Reflections on 25 Years Teaching on an Interdisciplinary Programme in Biotechnology

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Abstract

Interdisciplinarity is the combination of selected parts of two or more existing disciplines to create what is essentially a new discipline that straddles the parent disciplines. In this paper, some reflections on interdisciplinarity are presented based on the author's experience of more than twenty five years teaching bioprocess engineering as a minor subject of an interdisciplinary programme in biotechnology. While previous work by the author focused on challenges such as programme design and sustaining the interdisciplinary ethos, this paper is concern with two keys issues: (i) the recruitment of students into the programme and (ii) the independent learning challenges faced by students on the programme. These two factors, which are connected, have a significant bearing on whether any programme that is intended to be interdisciplinary, will actually succeed in its aims. We find that our student intake is generally high-achieving in biology, but not mathematics, and this fact, coupled with the very different approaches to learning that are required in biology and engineering, creates very significant challenges both for us as teachers and our students as learners. True integration of the disciplines is not helped by the fact that biologists and engineers teaching on our programme employ very different methods of assessment. It would appear that an honest appraisal of our programme reveals it to be multidisciplinary rather than interdisciplinary but it still produces graduates who go on to have very successful careers, albeit mainly in biology roles.

1. Introduction

There is quite a large literature on interdisciplinarity and interdisciplinary teaching but much of it tends to be somewhat abstract with an insufficient focus on the logistics and practicalities involved in this type of teaching [1-3]. However, in a recent paper, some of the more practical aspects of running a particular interdisciplinary programme, the BSc in Biotechnology at Dublin City University, were outlined and a variety of issues relating to management, resourcing, staff recruitment and retention, and teaching were discussed in detail [4]. These included (i) the design of the programme itself (what should be taught), (ii) learning challenges for students who might have to integrate disciplines that require very different approaches to learning, (iii) challenges for academics whose research might be firmly embedded in a narrow discipline and who may have difficulty pitching material at a level appropriate for an interdisciplinary audience, and (iv) logistical challenges, especially when laboratory sciences are involved.

The BSc in Biotechnology is a four-year degree programme whose content is summarised in Table 1. On a spectrum that runs from biology to chemical engineering, it lies closer to biology than engineering. In contrast the sub-discipline of biochemical or bioprocess engineering lies closer to chemical engineering than biology.

The total biology content is currently about twice that of the engineering content with the remainder devoted to other supporting subjects as well as the final year research project and the six-month work placement. The programme was conceived in the 1980s with the quite specific intent of providing suitably trained graduates to work in Ireland's growing bio-industries of that time. The basic idea was that those industries would require numerate graduates with a sound understanding of the basics of biology combined with knowledge of bioprocess engineering, particularly the problems of scale-up.

In this paper, we describe two specific challenges when providing an undergraduate programme in biotechnology, a programme that was originally intended to be interdisciplinary rather than multidisciplinary, and to be a synthesis of chemical engineering and biology. In particular we will focus in this paper on (i) student recruitment and (ii) the independent learning challenges facing students.

Table 1 Summary of content of the BSc in Biotechnology

Subject Area	Credits
Core Biology	82.5
Core Bioprocess Engineering	40
Research	22.5
Work Placement	15
Other*	65
Options (5 credits max in engineering)	15
Total	**240**

**Mathematics, Chemistry, Physics, Statistics, Scientific Communication etc.*

2. Student recruitment and pedagogical challenges

In Ireland, students enter third level education *via* a competitive points system based on performance in six subjects in the state examination known as the Leaving Certificate. Points are allocated to grades in both higher and ordinary levels of a wide range of subjects and access to college is a competitive supply-and-demand system managed by the Central Applications Office (CAO). In theory, there are over one thousand courses available from which students can choose but evidence suggests that Irish school-leavers tend to study mainly at geographically close institutions meaning that the system is less complex than many critics claim.

Given that the BSc in Biotechnology involves a mix of biology and engineering, the challenge for us is to connect with both the science and the engineering 'audience', but especially those students who are undecided between pure science programmes and engineering programmes. Making this connection is not easy because Irish students are subject to a huge amount of 'noise' when it comes to choosing their first preferences; the Leaving Certificate examination and the allocation of places in college have become extraordinarily large media events. Advice comes from all quarters: parents, counsellors, university presidents, business organisations and even CEOs of major multinationals. Within this environment, the subtleties of interdisciplinarity are easily drowned out.

Currently, the BSc in Biotechnology is attracting students whose Leaving Certificate points score places them in the top 15% of academic performers within the school-leaving population. Furthermore, we generally find that our students have performed slightly better than the general school-leaving population in higher level biology. But consider Figure 1 which shows the cumulative distribution of Leaving Certificate (higher-level) grades in mathematics for both the BSc in Biotechnology intake (in 2015) and the complete school-leaving population.

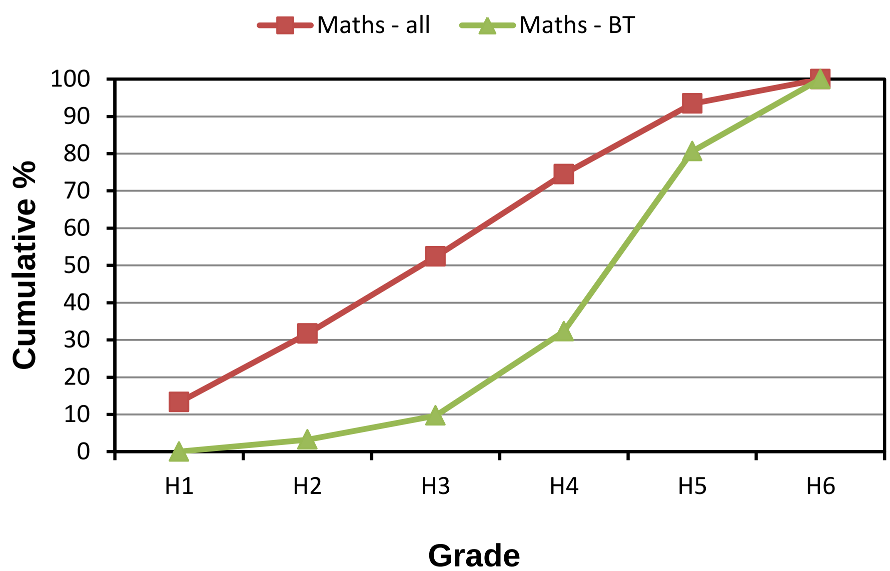

Figure 1 Leaving Certificate grades in higher-level mathematics obtained by the 2015 cohort of biotechnology (BT) students compared with the entire school-leaving population. Grades: **H1**:90-100%; **H2**: 80-89% etc.

It is clear that our students have performed considerably less well than the general population in higher level mathematics. To illustrate; about 30% of our students have achieved a mark at or better than 60% (H4) in Leaving Certificate mathematics while about 75% of the general population has achieved this mark. Thus, our students are relative underachievers in mathematics.
It would seem, therefore, that despite the fact that the programme is marketed as an interdisciplinary one, it is attracting students who have an interest in, and an aptitude for, biology rather than mathematics/engineering. It is likely that these students haven chosen to study biotechnology (as opposed to a pure biology) for quite utilitarian reasons, i.e., because, they feel that our programme, with its bioprocess engineering content, might offer better preparation for working in Ireland's burgeoning biopharma sector.

This means that we are faced with a significant pedagogical challenge: how do we engage students with engineering and how do we deal with the fact that their mathematical skills might not be what we want them to be? This is a challenge that, in many respects, we have never overcome; engineering is a subject that is best learned by immersion, something that our students do not get. Indeed, few of our graduates pursue careers that involve much real engineering and when it comes to choosing final year research projects, the general trend has been for biology projects to be favoured over engineering ones. Nonetheless, graduates of our programme frequently comment on how they have benefited from being exposed to the quantitative approach of engineering in their undergraduate studies.

The fact that students might be attracted to one of the contributing disciplines more than the other(s) is likely to be a challenge for all interdisciplinary or multidisciplinary degree programmes and this inevitably creates pedagogical challenges.

3. Learning challenges for students

While interdisciplinary programmes pose numerous teaching challenges for the lecturer [4], they also pose learning challenges for the students. For the purposes of this paper, second and third year students (N = 48) on our programme were surveyed and asked if they agreed (1.0), disagreed (0) or felt neutral (0.5) about a variety of statements related to their learning of biology and bioprocess engineering. In response to the statement, "*When studying biology, the majority of my time is spent reading*", the net score was 0.83, suggesting that reading with the aim of recalling and understanding *information* was their dominant mode of study. There was a moderate level of 'rote learning' (0.59) in which students actually memorised answers to potential examination questions. However, in response to the statement, "*When studying engineering, the majority of my time is spent solving problems*", the net score was 0.92. Taken together, these responses suggest that students approach the study of biology and engineering in very different ways.

Apart from the obvious differences between the disciplines of biology and bioprocess engineering, the key reason for this disparity in study methods is simple; the students are responding to the way that they are assessed. Questions on their biology examinations largely start with words like 'describe', 'explain', 'outline', 'discuss', 'write a note on', etc., and numerical questions are non-existent in their biology examinations. Their engineering examinations, however, typically start with words like 'show that', 'derive', 'calculate' but also words like 'explain' and less frequently, 'describe'.

In terms of reading or studying material other than that provided by the lecturer, it is worth noting that when asked whether they studied biology material other than lecture notes, especially material recommended by the lecturer, the score was 0.48. When students were presented with the statement, "*when studying engineering, I seek out new problems from textbooks*", the score was a very low 0.28. While these numbers might reflect a trend towards a dependency culture in modern university education, the particularly low score for engineering is consistent with an almost complete lack of suitable textbooks (or even electronic resources) available for students studying on interdisciplinary programmes. The average chemical engineering textbook, for example, tends to be pitched at a level that is inappropriately high and broad for our students and this leads to a situation where they become overly-dependent on study materials supplied by the lecturer.

4. Discussion and Conclusions

Interdisciplinarity and multidisciplinarity are two 'buzzwords' that tend to be used by educationalists and policy-makers alongside phrases like 'critical thinking', 'problem solving' and '21st century skills'. However, implementing interdisciplinary programmes, especially at undergraduate level, is fraught with difficulty for all sorts of reasons, including logistical, pedagogical and epistemological ones. One of the key difficulties is that inexperienced advocates of interdisciplinarity often argue from the perspective of the expert. However, as pointed out by Willingham [5], the perspective of novices (i.e. students) is often rather different. Thus what might seem clear and easy to us might be opaque and excessively challenging for the student. And that is before one considers the logistics of running an interdisciplinary programme.

References

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