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Reflections on interdisciplinarity and teaching chemical engineering on an interdisciplinary degree programme in biotechnology

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ABSTRACT

Some reflections on interdisciplinarity are presented based on the author's experience of more than twenty years teaching chemical and bioprocess engineering as a minor subject of an interdisciplinary programme in biotechnology. Key literature on interdisciplinary education is reviewed and some generic challenges faced in the delivery of interdisciplinary programmes are outlined. Finally, specific challenges faced by chemical engineers teaching chemical engineering as a minor component of an interdisciplinary programme are discussed. For an interdisciplinary programme to be successful, it needs to be designed and planned with great care, but also requires constant management and review to avoid the slide into unintended multidisciplinarity.

1. Introduction

This paper has been inspired by the author's long experience of teaching chemical and bioprocess engineering as part of an undergraduate programme in Biotechnology. The BSc in Biotechnology at Dublin City University was conceived in the late 1970s and produced its first graduates in 1984. Dublin City University, then the National Institute for Higher Education, Dublin (NIHED), was conceived as a 'technological university' with a remit to offer degree-level courses that were closely aligned with the needs of Irish industry. NIHED was intended to offer an alternative experience to that offered by the more traditional institutions of University College Dublin (UCD) and Trinity College Dublin (TCD), and this was reflected in the type of degree programmes that it offered. Examples of novel programmes (for the time) were Applied Physics, Analytical Science, Biotechnology, Languages and International Marketing, Applied Languages, Accounting and Finance, and Communications. Many of these programmes were interdisciplinary or multidisciplinary in nature and were unusual in that school-leavers entered these courses directly ('denominated entry') rather than entering a more generic first year to be followed by further specialisation—the norm at the time. From an organisational point of view, degree programmes often did not 'belong' to any particular school or department, and this led to the concept of a Programme Board, a committee made up of academics teaching on the programme and responsible for all academic issues related to the programme in question. The Programme Board was typically chaired by an academic from the school/department with the largest input into the degree programme. In a sense, interdisciplinarity and multidisciplinarity were built in to the very fabric of NIHED and if these approaches to education were to be successful anywhere it was in that institution.

The Biotechnology programme in particular was designed to be highly interdisciplinary in nature and the original curriculum designers were a mix of process biochemists, industrial microbiologists and a single UK-based academic chemical engineer. With the granting in 1982 of FDA approval for the first commercial recombinant product (human insulin produced by Genentech), there was a growing awareness that the 1980s and beyond would be characterised by an 'explosion'

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in the number of products that would be made using biological methods. Thus the BSc in Biotechnology was conceived with the aim of producing graduates who would have the chemical engineering skills and the knowledge of biology to work in the new bio-industries. To some extent, this concept of a *process biotechnologist* was not a new idea because the related disciplines of biochemical engineering and eventually bioprocess engineering were already emerging at that time. The first edition of the famous biochemical engineering textbook of Bailey and Ollis was published in 1979. However, if the 'centre' can be viewed as the half-way point between biology and chemical engineering, then the biotechnologist could be viewed as someone on the biology side of the centre while the biochemical or bioprocess engineer was on the engineering side of the centre.

The BSc in Biotechnology was led from the School of Biological Sciences, a department name that reflected the dominance, even then, of biology in the curriculum. This was later changed to 'School of Biotechnology' at the instigation of the chemical engineering staff who felt, naturally enough, that the use of the word 'biology' in its name did not capture the breadth of expertise within the school. Then, as now, teaching input was provided by the School of Chemical Sciences, the School of Mathematical Sciences and the School of Physical Sciences. In the early years of the programme, the DCU Business School provided modules in Cost Accounting and Marketing, a cross-faculty collaboration that sadly is no longer a feature of the programme.

The original complement of academics was an eclectic mix of chemical engineers, biochemists, microbiologists, microbial physiologists, an animal cell scientist and an immunologist. This was soon complemented by two microbial geneticists. The early cohorts of students who studied on the Biotechnology programme were somewhat pioneering in that many had deliberately chosen to study an unconventional course in a small college on the north side of Dublin rather than the well-established courses in the much more prestigious institutions of UCD and TCD. They found employment in the emerging bio-industries and brewing but, interestingly, many also went on to study at PhD level, mainly in sub-disciplines of the biological sciences. This suggested that the interdisciplinary training was providing sufficient depth in biology for students to pursue careers in that subject. In contrast, however, the number of graduates who pursued engineering and related careers was and remains very small. Most graduates who do not go on to postgraduate study find employment in biology roles (e.g. analytical biology and quality control) rather than true process roles. The perception of employers is that the Biotechnology graduates do not have enough depth or breadth in chemical/bioprocess engineering and with a healthy supply of 'real' engineering graduates, there is little reason for them to employ biotechnologists in engineering roles. The only engineering-related area where graduates have consistently found employment is process validation. Given this lack of success in penetrating the engineering market, the rationale for including chemical engineering in the curriculum continues to be based on the unproven but plausible argument that students will benefit in a hard-to-quantify way from being exposed to the mathematical and problem-solving approach of the engineer.

Over the years, many changes have occurred in higher education in Ireland. NIHED became Dublin City University (DCU) in 1989, most universities became semesterised and modularised, contact times were reduced as a matter of policy, and, crucially, the numbers attending third level education grew enormously, more than doubling between 1990/1991 and 2003/2004 (Ireland's Higher Education Authority, in press). In addition, the biological sciences advanced at an extraordinarily rapid rate as did computing power. Within biology, there was a profound shift towards molecular biology. In comparison, biochemical and bioprocess engineering seemed somewhat pedestrian. At the same time, the academic environment changed completely. It was now taken as a given that all academics must be research active and most institutions strove to be 'research intensive'. As universities came under increasing financial pressures, research potential, especially the ability to obtain grant funding, became a key metric to be used when recruiting new staff. Academics were no longer recruited strategically for their role as teachers but to be researchers with high earning potential who could also teach. Furthermore, the huge increase in undergraduate numbers drove the development of new undergraduate programmes and most of these were not of an interdisciplinary nature at all. In time, the School of Biotechnology in DCU became the lead department for a new degree programme in Genetics and Cell Biology. Consequently, recruitment began to be driven by more than just the need to service the Biotechnology programme but to staff the school with highly research-active molecular biologists and cell biologists who could teach not only on Biotechnology programme but also on the Genetics and Cell Biology programme. The expertise of new staff would also align with whatever strategic research themes that the university had adopted in the latest incarnation of its strategic plan. Many of these new staff had interests in highly topical areas of molecular biology, typically in biomedical fields, and most had only a passing interest in process biotechnology as originally conceived when the programme was designed.

The various demands placed on a department that was attempting to deliver laboratory modules in a variety of biological sciences and chemical/bioprocess engineering were also problematic. In particular, recruiting and retaining technical support staff for the engineering laboratories (teaching and research) was always difficult. In this context, it is not surprising that there was a steady drip of resignations amongst the engineering staff, academic and technical, a phenomenon that was not repeated on the biology side where the staff complement tended to remain very stable.

And so the biotechnology programme drifted somewhat, a consequence of the constant tinkering required to make the course content consistent with an ever-widening range of academic expertise within the school. While it was never truly interdisciplinary (having very few modules shared between biologists and engineers), the programme slid more and more into multidisciplinarity over the years.

The current programme structure is outlined in Tables 1–4 where modules taught predominantly by engineers are in bold and optional modules are in italics. Year 1 is largely devoted to building the students' basic skills and knowledge in the sciences and mathematics with a solitary module on bioprocessing included mainly to stimulate student interest and to give them a sense as to where the course is heading. Of the 180 credits in years 2–4 of the programme, at most 40 are delivered by chemical engineers, i.e., about 26% of modules (excluding work placement) are engineering-focused. Only two modules, the Year 2 module, Bioprocessing and Instrumentation Laboratory and the Year 4 module, Bioprocessing Laboratory, are taught jointly by engineers and biologists. Indeed, the latter is probably the only truly