proved the catalyst for Pietro's relocation to Cork to complete his doctoral thesis at the Bioelectromagnetics group.

2.4 Undergraduate Research

The group actively encourages undergraduate research. This initiative, in the spirit of the MIT UROP⁶ initiative, seeks to identify and encourage undergraduate research by engaging outstanding undergraduate students, generally in the second year of studies to consider careers in research and development.

2.4.1 Magnetic compression force estimation in surgical anastomosis

Tadhg Lambe (2011)

Funded by the Health Research Board Summer Scholarship and the Marie Curie Award, 'Smart Mag Solutions'.

Research Summary: MAGDA⁷ (MAGnetic force Determination Algorithm) is a free online tool which simulates magnetic compression force and pressure between two permanent magnetic and ferromagnetic geometries. The tool is maintained by the Bioelectromagnetics group to facilitate clinical researchers in the development of magnetic compression anastomosis devices in a variety of applications (*e.g.*, gastrointestinal, biliary, cardiovascular). Magnetic compression anastomosis is the formation of an *in-vivo* connection between two previously unconnected orifices by prolonged application of magnetic compression on the neighbouring tissue walls. MAGDA's Application section documents the tool's application to quantify force and pressure in reported clinical use of magnetic compression for anastomosis.



Figure 4. The MAGDA online interface is an easy-to-use *Python*-based tool which is design for clinical applications.

MAGDA was developed by Tadhg Lambe, a third-year student in electrical and electronic engineering who has excelled since coming to UCC. He worked over six months to design and develop MAGDA (Magnetic force Determination Algorithm) which is now available as an online tool for clinical investigators. Tadhg is also lead author in a recently accepted submission [2] to Surgical Innovation (impact factor of 2.126) detailing the application of MAGDA to reported clinical anastomoses using magnetic compression.

Collaborators: Mercy University Hospital Department of Surgery
Beaumont Hospital (Dublin) Department of Surgery

⁶ <http://mit.edu/urop>

⁷ <http://magda.ucc.ie>

Outputs: Free online simulator and peer-review journal publication

2.4.2 Virtual bronchoscopy front-end interface for Slicer 3D

Ian Murphy (2012)

Funded by the SEFS Undergraduate Scholarships Scheme and the Marie Curie Award, 'Smart Mag Solutions'.

Research Summary: This work complimented the Erasmus MEngSc research detailed in 2.3.1 and involved the implementation of a *java*-based front-end for user interaction and execution of the virtual bronchoscopy tool developed in Slicer 3D.

The tool was developed by Ian Murphy, a third-year student in electrical and electronic engineering who ranked 1/32 in his first year at UCC. Ian contributed meaningfully to the development of the Slicer module interface (see 2.3) by building a *java*-based front end for the end-user. This is now in *beta* development and it is planned to launch the module to the Slicer community in 2013.

Outputs: Free online module for virtual bronchoscopy using Slicer 3D (available to Slicer community since 2013)

2.5 Postdoctoral Research

2.4.1 Self-deployed Magnetic Polygons

Dr. Robert McEvoy, (2011-), Martin McMEnamin (2012-2013).

Funded by the Marie Curie Reintegration Award entitled 'Smart Mag Solutions'

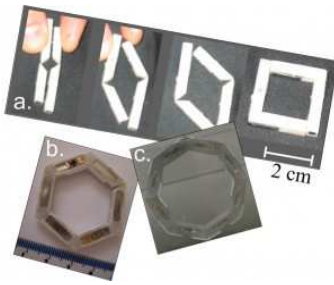


Figure 5. Examples of the self-deployed magnetic systems under development at UCC.

Research Summary: Magnetic attraction, due to the north-south attraction of opposing magnetic poles, is a very useful tool in developing new devices that can fold and unfold when required. This is a particularly useful property for devices which need to be deployed in the human body to help surgeons and endoscopists in advanced clinical procedures. The group uses these properties to develop a variety of self-deployed permanent magnetic devices which are capable of delivery using either laparoscopic or endoscopic means. Recently reported results [1,7,10] indicate the potential for such devices in minimally-invasive surgery and cardiovascular applications. This work was completed by Robert McEvoy, Ph.D., currently an undergraduate medical student at UCC, who has been engaged at the group on a part-time basis in parallel with

his medical education.

Research Outputs: One peer-review journal publication and minor masters thesis at UCC

2.5 Attraction of Research Students

In a short period, the group at UCC has established a national and international visibility which has proven attractive for high-calibre research students, as evidenced by the credentials of the research students currently within the group:

Student	Candidate	Credentials
Kilian O'Donoghue	Ph.D. graduate	Ranked 1/35 in graduating class in electrical and electronic engineering (2011), UCC College Scholar (2008-11), IRCSET scholarship recipient (2011), UCC IEEE chapter president. PhD award (2014). Founded of Smudge Electronics.
Pietro Nardelli	Ph.D.(Elec)	Graduated <i>cum laude</i> from University of Genoa (2012), M.Eng. thesis completed at UCC under Erasmus programme (2012)
Conor O'Shea	Ph.D. (Mech)	Ranked 4/30 in graduating class in civil and environmental engineering (2012), UCC College Scholar (2009-2012), Inventor of ProDural, Patent author.
Alex Jaeger	PhD. (Elec)	Imperial College London intern (2014), winner of IEEE/IBM Global Challenge competition (2012), graduate of electrical and electronic engineering (UCC, 2014).

Attraction of high quality students is achieved by:

- A strong web presence using a combination of a static webpage³ and YouTube video channel⁸

⁸ <http://www.youtube.com/user/bioelectromagnetics>

- Use of social media (e.g., LinkedIn⁹ and Twitter¹⁰) to increase visibility among students and collaborators
- Engaging high-potential UCC undergraduates within the Bioelectromagnetics group (see section 2.4)
- Identifying final year students with research pedigree as evidenced by final-year engineering project outputs
- Encouraging and fostering research outputs within the teaching environment by means of the award-winning Biomedical Design¹¹ module.

2.6 On-going Workload

In addition to the research outputs outlined (see 2.1 and 2.2), the group has ambitious plans to expand in 2015 and beyond. This includes the following pending and planned projects:

2.6.1. Developing medical devices within the ISO 13485 framework

Conor O'Shea (2013-2016)

Funded by UCC SEFS start-up funding allocated to Dr. Cantillon-Murphy and Smart Mag Solutions.

Research Summary: This project will look to develop three independent medical devices within the ISO 13485 protocol standard for medical devices, applied to the university academic environment. The work is commercially relevant with the following end-goals:

- Clinical evaluation of the SecuRetract device (see 2.2.1)
- Development and pre-clinical testing the ProDural epidural needle placement system, developed as part of the UCC BioDesign module in 2011/12 and awarded the Cleveland Clinic / Enterprise Ireland Clinical Innovation Award in 2012.
- Development and pre-clinical testing of the ColonAssist device, an innovative solution to reducing risk of multiple colonoscopy, developed as part of the UCC BioDesign module in 2012/13.
- Implementing a framework for ISO 13485 protocol compliance within the Bioelectromagnetics group for these three devices
- Actively engaging with the UCC Technology Transfer Office to exploit potential IP arising from the devices
- Exploit any identified commercial potential associated with these devices by means of a commercial entity (UCC spin-out).

This project will see the engagement of Conor O'Shea to begin a doctoral research project at UCC from September 2013.

Collaborators: National Standards Authority of Ireland

Department of Surgery, Cork University Hospital

Department of Surgery, Mercy University Hospital, Cork

Department of Surgery, South Infirmary Victoria University Hospital

2.6.2 Technology Enhanced Learning (TEL) for Health at UCC



As a key partner in the UCC TEL for Health¹² initiative at UCC, the group leverages considerable research currency within the UCC College of Medicine and Health. The TEL for Health comprises

⁹ <http://ie.linkedin.com/pub/padraig-cantillon-murphy/14/15a/222>

¹⁰ <https://twitter.com/CantillonMurphy>

¹¹ <http://biodesign.ucc.ie>

¹² <http://www.ucc.ie/en/telforhealth/>

medical educators and experts in technology, human factors and engineering who together develop novel applications of TEL to undergraduate and postgraduate healthcare education. TEL for Health have formed strong collaborations with leading institutions around the world to join in the pursuit of excellence in TEL innovation. Within the global scope of TEL for Health, the focus is research questions likely to render to “real world” health, societal or economic benefit. Clearly, these goals are in parallel to those of the group at UCC. Planning is at an advanced stage for a new building (at the Brookfield Health Sciences Complex) which will host core competencies within the TEL for Health initiative. The ASSERT (Application of Science to Simulation, Education, Research and Training) Centre will be a state-of-the-art, simulation-based medical and healthcare training centre located in UCC. The School of Medicine (UCC), in partnership with the Health Service Executive and the Higher Education Authority, is planning to create the ASSERT Centre to promote clinical learning, through the use of simulation, by undergraduate and postgraduate health professionals in the southern region of Ireland. The group will be a **key partner** in this undertaking.

2.6.3 Industry Partnership

Negotiations are at an advanced stage with a **leading US multinational** medical device manufacturer, with significant research and development capabilities in Ireland, to support a fourth doctoral thesis topic within the group with the working title of “Robotically-guided navigation using spiral-cut flexible catheters.” This work, which it is proposed to sponsor with a combination of industry funding and the Enterprise Ireland industry partnership initiative, would represent a natural synergy with the group’s high commercial value technical outputs.

3.3 Funding Initiatives

3.3.1 Enterprise Ireland Commercialisation Funding for Studentships

The aim of the Enterprise Ireland (EI) Commercialisation Fund Programme is to improve the competitiveness of the Irish economy through the creation of technology based start-up companies and the transfer of innovations developed in Higher Education Institutes and Research Performing Organisations to industry in Ireland. However, historical precedent and bad experiences led EI to withdraw funding for studentships in 2010/11. In our view this was an unfortunate consequence of bad management and unrealistic goals from grant awardees. As a result of attending the seminars from UCC BioDesign 2011/12, EI agreed to consider a 'pilot' study to revisit funding studentships through the award. The subsequent proposal which funds the SecuRetract device development (see 2.2.1) is the result of significant investment by EI in, not just technology, but a new model of funding commercially relevant research in the university sector. EI, who regularly attend SecuRetract team meetings, have expressed immense satisfaction at the fresh approach to project management and the interdisciplinary nature of this work. As a result, we have been actively encouraged¹³ to submit further commercialisation award proposals resulting from the UCC BioDesign module which might include MEngSc studentships as part of the award.

3.3.2 Integration of teaching and research



Figure 6. The UCC BioDesign module has its own online presence (<http://biodesign.ucc.ie>) which serves a valuable interface for collaborators, clinical mentors and students.

Interdisciplinary learning is often limited to students which already have significant overlap in their respective curricula or who interact in day-to-day duties. This is not generally true of engineers and clinicians, and almost never the case for engineering and medical students. BioDesign at UCC addresses this shortcoming in an innovative way. In an initial feasibility study (2011/12), interdisciplinary learning outcomes were assessed in six teams comprising engineering and medical students at UCC. Each team was paired with a senior clinician, who acted as mentor, to solve a real-world clinical need over a twelve week semester. The teams were guided through the process of innovation by structured lectures in TRIZ (the "Theory of Inventive Problem Solving") to address their clinical problem. While the primary programme outcomes are pedagogical, the tangible outputs (product prototypes) from each of the six

teams represented worthy proofs-of-concept¹⁴ (see 2.2.1 for case of the SecuRetract device which won UCC BioDesign 2011/12). The innovative nature of the programme has been

recognized by an Enterprise Ireland commercialization award for one of the devices developed in 2011, the FP7 Lifelong Learning Programme¹⁵ and the UCC President's teaching awards. The sustainability of the programme is demonstrated by an oversubscription of students and clinicians in 2012/13. Again, a high-calibre project outputs with excellent future research and commercial potential has resulted. This is likely to be exploited within the Bioelectromagnetics group in 2013, leading to new funding proposals and partnerships.

3.3.3 Future funding strategy

Working in close cooperation with the UCC Research Office and the UCC Technology Transfer Office, a coherent strategy and prioritisation of funding goals has been established for the group for the period 2013-2018. This is summarised here:

¹³ Christian Stafford, Enterprise Ireland. *Private communication, December 19, 2012.*

¹⁴ <http://biodesign.ucc.ie>

¹⁵ <http://www.bioapp.eu>

3.4 Successful Funding Awards (2010-2014)

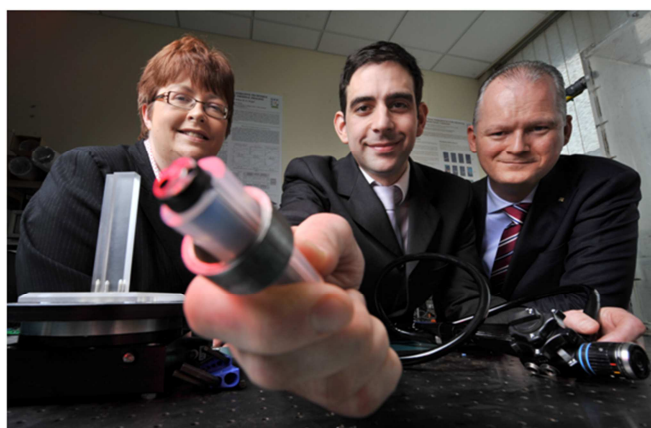
Sponsor	Title	Term	Value (€ '000s)	Collaborators	Comments
FP7 Marie Curie	Smart Mag Solutions (PI)	2010-2014	100	MIT	Reintegration Award
FP7 Erasmus Lifelong Learning	BioApp (co-PI)	2011-2013	300	KU Leuven, Semmelweiss, OUNL	Follow-on proposal (MedInvent) submitted Jan 2013
Irish Research Council	Magnetic guidance for endoscopic surgery (PI)	2011-2014	75	Kilian O'Donoghue (PhD candidate)	
Enterprise Ireland	SecuRetract (PI)	2012-2014	146	Cork University Hospital, Mercy University Hospital, Open Innovation Partners, Creagh Medical, Mr. John McSweeney (consultant)	
Health Research Board	A Smart Navigation Platform for Endoscopic Needle Biopsy in Lung Cancer (PI)	2012-2015	300	Harvard Medical School, Cork University Hospital, MD Anderson Cancer Center	Patient-oriented research award under HRB research funding
Health Research Board	Summer Scholarship Scheme (PI)	2011	2		Used as feasibility study for follow-on award
TOTAL FUNDING (2010-2013)*			€923,000		

* exclusive of overhead (20% on EI and HRB awards) and internal SEFS start-up funding of €100,000, 74% of which remains unspent to date.

3.5 Innovation and Adaptability

3.5.1 Innovation

Academic research, while original, is often incremental rather than innovative. Inspired by Altshuller's philosophy¹⁶ that **"everybody can be creative"**, research students within the Bioelectromagnetics group are encouraged to participate in the UCC BioDesign module (see 3.3.2) in order to foster a truly innovative nature to research and development within the group. The result is an organic growth of new ideas, many of which arise at the monthly group meetings (where one



¹⁶ "TRIZ: The theory of inventive problem solving," G. Altshuller, Technika (2004).
Figure 7. UCC Vice President for Research, Professor Anita Maguire, and EE Professor Peter Kennedy pose with the iPEG device at the UCC Invention of the Year 2011 photo shoot.

member of the group presents their research in an informal, supportive environment). Tangible outputs include two European patent applications {1-2} and active engagement with Enterprise Ireland (the national body responsible for innovation in Ireland) and the UCC Technology Transfer Office. In 2012, the iPEG device (4) was awarded UCC Invention of the Year¹⁷ (see Figure 7), establishing the group as a leader in innovation within the UCC research community.

3.5.2 Adaptability

The Biomedical Design research group has established and published credentials in the area of electromagnetic devices for endoscopic and clinical applications. However, in response to well-defined user needs defined by clinical collaborators, high potential technical outputs arising from the UCC BioDesign module and the significant presence of US multinational medical device manufacturers in the Cork area (Boston Scientific, Stryker Instruments and DePuy Johnson and Johnson), the group has diversified its research interests in the past two years to include (i) mechanical design and development and (ii) medical image processing. Medical image processing (albeit MRI rather than CT) is an established skillset of the PI but application to lung reconstruction (see 2.1.2) highlights an adaptability and fluidity in the group's focus.

Diversification in the mechanical domain is enabled by a ready cohort of skilled graduates from the School of Engineering B.E. honours programme in civil and environmental engineering, the symbiotic outcomes of the UCC BioDesign module and the well-defined needs of the local surgical community. Results of this adaptability in research focus is outlined in section 2.2.1.




3.6 Interdisciplinary Collaboration

The Biomedical Design group at UCC is an interdisciplinary research laboratory with links to a number of national and international collaborators across engineering, medicine, computer science, biochemistry and biology.

3.6.1 External Collaborators




Institution	Research Area
 MIT Research Laboratory for Electronics	The group is actively working with Professor Jeff Lang at the Research Laboratory for Electronics (RLE) to develop self-deployed magnetic for endoscopic surgery [1].
Imperial College London The Hamlyn Centre at Imperial College	The group is collaborating with Professor Guang Zhong Yang at the Hamlyn Centre, Imperial College, to develop the next generation of magnetic anastomotic devices for natural orifice and minimally invasive surgery. To that end, I was recently awarded an honorary appointment (see 3.6.3) at the Hamlyn Centre with funding for a doctoral candidate at Imperial College.
 Harvard Medical School Surgical	The group is working with Professor Raul San Jose Estepar and the Surgical Planning Laboratory at Harvard Medical School (1) to develop 3D


¹⁷ <http://www.siliconrepublic.com/innovation/item/26435-tyndall-scientist-wins-ict>

<p>Planning Laboratory</p>	<p>augmented reality imagery of the human lung.</p>
 <p>University of Pisa</p>	<p>The group is working with Dr. Federico Carpi at the Department of Biomedical Engineering at the University of Pisa (2) to develop the next generation of magnetically guided capsule endoscope technology.</p>
 <p>Cork University Hospital</p>	<p>The group is working with the Departments of Surgery and Radiology at CUH, who collaborate closely on a number of projects, contributing anonymised CT data in line with UCC and CUH codes of ethics. The group also collaborates with the Department of Respiratory Medicine (3) in the development of 3D magnetic navigation platform for endoscopic needle biopsy in the human lung.</p>
 <p>Mercy University Hospital, Cork</p>	<p>The group is working with the Mercy University Hospital to develop new devices in magnetic capsule endoscopy (2) and minimally invasive surgery {1],[2].</p>

3.6.2. Internal Collaborators

The group collaborates with a number of other centres, institutes and laboratories across the UCC campus.

Institution	Research Area
 <p>Tyndall Life Sciences Interface</p>	<p>The group is working with Dr. Paul Galvin and Carlo Webster to identify disruptive technologies in the endoscopic and surgical fields to exploit Tyndall’s OCT and sensor mote technologies.</p>
 <p>The Cork Cancer Research Centre</p>	<p>The group is collaborating with Dr. Declan Soden and Dr. Pat Forde to identify the mechanisms of cellular response to high-voltage electrical fields. This work is seeking to identify ways to decrease adverse patient outcomes and side-effects in the clinical application of electroporation for gastrointestinal cancer treatment.</p>
 <p>UCC School of Medicine</p>	<p>The group is working with Professor George Shorten, Dr. Colm O’Tuathaigh and Dr. Louise Burgoyne at UCC School of Medicine as partners in the TEL for Health and ASSERT centre initiatives (see 2.6.2). The</p>

	<p>group also collaborates through outputs from the UCC BioDesign module which have been absorbed within the research of the group.</p>
 <p>UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh</p> <p>UCC School of Engineering</p>	<p>The group is collaborating with Dr. Liam Marnane (digital signal processing for noise reduction in CT images), Dr. Emanuel Popovici (pressure sensing in closed casts), Dr. Guangbo Hao (disposable adapters for robotic surgery) and Dr. Denis Kelliher (augmented reality imaging using NURBS) at the UCC School of Engineering.</p>

3.6.3 The Hamlyn Centre for Robotic Surgery at Imperial College London

As the result of ongoing collaborations with Professor Guang Zhong Yang and his colleagues at the Hamlyn Centre for Robotic Surgery, Imperial College, I was recently awarded an honorary appointment at the Hamlyn Centre with funding for a doctoral candidate at Imperial College. This work's outputs, which will seek to develop the next generation of magnetic anastomotic devices for natural orifice and minimally invasive surgery, will be purely academic with no commercial end and involve no overlap with existing research of the Bioelectromagnetics group at UCC.

Imperial College London

CID: 790300

20 February 2013

PERSONAL

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Jacqueline Uzoka BSc (Hons)
HR Adviser

Dear Dr Cantillon-Murphy

Honorary Lecturer

I am pleased to offer you association with Imperial College London as **Honorary Lecturer** in the **Institute of Global Health Innovation** within the **Faculty of Medicine**, based at the **South Kensington Campus**. The association will begin on **1 March 2013** and will continue until **28 February 2016** and carries no remuneration.

The association is offered in recognition of your valuable contribution to the Department.

In accepting this association, you will be accountable to the College for the execution of any research grants or contracts entered into on its behalf and you and your employer (if you are employed elsewhere) agree that any Intellectual Property created during your association shall be subject to the College's Intellectual Property Policy and agree to assign to the College any of that Intellectual Property that the College requests. The College's Intellectual Property Policy is available from:

www3.imperial.ac.uk/researchsupport/contractsandip/ippolicypublicaccess

You are also required to familiarise yourself with the College's Conflict of Interest Policy. If after referring to this policy, you consider that there may be a conflict of interest, please contact Professor Guang-Zhong Yang to discuss this matter. The College's Conflict of Interest Policy is available from:

https://workspace.imperial.ac.uk/hr/Public/Procedures/conflict_of_interest/coi.pdf

I am enclosing two copies of this letter and I would be grateful if you could confirm your acceptance of this association by signing one copy and returning it to me.

I would be grateful if you could also complete the attached Personal Details form and return it to the above address.

I very much hope that you will accept; thank you for your contribution.

Yours sincerely



Jacqueline Uzoka
HR Adviser

4. Other Activities

4.1 Journal contributions

- IEEE Transactions on Biomedical Engineering reviewer
- IEEE Transactions on Education reviewer
- IEEE Transactions on Magnetics reviewer
- IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control reviewer
- Journal of Magnetism and Magnetic Materials reviewer

4.2 Peer review

- **FP7 reviewer** (2012-) in Health Innovation
Phase 1 and 2 reviewer for call on 'imaging on rare diseases using multiple imaging modalities' (November 2012)
- **H2020 reviewer** (2013-)
- Phase 1 and 2 reviewer for call on medical imaging (in vivo [2013] and in vitro [2014])
- Enterprise Ireland (2014-) commercialisation fund reviewer
- Scholarship Reviewer for the Irish Research Council (2011-)

4.3 Conferences and Workshops

- Conferences: see section 1.2
- Workshops: see section 1.3

4.4 Invited Speaker

- "Self Resonant Properties in Oesophageal Stenting," Seminar presentation at the Tyndall National Institute (July 2010)
- "Novel Uses for Magnets in Medicine," Grand Rounds at Cork University Hospital (September 2010)
- "Self-deployed Magnets for Biomedicine," Seminar presentation at the National Centre for Biomedical Engineering Science, NUI Galway (February 2011)
- "Novel Uses for Magnets in Natural Orifice Surgery," Guest lecture at the Royal College of Surgeons of Ireland (February 2011)
- "Novel Uses for Magnets in Minimally-Invasive Procedures," Invited seminar at the Clarendon Laboratory, Oxford University (April 2011)
- "Can Magnets Aid in Minimally-Invasive Surgery," Invited speaker at the 2011 SCath Workshop (ERC Consortium on Advanced Technology for Minimally-Invasive Surgery), July 2011.
- "The Role of Self-Deployed Magnetic Systems in Minimally-Invasive Surgery," Hamlyn Centre for Robotic Surgery at Imperial College, London (December 2012).

4.6 TEDxUCC 2011

TED Ideas worth spreading



In the spirit of "ideas worth spreading," TED created TEDx. TEDx is a programme of local, self-organised events that bring people together to share a TED-like experience where x = independently organized TED event. At TEDxUCC (October 2011), I explained the use of magnets in biomedicine, in particular, in the area of minimally invasive advanced minimally-invasive surgery

surgery. The evening's recordings are available on YouTube¹⁸ and, to date, my talk has been viewed almost **1300 times**. This event was organized by the School of Medicine at UCC and focussed on simulation in health care education. Other speakers included Professor Richard Satava from University of Washington and Dr. Marian McCarthy from the Teaching and Learning Centre at UCC.

4.7 Consulting

- Hoya Corporation, Toyko, Japan (2012). Produced in-depth report for the parent company of Pentax Endoscopy highlighting business opportunities related to the use of magnetics in surgical technology

4.8 Trained pre-clinical investigator

- Department of Health registered licensee to conduct research on pre-clinical animal models for the purposes of device development and testing
- LAST Ireland trained (October 2011)
- UCC committee on animal ethics approval for three independent protocols (valid to 2015)
- Collaborator with the UCC Biological Services Unit who facilitate pre-clinical investigations at UCC

4.9 Professional bodies

- Senior Member of IEEE (2013 -)
- Royal Irish Academy working group on biomedical engineering

¹⁸ <http://www.youtube.com/watch?v=MQz1QUyTyP4>

5. Teaching and Examining

5.1 Teaching Load

Credits	Year	Module	Students	Hours	Student-hours
LECTURES					
10	2010/2011	EE1001	78	48	3744
5	2010/2011	EE4012	12	12	144
5	2011/2012	EE1005*	57	24	1368
5	2011/2012	EE4012/EE3901*	24	24	576
5	2012/2013	EE1005	61	24	1464
5	2012/2013	EE4012/EE3901	30	24	720
5	2012/2013	EE2012*	64	24	1536
5	2012/2013	EE2013*	65	24	1560
TUTORIALS					
10	2010/2011	EE1001	78	24	1872
5	2011/2012	EE4012/EE3901*	24	12	288
5	2012/2013	EE4012/EE3901	30	12	288
5	2012/2013	EE2012*	64	6	384
5	2012/2013	EE2013*	65	6	390
PRACTICALS					
10	2010/2011	EE1001	78	30	2340
5	2012/2013	EE2012	64	8	512
5	2012/2013	EE2013	65	8	520
OTHER					
-	2010/2011	EE1001#	1	24	24
20	2010/2011	EE4020+	2	24	48
30	2010/2011	ME6019+	2	48	96
20	2011/2012	EE4020+	4	48	192
30	2011/2012	ME6019+	2	48	96
20	2012/2013	EE4020+	3	36	108
-	2012/2013	EE2012#	1	12	12
-	2012/2013	EE2013#	1	12	12

* new module or significantly revised content

office hours

+ scheduling research meeting

Year	Students	Hours	Student-hours
2010/2011	94	234	21,996

2011/2012	86	180	15,480
2012/2013	223	196	43,708

Total teaching load over three most recent academic years

5.2 Undergraduate research projects

*EE4020: Electrical Engineering Final Year (Capstone) Project
Supervisor (Autumn and Spring semesters, 2010 - present)*

The capstone design project in electrical and electronic engineering is a two semester project which embodies 20 credits for final year undergraduates in electrical and electronic engineering. Project topics for 1 or 2 students are proposed in September and the supervisor is responsible for the scope and direction of the project over the following months. To date, I have supervised five 2-person projects at UCC. Topics to date have included "3D Lung Guidance in a Benchtop Phantom" (2010-11) and "Magnetic Capsule Guidance with Microcontroller-based Navigation" (2011-12). Both of these projects resulted in **peer-reviewed workshop or conference publications**^{19,20,21} (SCath 2011, Graz and SMIT 2012, Barcelona) and led to subsequently successful research funding applications. Currently, two projects are under supervision looking at minimally invasive methods for chemotherapy administration in the GI tract and a magnetic coupling mechanism for percutaneous endoscopic gastrostomy (PEG). I meet formally, once a week, with each group while spending as much time in the laboratory as is required, particularly in the early stages when additional guidance is required. I correct and grade final and interim reports as well as an AV presentation of work from other groups at the end of the Spring semester.

5.3 Supervision of minor theses

*EE6019/ME6020: Mechanical Masters Minor Thesis Supervision
Supervisor (Autumn and Spring semesters, 2010 - 2012)*

As part of the departmental masters programme in mechanical engineering, each student is assigned an academic supervisor for the completion of a capstone project in the programme. I have supervised one student each year since 2010 with similar responsibilities to the EE4020 undergraduate project supervision. Project topics have included a mechanical coupling for PEG procedures, presented at **BIODEVICES 2011**²² and subsequently the subject of a European patent application²³, and self-deployed magnetic assemblies for minimally-invasive procedures, published in **IEEE Transactions on Magnetics**²⁴.

¹⁹ D. Hogan, M. Healy, J. Griffiths, T. Power, M. O'Shea, K. O'Donoghue, M. Kennedy, and P. Cantillon-Murphy. "Two-dimensional Magnetic Catheter Navigation with Applications in Endoscopy". 24th International Conference of the Society for Medical Innovation and Technology (SMIT), Barcelona, Spain. September 20-22, 2012 (oral presentation)

²⁰ C. O Lionaird, S.P. Walsh, L. Barry, M. Buckley, J. Griffiths, T. Power, M. O'Shea, K. O'Donoghue, F. Carpi, and P. Cantillon-Murphy. "An Optimised Electromagnetic System for Endoscopic Capsule Propulsion: Report on a Benchtop Feasibility Study." SMIT 2012, Barcelona, Spain. September 20-22, 2012 (oral presentation)

²¹ K. O'Donoghue, S. Winters, and P. Cantillon-Murphy, "A 2D Magnetically Guided Catheter for Minimally Invasive Procedures," Smart Catheterisation (SCath) Workshop on Advanced Technology in Minimally Invasive Surgery (invited paper), Graz, July 2011.

²² P. Cantillon-Murphy, T. Lambe and D. Cronin, "A Magnetic Coupling to Improve Placement of Gastroenteral Feeding Tubes," BIODEVICES 2012, Vilamoura, Portugal, February 1-4, 2012.

²³ P. Cantillon-Murphy, D. Cronin, "A magnetic coupling to improve placement of gastroenteral feeding tubes and colostomy tubes", European Patent Application EP11193758.7, Dec 2011.

²⁴ R. McEvoy, M. McMenamin, G. Ha, J. Lang, and P. Cantillon-Murphy, "Self-deployed Magnetic Polygons: Design, Construction and Application," IEEE Transactions on Magnetics, 39, 496 – 505, Jan 2013.

5.4 Teaching across levels

Offered	Module	UG/PG	Student Year	Student Cohort
2010/11	EE1001	UG	1	Engineering (energy and electrical)
2011/12-present	EE1005	UG	1	Engineering (all disciplines)
2010/11	EE4012	UG	4	Engineering (electrical)
2011/12-present	EE4012/EE3901	UG/PG	4 or PG	Engineering (electrical and civil); Mechanical engineering PG; Medicine PG; Medicine UG
2012/13	EE2012	UG	2	Engineering (electrical and energy)
2012/13	EE2013	UG	2	Engineering (electrical and energy)

5.5 Examining and assessment

Offered	Module	Module Coordinator	Continuous Assessment	Final Examination
2010/11	EE1001	Y	Y (2 hrs in-class)	Y (3 hrs)
2011/12-present	EE1005*	Y	Y (2 hrs in-class)	Y (1.5 hrs)
2010/11	EE4012	Y	N	Y
2011/12-present	EE4012/EE3901	Y	Y (1 hr in-class) Weekly assignments	N
2012/13	EE2012*	Y	Y (2 hrs in-class)	Y (1.5 hrs)
2012/13	EE2013*	Y	Y (2 hrs in-class)	Y (1.5 hrs)

* These modules carry 40% of the student mark from laboratory assignments (not included here)

5.6 Student Accessibility

EE1005 Introduction to Electrical and Electronic Engineering

EE1001 Circuit Analysis

EE2012 Linear Circuit Analysis

EE2013 Non-linear Circuit Analysis

For undergraduate modules (above), students are invited to contact me directly after any lecture, via email or telephone, and by using the regularly scheduled office hours (1 hour per week).

EE4012/EE3901 Biomedical Design

For EE4012/EE3901, students work in teams to develop solutions to real-life clinical problem under the mentorship of senior clinician. Scheduled office hours have been found unsatisfactory in this module due to conflicting timetables within the group. Therefore, I am available to meet the teams upon request via email. This works well for a mature (final-year and PG) student cohort who are not hesitant to avail of mentorship.

EE4020 Final Year Capstone Project in Electrical Engineering

ME6019/ME6020 Mechanical Engineering Minor Thesis

Each student or two-student group has a regularly scheduled meeting hour (weekly) as well as being encouraged to come to see me unannounced at any time when the need arises.

5.7 Student affairs and mentoring

- Formal academic mentor to six (departmental assigned) undergraduate students within electrical and electronic engineering as well informal mentor, particularly to final year students in relation to employment and postgraduate opportunities.
- Affiliate and strong advocate for IEEE Student Chapter within the department of electrical and electronic engineering. The current chapter president is a PhD candidate in the group.

5.8 Adult and continuing education

Currently, EE4012/EE3901 (the UCC module entitled Biomedical Design²⁵) is the corner-stone of a European-wide FP7-funded consortium²⁶ which seeks to embed methodologies of innovation in medical devices within engineering and medical school curricula in Europe. Based on the **outstanding success of BioApp and UCC BioDesign**, a follow-on proposal was invited by the European Commission. This new proposal is to create an online version of BioDesign and the plan was submitted to the FP7 Lifelong Learning Programme for evaluation in January 2013. A decision is due in June 2013. The consortium, which includes **UCC, TU Delft, University of Ljubljana and Open University of the Netherlands**, would represent a key enabler for European SMEs to cross the chasm of innovation beyond an initial product launch.

There is a growing recognition of the potential for current and emerging technologies to support and develop pedagogic practice, and to assist educational/training institutions to meet big picture challenges including skills development in the European medical device sector. Under the Digital Agenda initiative, the EU Commission has particularly emphasised the importance of helping entrepreneurs and SMEs to fully exploit the potential of ICT. Case studies conducted in Atlantic Canada have shown that SMEs benefit significantly from implementation of **e-learning platforms** with a skills focus, specific benefits including reduced training costs, geographical flexibility and transferability across multiple sites, which all help to ensure growth and sustainability²⁷.

The UCC-led consortium (in which I am co-PI) propose the design and development of an innovative e-learning platform, which will provide an effective and efficient means by which users (across engineering and medicine) and employees develop skills in design and innovation in a biomedical engineering context. This will involve development and pilot-testing of an innovative online module which will incorporate the BioApp skills 'toolbox', with a view to extending structured innovation skills in design to European SMEs and HEI students.

6. Integration of Research and Teaching

Biomedical Design is an innovative taught postgraduate and undergraduate module offered by the Schools of Engineering and Medicine. I designed and coordinate the module and deliver the largest portion of taught material. UCC BioDesign brings together interdisciplinary teams of medical and engineering students to solve real-life clinical problems working with mentors at local teaching hospitals. The award-winning module is a ground-breaking initiative by the Schools of Medicine and Engineering at UCC. For the first time in 160 years of

²⁵ <http://biodesign.ucc.ie>

²⁶ <http://www.bioapp.eu>

²⁷ Roy A (2010) SMEs: How to Make a Successful Transition From Conventional Training Towards e-Learning. International Journal of Advanced Corporate Learning (iJAC), Vol 3, No 2 (2010).

education BioDesign affords medical and engineering students the opportunity to sit together in the academic setting and create solutions to today's health care challenges.

The module is run in 12 two-hour seminar-style units, as detailed in Figure 2. Details of the curriculum's genesis and development are outlined in 4.1 and 4.3. As part of the module, the student teams had to maintain a **public website** using WordPress (see Figure 4). A number of teams generated video outputs as part of the module to demonstrate their device²⁸. The class also has its own WordPress site²⁵ which was originally developed to showcase the students' outputs. However, the site now represents an invaluable resource at the **threshold of research and teaching** for students involved in the module, clinical mentors and third-parties interested to learn more about the Biomedical Design module at UCC.

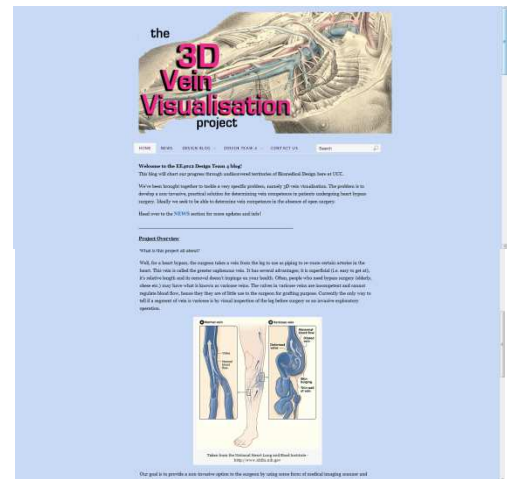


Figure 6. This student team webpage from UCC BioDesign 2011/12 is available online at <http://blogs.ucc.ie/wordpress/designteam4/>

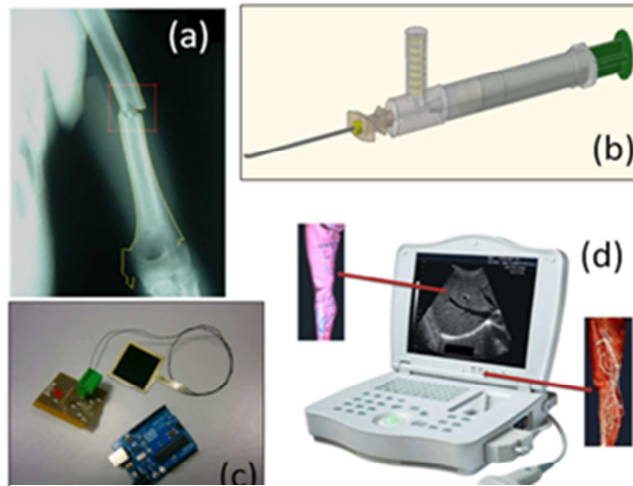


Figure 8. Examples of the project outputs from the interdisciplinary biomedical design module in 2011/12 included (a) an automated fracture detection algorithm for orthopaedic fractures, (b) a 'smart' needle suitable for epidural procedures, (c) an integrated monitoring device for pressure sensing in closed casts and (d) a 3D reconstruction tool for the greater saphenous vein using standard ultrasound technology.

Figure 9. The Biomedical Design module culminates with a public symposium showcasing the design solutions from each of the teams. In 2011/12, a novel laparoscopic retractor was awarded the John Francis Burke Prize for Biomedical Innovation based on its commercial and clinical potential. This design, SecuRetract, went on to be awarded over €140,000 in commercialisation funding from Enterprise Ireland in 2012.



²⁸ http://www.youtube.com/watch?v=CPpr_UqVPfk

6.1.1 Undergraduate student feedback

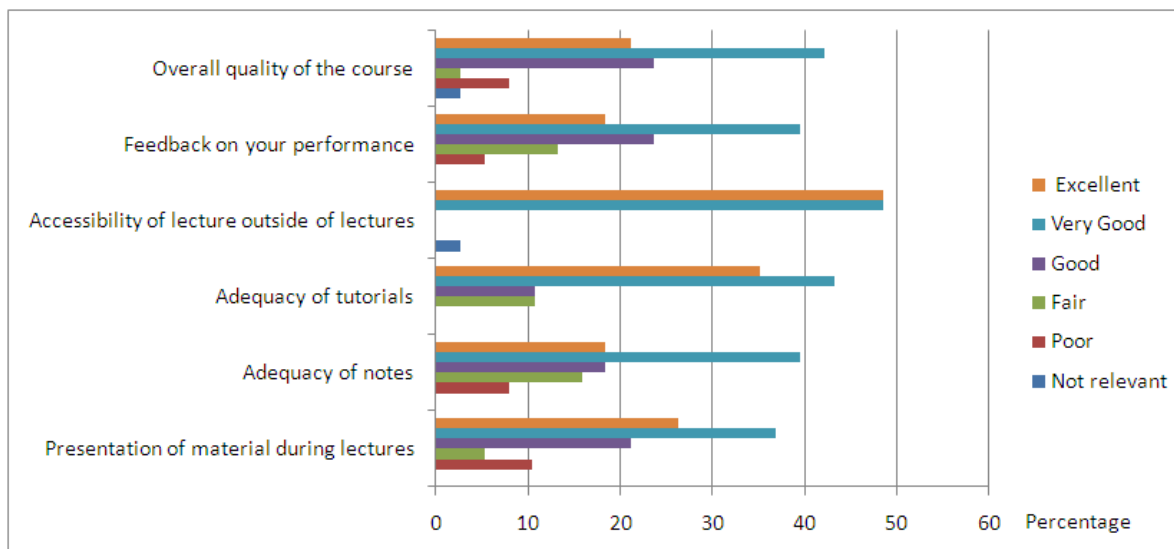


Figure 10. Student feedback on EE1001 (2010/11) based on online survey response using surveymonkey.com. The survey was part of a required computer-based laboratory assessment which ensures virtually full class participation.

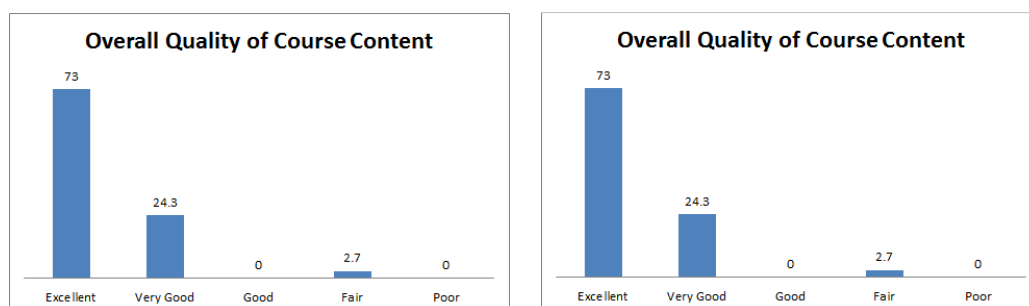


Figure 11. Student feedback on EE1005 (2011/12) based on in-class written survey. Hardcopies of all student feedback is retained by the lecturer and is available for review.

6.1.2 EE4012/EE3901 Biomedical Design

Student impact of BioDesign was evaluated by a **pre- and post-evaluation** on the Readiness for Interprofessional Learning Scale (RIPL) independently of the module coordinator thanks to the involvement of the School of Medicine. The study feedback, which is the subject of two separate peer-review journal submissions^{29,30}, identified 68% of students who said that “the module challenged me to think to a great extent,” while **95% of students** agreed that “the module **improved my understanding of concepts and principles** significantly or to a great extent.”

Seven students from across disciplines were selected for a **post-module focus group** which highlighted the following impact. Students identified a number of attractive and unique “module design” attributes including (i) promotion of creativity and freedom of expression; (ii) use of “ideation” tools and interdisciplinary interaction to promote innovative solutions; (iii) module structure, with course content during each teaching session appropriate to the design development

²⁹ “Addressing biomedical problems through interdisciplinary learning: a feasibility study,” P. Cantillon-Murphy, J. McSweeney, C. O’Tuathaigh, L. Burgoyne, S. O’Flynn and G. Shorten, International Journal of Engineering Education, (under review), March 2013.

³⁰ “Bridging the translational gap: bringing medicine and engineering students together to develop novel healthcare engineering solutions to real-life clinical problems,” H. Spoelstra, S. Stoyanov, L. Burgoyne, D. Bennett, C. Sweeney, K. Vanderperren, S. Van Huffel, G. Shorten, S. O’Flynn, P. Cantillon-Murphy, and Colm O’Tuathaigh, Academic Medicine, (in preparation), March 2013

stage; (iv) opportunity to present design prototypes in front of an audience of clinicians, academics, and industry stakeholders; (v) opportunity to apply engineering solutions to “real world” clinical problems, and (vi) development of a commercialisation “mindset”, including increased awareness of regulatory issues and marketability. Other (anonymised) comments included the following:

“I liked it, it was **completely different to other modules** we have done.” (Tim)

“I have never seen anything like it.” (Paul)

“It’s very practical, it’s work that you are doing as opposed to work that you are learning.” (Tara)

“But eh, presentations there, one other point, which I found very good, you are **actually dealing with people from industry**, hotshots that are out there, [like] I really thought it was brilliant.” (Jim)

6.2 Updating and Reflection

6.2.1 Undergraduate Curricula

As part of ongoing betterment of the undergraduate experience within the School of Engineering and in response to specific concerns expressed by employers of UCC engineering graduates, the EE1001 module (Circuit Analysis) was scrapped after 2010/11. In fulfilment of requirements for future semesterisation, the module was replaced with two entirely new offerings which now form the core of second-year education in electrical and electronic engineering: EE2012 (Linear circuit analysis) and EE2013 (Non-linear circuit analysis). These newly designed modules, which I designed, implemented and update on an ongoing basis, are based loosely on the MIT 6.002 module which I served as teaching assistant in 2005 and 2007. 6.002 is the core introductory class to electrical engineering at MIT and serves as the technical template for the open-access initiative MITx³¹ (now part of the Edx initiative led by MIT). The 2012/13 academic year sees the introduction of EE2012 and EE2013 to the second-year student cohort (see Figure 4 and 5 for representative course material). The modules represent the culmination of over one year of research and preparation including direct interaction with former colleagues at MIT. The course textbook³², which is encouraged but not required reading, is identical to that used in 6.002 at MIT. The new UCC modules are **topical, current, engaging** and draw on a wealth of prior experience in the teaching of electrical circuits. Laboratory sessions emphasise group learning (students work in random pairs to implement a number of pre-defined tasks) and **conscientious preparation** (students are required to complete a pre-laboratory exercise before arriving for their session. An example of EE2013 laboratory assignment is shown in Figure 12. EE2013 culminates with a **mini-design project**. In 2012/13, this involves the design and simulation of an FM radio receiver. Students are graded on (i) presentation, (ii) innovation of design, (iii) design cost and (iv) minimisation of components. There is an **emphasis on continuous learning and assessment** in all my undergraduate modules, exemplified by a 50:50 distribution of student grades between continuous assessment and final examination.

³¹ <https://6002x.mitx.mit.edu/>

³² “Foundations of Analog and Digital Electronic Circuits,” by Anant Agarwal and Jeffrey H. Lang. Published as part of Morgan Kaufmann Series in Computer Architecture and Design (2007).

EE1005 is another entirely new module to UCC School of Engineering. The module, which I co-teach with Dr. Alan Morrison (who coordinates laboratories), is loosely based on Neil Storey's textbook³³. The module is a first introduction to electrical and electronic engineering. A key teaching goal of the module is to **motivate students** for the subsequent years of study in their discipline. Much thought, **research and reflection** was invested in the preparation of the module, culminating in an engaging and interactive learning environment with significant use of in-class demonstrations (see Figure 3) to emphasise key concepts. An example of a simple *vignette* used to emphasise the overall context for the module is included below.

Motivating the First Year Engineer: "Why should I care about electrical and electronic systems?"

Given that EE1005 is a school-wide elective to first year engineers, motivating students outside of the discipline to care about electrical and electronic systems is a cornerstone of the module. To this end, the use of non-electrical examples proves very helpful. Drawing on my own **research experience** and the **power of analogy**, the use of the electrical circuit analogue to the human heart is one that elicits immediate student participation and engagement.

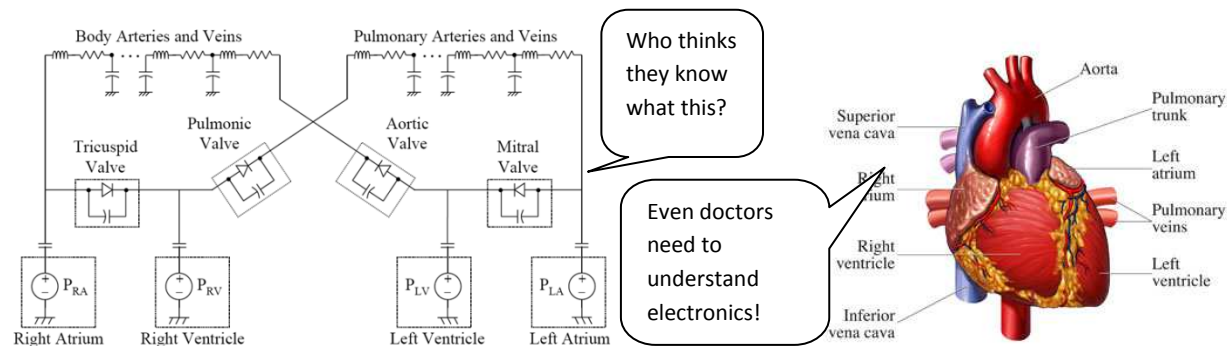


Figure 19. The electrical analogue to the human heart is a superb example of how electrical and electronic system analogies can be used to understand complex, non-electrical systems in a simple and easy manner.

6.2.2 PG Curricula

EE4012/EE3901 (Biomedical Design) is the result of a careful and methodical planning and updating the pre-existing EE4012 (Biomedical Electronics) and EE3901 (Biomedical Signal Processing for Medical Professionals) modules. The newly developed EE4012/EE3901 module (first offered in 2011/12), places student learning outcomes as its primary mission. Students are educated in a methodology of design and innovation (TRIZ), which is applied to clinical challenges but which represents a valuable tool for their future formation as engineers. Clinician-mentored biomedical design is well established and has a proven track record. A careful and methodical review of existing methodologies was undertaken prior to implementation of the new module. At Vanderbilt University, Professor Paul King pioneered the capstone project for senior biomedical engineering students³⁴. MIT's Precision Machine Design³⁵ module is a more recent interpretation. This module, which is supported by the Center for Integration of Medicine and Innovative Technology in Boston, has led to commercial ventures and significant follow-on research. At Harvey Mudd College, the Engineering Clinic³⁶ seeks to address major clinical challenges with a team-based approach and significant resources. Other well-resourced programmes include Stanford University's Biodesign³⁷ programme, University of Minnesota's New Product Design and Business Development course and, Johns Hopkins University's Biomedical Device

³³ "Electrical & Electronic Systems," by Neil Storey. Published by Pearson Education Canada (2004).

³⁴ P.H. King and R.C. Fries, Design of Biomedical Devices and Systems, New York: Marcel Dekker Press. 2002

³⁵ N. Hanumara, C. Walsh, L. Osborn, and A. Slocum, "Solving Medical Challenges while Teaching Mechanical Engineering Design," ASME Journal of Medical Device draft, unpublished

³⁶ A. Bright, and J.R. Philips, 1999, "The Harvey Mudd Engineering Clinic: Past, Present and Future," Journal of Engineering Education, vol. 88, pp. 189–194, 1999

³⁷ S. Zenios, J. Makower, and P. Yock (Eds), Biodesign, New York: Cambridge University Press. 2010

Innovation and Design³⁸ course and the Postdoctoral Programme in Biomedical Engineering at Katholieke Universiteit Leuven³⁹. The Stanford programme is a template for the Enterprise Ireland-funded BioInnovate programme⁴⁰ at NUI Galway which focuses on medical device innovation in clinical sub-specialties. BioDesign at UCC is the first time that TRIZ has been methodically applied to real-life clinical problems in the university setting. A second unique aspect of BioDesign is that it places medical and engineering students in the same classroom, which poses many logistical and communication challenges. These were addressed head-on by innovative approaches (e.g., the ‘jargon-buster’ for clinical terminology) and hands-on team management where required.

6.3 Research and Teaching

The integration of research and teaching is a key element in my teaching. This is exemplified by the use of analogies in first year engineering (see Figure 13) and, more imaginatively, in the evolution of student team outputs from the Biomedical Design module at UCC into the Bioelectromagnetics group as research projects. An example of such an evolution is the development of SecuRetract, a novel laparoscopic retractor designed as part of EE4012/EE3901 in 2011/12, for atraumatic retraction in abdominal surgery.

6.4 Teaching awards

- UCC President’s Award for Research on Innovative Form of Teaching and Learning (2011/2012). This award enabled prototyping of student devices within the BioDesign module.
- BIOAPP⁸ – FP7 funded Erasmus Lifelong Learning award to investigate methodologies of innovation applied to medical devices across disciplines. A follow-up consortium has been assembled for the MEDINVENT proposal (see 1.8) and a decision is expected in May 2013.

7. Leadership and Curriculum Design

7.1 Positions of responsibility

Offered	Module	Module Coordinator	New Module Designer
2010/11	EE1001	Y	N
2011/12-present	EE1005	Y	Y
2010/11	EE4012	Y	N
2011/12-present	EE4012/EE3901	Y	Y
2012/13	EE2012	Y	Y
2012/13	EE2013	Y	Y

7.2 Exchanges and Placement

3.2.1 Erasmus exchange student supervision

The Department of Electrical and Electronic Engineering has a long history of supervising research as part of Erasmus masters requirements for European partner universities. The Bioelectromagnetics group has engaged

³⁸ Johns Hopkins University. The Center for Bioengineering Innovation and Design [website] Available: <http://eng.jhu.edu/wse/cbid/page/projects>

³⁹ KatholiekeUniversiteitLeuven. Postgraduate Programme in Biomedical Engineering [website]. Available: <http://www.mech.kuleuven.be/en/bme/education/PostgraduateProgramme>

⁴⁰ <http://bioinnovate.ie>

with the University of Genoa in particular to this end. In 2011/12, I supervised a thesis entitled "Semi-automated airway segmentation of 0.64mm lung CT using 3D Slicer," by biomedical engineering student, Pietro Nardelli. This work, recently accepted for peer-review oral presentation at CARS 2013, represented the validation data for a subsequently successful funding application to the Health Research Board of Ireland (€300,000 in October 2012) and proved the catalyst for Pietro's relocation to Cork to complete his doctoral thesis at the Bioelectromagnetics group.

7.2.1 MIT student placement

Leveraging personal and professional connections to MIT, I have established a highly sought after work placement position within the MIT Energy Initiative (MITEI⁴¹), an interdisciplinary centre of excellence in energy research with the goals of developing innovative and transformational energy technologies, alternative energy sources, and global systems to meet energy and environmental challenges through a multidisciplinary systems approach that integrates policy design and technology development. Thanks to this placement, Ben Hudson, a third year student in energy engineering at UCC spent five months working with MITEI on shale gas drilling practices in 2012. In 2013, another third year energy engineering student, Richard O'Shea, will work with MITEI. This valuable connection increases UCC visibility internationally in a highly prestigious institution and could only be enacted by direct engagement.

7.2.2 University of Notre Dame Naughton Fellowship Exchange

The Naughton exchange programme with University of Notre Dame is an innovative and well-funded initiative to facilitate two-way exchange of engineering students between UCC and Notre Dame. This is a new initiative. However, the Bioelectromagnetics group has presented an attractive research proposal to Notre Dame students and there appears increasing likelihood that Notre Dame exchange students will be placed within the group in 2013.

7.4 Curriculum Committees

- School of engineering first year curriculum committee member (2011-12)
- Department of electrical and electronic engineering, undergraduate committee member (2011 -)

7.5 Curriculum design and new modules

7.5.1 EE1005 Introduction to Electrical and Electronic Engineering

EE1005 is the introductory course in electrical engineering at UCC and provides the basics of circuit analysis, digital systems, power electronics and control to first year engineering students across the School of Engineering. As module coordinator, I am responsible for writing and delivering all lectures (24 x 1hr), tutorials (12 x 1hr) and coordinating laboratory sessions (8 x 2 hr). Lectures are informal. Students are encouraged to ask questions throughout and I make a point of knowing the names of my students. Laboratory sessions are hands-on introductions to the basics of microcontroller programming and applications culminating in an end-of-term team mini-project. Last year's project in EE1005 involved the Arduino microcontroller to deliver morse code signals over an optical communication link. As with all modules for which I am coordinator, I also compose and correct written examinations.

7.5.2 EE2012/EE2013 Linear and Non-linear Circuit Analysis

EE2012 and EE2013 are the cornerstones of the honours bacheloreate degree in electrical and electronic engineering at UCC. They cover the analysis and use of passive devices (resistors, capacitors, inductors) in the time and frequency domains (EE2012) as well as non-linear devices such as op-amps, diodes and transistors (EE2013). I serve as module coordinator and lecturer for both modules. These sister modules are delivered through a combination of lectures (48 x 1 hr), tutorials (24 x 1hr) and laboratory sessions (8 x 2hr). Typical class sizes are 60-70 students in the undergraduate electrical and energy engineering programmes at UCC. In

⁴¹ <http://mitei.mit.edu/>

EE2012, laboratories focus on the basic elements of passive circuit design, construction and testing (e.g., first-order linear transient and frequency domain behaviour) while EE2013 involves an introduction to circuit simulation techniques (PSpice and MultiSim) followed by a two-person design project. In 2012/13, the module involved the design of a radio receiver.

7.5.3 EE4012/EE3901 Biomedical Design

Biomedical Design is an innovative and award-winning module at UCC where students are presented with real-life clinical challenges to solve under the mentorship of a consultant-level clinician over 12 weeks. Teams are hand-held through the process of innovation by structured lectures which teach them to apply TRIZ (translated as the “theory of inventive problem solving”) to address their clinical problem. Feedback from both students and clinical mentors is assessed using pre- and post-questionnaires, focus groups and individual interviews. In 2011/12, the learning outcomes were convincing and feedback was overwhelmingly positive from both students and clinicians. As an added benefit, the tangible outputs (e.g., prototype or software tool) from each of the 6 teams represented a worthy proof-of-concept, in some cases suitable for future research or commercial exploitation. For example, the SecuRetract device (see 2.4.1) resulting from the 2011/12 module led to a successful application to Enterprise Ireland (the state body responsible for promoting innovation) for a research commercialisation award to the value of €146,000. The results of the 2011/12 module are documented in a peer reviewed journal submission to the International Journal of Engineering Education.

8. Innovation and Personal Development

8.1 Novel Approaches

8.1.1 EE4012/EE3901 Biomedical Design

Interdisciplinary learning is often limited to students which already have significant overlap in their respective curricula or who interact in day-to-day duties. This is not generally true of engineers and clinicians, and almost never the case for engineering and medical students. BioDesign at UCC addresses this shortcoming in an innovative way. In an initial feasibility study (2011/12), interdisciplinary learning outcomes were assessed in six teams comprising engineering and medical students at UCC. Each team was paired with a senior clinician, who acted as mentor, to solve a real-world clinical need over a twelve week semester. The teams were guided through the process of innovation by structured lectures in TRIZ (the “Theory of Inventive Problem Solving”) to address their clinical problem. Feedback from both students and clinical mentors was assessed using pre- and post-questionnaires, focus groups and individual interviews. While the primary programme outcomes are pedagogical, the tangible outputs (product prototypes) from each of the six teams represented worthy proofs-of-concept (<http://biodesign.ucc.ie>). The innovative nature of the programme has been recognized by an Enterprise Ireland commercialization award for one of the devices developed in 2011, the FP7 Lifelong Learning Programme (www.bioapp.eu) and the UCC President’s teaching awards. The sustainability of the programme is demonstrated by an oversubscription of students and clinicians in 2012/13. Again, early indications are of a high-calibre project outputs with excellent future research and commercial potential. However, the primary outcome of the module is the pedagogical benefit to students across disciplines, learning new approaches to solve real-life problems.

8.2 New Methods of Assessment

8.2.1 UG assessment

- Use of in-class examinations in MQS format (EE1005, EE2012 and EE2013)
- Pre-requisite exercises for laboratory assignments to reinforce learning outcomes (EE2012 and EE2013)

- Team laboratory assignments to facilitate peer-to-peer learning and improve team-working skills

8.2.2 PG assessment: Biomedical Design

- 100% continuous assessment with no final examination.
- Proportion of marks awarded to team rather than individual performance .
- Weekly deliverables which add coherently to form components of a final team report.
- Final student seminar graded by invited independent experts from industry and academia (see Figure 9, 25% of the final team grade).
- Student continuous assessment is partly based on a webpage format presentation (see Figure 6) of weekly deliverables.
- Use of social media to document results is highly encouraged (one 2012/13 team used a Twitter account to update their clinical mentor).

8.3 Novel Course Materials

8.3.1 Case Study: Building a business model for your medical design

One component of the EE4012/EE3901 module is to facilitate interdisciplinary learning in areas not usually considered in engineering or medical school curricula. One such element which is considered in UCC BioDesign is the generation of a business model for the team's biomedical design. The model, which is based on the award-winning text by Alex Osterwalder⁴², is introduced by means of a novel example which is easily related to the student experience: flying on Ryanair. Students participate in building the 'model' in class based on their own knowledge of the airline company. The result is 'learning by doing' applied to business model generation (see Figure 15). The students' assignment for that week is to repeat the exercise, applying it to their biomedical design created as part of the module.

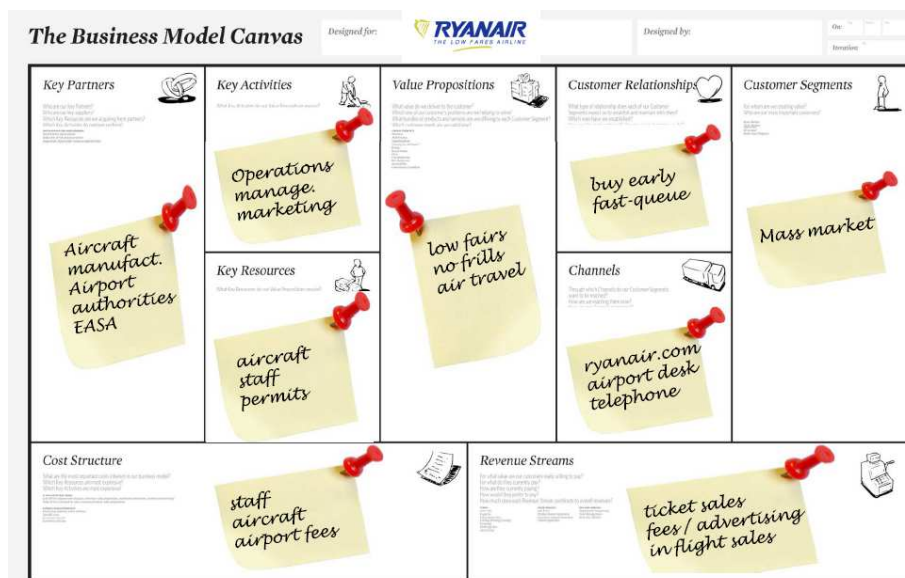


Figure 15. The business model canvas for Ryanair, which is completed interactively by each student group and then shared with the class, illustrates the 'learn by doing' methodology which is pivotal to the success of UCC BioDesign.

See sections 3.4.3 and 4.1 for further details of the novel course materials used in EE4012/EE3901 at UCC.

⁴² "Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers," by Alexander Osterwalder and Yves Pigneur, Wiley Press (2010).

8.4 ICT Integration

- Use of the BlackBoard portal for student communication and interactive forums.
- Use of Wordpress webpage outputs for students in EE4012/EE3901 (see Figure 6).
- Use of Dropbox for off-campus access to lectures, tutorials and laboratory materials (EE1005, EE2012, EE2013) as well as uploading of student assignments (EE4012/EE3901).
- Course webpage for EE4012/EE390125
- Twitter account⁴³ to provide linkage between teaching and research activities

8.5 Distance and Open Learning

See section 1.8

8.6 Scholarship

“Addressing biomedical problems through interdisciplinary learning: a feasibility study,” P. Cantillon-Murphy, J. McSweeney, C. O’Tuathaigh, L. Burgoyne, S. O’Flynn and G. Shorten, International Journal of Engineering Education, (in press), March 2013.

4.7 Evidence of Personal Improvement

- New Supervisor Training Workshop (August 2010)
- The Ph.D. student life-cycle seminar (September 2010)
- The UCC Peer-Mentoring Programme (October 2010)
- Content Management System Training (October 2010)
- Performance & Development Reviews Walk-Through Sessions (January 2011)
- Bluehost⁴⁴ Wordpress online tutorials (June-August 2011)
- UCC Health and Safety Training (2011- present)

⁴³ <https://twitter.com/CantillonMurphy>

⁴⁴ <http://www.youtube.com/watch?v=w9OhG7Wx1CY>