Articulation and progression: an investigation into the transition of engineering students from applied to theoretical programmes

Llorens, M
Lecturer
Dublin Institute of Technology
Dublin, Ireland

O'Shaughnessy, S[1]
Lecturer
Dublin Institute of Technology
Dublin, Ireland

Carr, M
Lecturer
Dublin Institute of Technology
Dublin, Ireland

Sheridan, D
Lecturer
Dublin Institute of Technology
Dublin, Ireland

Sorby, S
Visiting Professor, Engineering Education and Innovation Centre
Ohio State University
Cleveland, Ohio, USA

Bowe, B
Head of Learning Development, College of Engineering & Built Environment
Dublin Institute of Technology
Dublin, Ireland

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INTRODUCTION

One morning, when Gregor Samsa woke from troubled dreams, he found himself transformed in his bed into a horrible vermin. He lay on his armour-like back, and if he lifted his head a little he could see his brown belly, slightly domed and divided by arches into stiff sections. The bedding was hardly able to cover it and seemed ready to slide off any moment. His many legs, pitifully thin compared with the size of the rest of him, waved about helplessly as he looked. [1]

Intellectual life is a succession of developmental states that progress from the basic acquisition of language to the furthest development of abstract reasoning. It is to be hoped that the transition from one state to another may be accomplished with less emotional violence than that suffered by Gregor Samsa when he awoke to find his new state that of an insect, and, indeed, it may be regarded as the duty of educators from pre-school to post-graduate studies to ensure that this is the case.

One obstacle to achieving a smooth transition is the haphazard development of the educational system. For most of the past 2000 years, the majority of the population was illiterate, with universal education only appearing after the demands of the Industrial Revolution required basic literacy and numeracy amongst

[1] Corresponding Author
O'Shaughnessy, S

workers. In Ireland, a national system of primary education began in 1831, with the Government providing funds for the establishment of local schools; a similar initiative began in England in 1833 [1]. Scotland, however, began a national parish based school system in 1616. The focus in primary schools was on the so-called 3Rs: reading, writing and arithmetic. The UK Elementary Education Act of 1880 made schooling compulsory from the ages of 5 to 10; since then, the age of compulsory schooling has gradually increased to 16, with UK students from 2015 onwards required to attend to age18. Until the mid-20th century, most pupils left full-time education at the age of 12, with sufficient skills to train for work.

In the UK, the 1944 Education Act established the right to free secondary education. In 1962, a further Act established the right of most students to maintenance grants at higher education institutions. This led to a very rapid increase in both the number of undergraduates and the number of institutions, in many cases to unintended levels. The expectation in the UK following the 1962 Act (The Robbins Report) was for numbers to grow from 130,000 in 1962 to 220,000 in 1973; the reality was that 400,000 were enrolled by 1973, and following the conversion of polytechnics to university status in 1992, 2.1 million students in the UK were enrolled in all forms of higher education.

Trow [3] defined ‘elite’ education as the preparation of a fairly small proportion of cohorts (at most 15%) for exclusive occupational roles involving membership of an informal ‘ruling class’. He defined ‘mass’ education as the transmission of skills for a fairly broad range of technical or professional roles to a larger proportion of cohorts (between 16 and 50%), while universal higher education implied 50% or more of the relevant age cohort participating [4]. The intention in the UK in 1962 was to move from elite to mass; the result was universal higher education.

1. THE IDEA OF A UNIVERSITY

But what is a university or institution of higher education? The Christian church was the sole focus of education in the first millennium, with centres of learning developing around monasteries (e.g. Cluain Mhic Nóis in 546)). Some of these monastic schools, such as Paris (1150), developed into universities in the late middle ages, but most of Europe’s early universities were secular counterparts to the guild system of craft education (e.g. Bologna (1088) and Oxford (1167)). They were seen as a separate community of teachers and students, *universitas magistrorum et scholarium*, from which is derived the English word university.

The University of Bologna made its reputation from the teaching of Roman law; all early universities concentrated on a classical education, studying the philosophy of Plato and Aristotle and the literature of Euripedes and Virgil. Even into the 20th Century, many traditional universities prided themselves on the classics, and either ignored or downplayed newer disciplines, especially the sciences. One consequence of this in the late 19th century was the development of dedicated technical colleges outside the traditional university system, still rooted in the classical world. And even in the 21st century, the classical education rules, or at least governs our rulers. In the current UK cabinet, David Cameron, William Hague, Jeremy Hunt and Philip Hammond all studied Philosophy, Politics and Economics at Oxford, as did many of the alternatives, such as Ed Miliband, Ed Balls and Danny Alexander of Labour.

However wonderful the philosophy of Aristotle may be, the world of the 21st century is built on science and technology and it requires a workforce trained in these crucial disciplines. This is a particularly acute problem for engineering education, where major western economies such as the UK and the US are not producing enough graduate engineers.

2. THE HIGHER EDUCATION SECTOR IN IRELAND

Ireland has seven traditional universities, ranging from the oldest, Trinity College (TCD, founded in1592) to the newest, NUI Maynooth (1997). Then there is the Dublin Institute of Technology, a member of the European Universities Association, with degree awarding powers to doctorate level as well as 13 other Institutes of Technology. There are also small private colleges and other independent colleges.

Admission to higher education in Ireland is via a central office; with access to programmes allocated on the basis of points obtained in the State Leaving Certificate examination (maximum attainable points were 600 over a range of six subjects, now 625 with a bonus for passing the higher level mathematics exams). Qualifications are graded according to a scheme devised by the National Qualifications Authority of Ireland (NQAI). In this scheme, Level 7 is an Ordinary bachelor degree, Level 8 is an Honours bachelor degree, Level 9 is a master's degree and Level 10 is a doctorate, as shown in Figure 1 below [5].

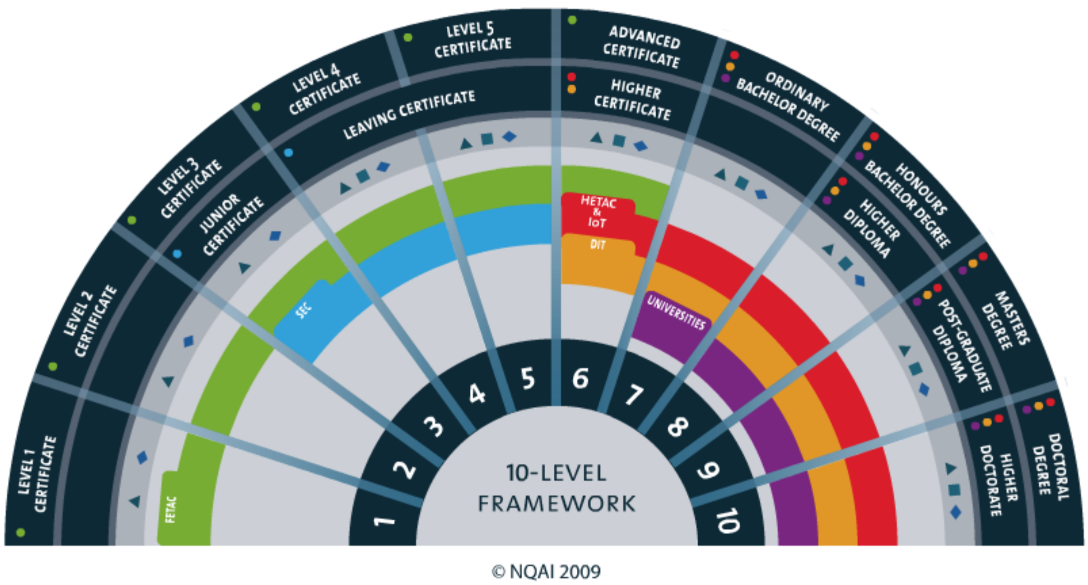

Fig. 1. NQAI Framework of Levels in the Irish Education System

In this group, DIT has perhaps the most interesting history, having grown organically from a late 19th century group of technical colleges that dealt mainly with craft education, into a degree level institute – initially with degrees awarded by TCD. Since 1993, DIT has been a fully independent institution with degree-awarding powers, covering the full-range of higher education courses, from Level 6 certificates all the way to Level 10 doctorates.

3. ENGINEERING EDUCATION AND THE MATHEMATICS OBSTACLE

One stumbling block for professional engineering education is mathematics, which must be taken by second-level students at a sufficiently high level. In Ireland, the professional body for engineers, Engineers Ireland, requires that all accredited Level 8 engineering programmes have a minimum of grade C in Leaving Certificate higher level mathematics as a condition of entry. This greatly restricts the potential entrants, as the numbers taking higher level maths have been consistently less than 20%. A major change to the syllabus and the awarding of bonus points have seen the numbers taking higher level mathematics rise to around 25% in 2013 (In 2013, 50, 856 students took Leaving Certificate mathematics, but only 13, 014 took the higher level paper.)

A second problem for engineering education is the gender performance at second level, with males, who favour engineering programmes more so than females consistently underperforming in examinations, with a 2003 report showing a 4% difference in grades achieved by females. [6]

A way around this problem is to provide programmes at a lower, less theoretical, level and allow successful graduates to transfer to a professional engineering programme. In the UK, the transition is from Higher National Certificates (HNC) and Higher National Diplomas (HND) in colleges to degree programmes in universities. This 'articulation route to degree level study is a key element of government policy on widening access to degree study and promoting efficient, flexible learner journeys' [7]. In Ireland, in contrast, Institutes of Technology provide both the Ordinary Level 7 and the professional Honours Level 8 programme.

In the US, the closest parallel to the Ordinary/Honours transition described in this paper is the articulation of students who transfer from a community college to a university. There, the community college plays a vital role in the higher education landscape, enrolling more that 50% of first-year students. The three primary functions met by a community college are:

1) programme completion in foundational subjects to prepare students for advanced study at a university (typically thought of as 2+2),
2) education or training in various vocational or technical fields where a bachelor degree is not required, and
3) continuing education for established professionals who seek additional education or credentialing [8].

Berger and Malaney [9] investigated student transition from community colleges to universities and found student satisfaction with the university to be a predictor of persistence – i.e., students who were satisfied with the programmes and extracurricular opportunities at the university were more likely to be retained and eventually graduate compared to those who were not satisfied.

In a comprehensive report published in the US in 2005 [10], strong partnerships between community colleges and universities were cited as factors in successful transfer. Regular communication between lecturing staff at the community college and university was seen as key to successful articulation. The communication was necessary to ensure that lecturers at both institutions were aware of programmatic changes and that staff at the community college would be good advocates and recruiters for the university and for the engineering programmes offered there. In addition, well-defined articulation agreements between the community college and the university are viewed as critical to the progression of transfer students. Similar conclusions were derived from a study of articulation between colleges and universities in Scotland [6]. At DIT, however, the staff teaching the Ordinary and Honours programmes are typically in the same department and, in fact, most lecturers teach on both programmes. Thus, it appears that conditions are ripe at DIT for successful transition of students between the programmes.

Several researchers in the U.S. have identified a phenomenon known as 'transfer shock' [11]. Through transfer shock, community college students who transfer to a university typically experience a drop in grades for the first semester or two immediately after articulating. Grade point averages will typically recover by the time that students graduate and the dip in grades is typically attributed to the effort it takes to make the transition from one educational setting to another. For students at DIT, transferring from a Level 7 to a Level 8 programme in the same institution and with the same lecturers, can such a process be avoided?

Across Europe, many countries have adopted a new articulated structure as a result of the Bologna Process. Germany, for example, has largely moved from the Humboldtian *Diplom* (a 4 or 5-year degree programme, although typically taking most students up to 7 years to complete) to a two-stage bachelor and master (3 + 2) study structure. Many students at German universities and *Fachhochschulen* (equivalent to Institutes of Technology) move to another institution for their second degree – 56% in a recent survey [12] – and mirroring the shift of location required of articulating students in the UK and US. Of engineering and technology students surveyed, 42% could definitely envisage studying in the future, with 49% possibly undertaking further studies. Of those who planned to continue, 42% would choose to do a consecutive master's, 15% to do a non-consecutive master's and 29% to do a doctorate. The main reasons stated for wanting to do further studies was that for 17% a master's degree was the usual final qualification for their discipline, for 40% it was the desire to specialise in an area of their discipline and for 41% improved job prospects and pay were the main factor. While the Bologna structure gives German engineering students the opportunity to complete their studies with a bachelor degree within 3 years, it is clear that very few opt to do so. This has some parallels with the experience of articulating Level 7 students at DIT.

4. BACKGROUND TO THE DIT TRANSFER STUDENTS

The first-year Level 7 students of Mechanical Engineering in DIT constitute an above average (for Level 7 nationally) group of students, with Leaving Certificate entry points typically around 350. The class numbers are usually between 60 and 70, though in the academic year 2012-13 the number was 94 and in the academic year 2013-14 the number was 73. It is also worth mentioning the overwhelming male bias of the 2012-13 and 2013-14 groups, with only three female students on the programme in each. This year, for the first time, students were asked about their expectations after graduation, as shown in Table 1.

Table 1. Student Expectations at Start of First Year 2013-14

Question: What is my next step after this programme?	N = 44	Percentage
Job	9	20%
Transfer to the Level 8 programme	32	73%
Don't Know	3	7%

So, excluding the 'don't know' group, 78% of first-year Level 7 Mechanical Engineering students want to progress to the equivalent Level 8 programme. This level of expectation almost removes the legitimacy of the Level 7 programme in its own right; the vast majority of students see it as a back-door to the Level 8 programme.

The results of the Scottish survey mentioned earlier were quite different on this question, with only 13% deciding on degree study at the start of their HNC/D study. 57% decided part-way through, and 31% decided at the end of their HNC/D courses [7].

Table 2 shows a combined analysis for the DIT Mechanical Engineering classes of 2009 and 2010. A total of 85 students who graduated had come from an Honours degree background (i.e. they had entered the programme directly from secondary school), while 33 students graduated who had entered the Honours degree programme from the 3-year Level 7 degree.

Table 2. Level 7 Student Performance in Level 8 in 2009 and 2010

2009 and 2010	Direct Entry (School leavers) to Level 8	Entry via Level 7 course
N	85	33
Average mark (Standard deviation)	53.4 (18.8)	62.1 (8.1)
Number with grade greater than 60%	37 (44%)	27 (81.8%)

The average mark of the direct entry students was 53.4 % with a standard deviation of 18.8. In contrast the students who had entered via the level 7 Ordinary degree had an average of 62.1% with a standard deviation of 8.1%. A two sample t-test was applied to this data and the average mark of the Ordinary degree students was found to be significantly different with p=0.000.

In addition, the proportion of students who achieved a 2.1 degree or higher was determined. Of the direct entry students 44% achieved a 2.1 degree or higher in comparison with the Ordinary degree students, of whom 81.8% achieved a 2.1 degree or higher. This difference was found to be significant using two proportion test (p = 0.000) and the Fisher exact test (p = 0.000).

Then, somewhat surprisingly, it was noted that there is little or no correlation between the 3rd year Level 7 mathematics grade and the third year Level 8 mathematics grade with a correlation coefficient of R^2 = 0.139 and p = 0.454, see Table 3 below. The expectation was that students who had successfully completed Level 7 mathematics should be able to adjust easily to the demands of Level 8. However, while this phenomenon echoes the transfer shock observed in American articulating students, a more likely explanation is that these students are relaxing in this non-award year after the pressure of the Level 7 degree exams.

Table 3. Correlation between Level 7 and Level 8 Results

Correlation Coefficient (R^2)	3rd Year Level 8 Mathematics R^2 (p value)	4th Year Level 8 Mathematics (p value)	4th Year Level 8 Overall (p value)
3rd year Level 7 Mathematics	0.139 (0.454)	0.533 (0.001)	0.57 (0.001)

This becomes clear when we look at the relationship between the 3rd year Level 7 grade and the 4th year Level 8 grade in mathematics, where there is a strong correlation (R^2 = 0.57) that is highly significant (p= 0.001). There is also seen to be a strong relationship between the 3rd year Level 7 mathematics grade and overall performance in the final year (4th) of the Level 8 honours degree, (R^2 = 0.57, p = 0.001).

Given the strong correlation between the Level 7 mathematics grade and the overall grade in 4th year Level 8, it is clear that the 3rd year Level 7 mathematics grade should be used to select students for entry onto the Honours programme.

CONCLUSION

It is a logical fallacy, as Aristotle pointed out many years ago, to argue from the particular to the general. That being so, it is still worth remarking on the high success rate of articulation in DIT, as compared to other systems such as in the UK and US. It seems that the common community of learning, the *universitas magistrorum et scholarium,* is important in enabling students to progress to professional engineering qualifications, despite beginning their higher education with a level of mathematics deemed insufficient by the professional bodies for that status, while the radical culture change for students moving from one type of institution to another, e.g. community college to university, can present serious obstacles to many students.

This project is only beginning, and the data obtained so far is limited. It is intended to build on this over the next few years. But the results are interesting, and quite counter-intuitive. Students delineated as weak at school-leaving, particularly in mathematics, and not of sufficient standard for a professional engineering course end up out-performing their allegedly better colleagues at the end of a Level 8 engineering programme.

This raises two important questions for engineering education: firstly, as the world needs more and more engineers, why not broaden the entry pool by formally accepting such students onto a programme that will deliver the required mathematical standard? And secondly, why build a higher education system for the 21^{st} century on an 11^{th} century model that was only ever designed for a small elite?

There is nothing wrong with the world's elite universities; far from it. But to suppose, as so many do, that Harvard and Yale, Oxford and Cambridge, provide the model for universal higher education seems misguided. Universal higher education needs universal institutions, not elite ones with feeder colleges; such an approach reverses the logic of the problem. Institutions that deal with all levels of higher education, from Levels 6 to 10 in the NQAI framework, are universal and on this, admittedly limited, data, deliver better outcomes for students. And an integrated community of teachers and scholars prevents the kind of violent transformations experienced by the unfortunate Gregor Samsa!

REFERENCES

[1] Kafka, F (1915), Die Verwandlung, trans. Wyllie, D, (2002) Metamorphosis, Project Gutenberg.

[2] Coolahan, J, (1981), Irish Education: Its History and Structure, Institute of Public Administration, Dublin.

[3] Underdal, A, (2010), Implications of the change from elite to mass or multi-purpose institutions, Portland Press.

[4] Trow, M, (1999), From Mass Higher Education to Universal Access: The American Advantage, *Minerva,* 37, 303-328.

[5] National Qualifications Authority of Ireland, (2009), http://www.nqai.ie/FanDiagram/nqai_nfq_08.html, accessed 9/5/2014.

[6] Howieson, C, (2012), Students' Experience of the Transition from HN to Degree Study, 2011-12, University of Edinburgh, Centre for Educational Sociology.

[7] Elwood, J. and Carlisle, K. (2003), Examining Gender: Gender and Achievement in the Junior and Leaving Certificate Examinations 2000/2001, report for the National Council for Curriculum Assessment.

[8] McQuay, P L, (2000), College Transfer: Community College to University, United States Community College System. *Proceedings of the Meeting of the Inter-American Bank Countries,* Cambridge, MA.

[9] Berger, J B, Malaney, G D (2003), Assessing the Transition of Transfer Students from Community Colleges to a University, *NASPA Journal,* 40, 1-23.

[10] Mattis, M C and Sislin, J, (Eds) (2005), Enhancing the Community College Pathway to Engineering Careers, National Academies Press, Washington, DC.

[11] Cejda, B D, (1994), Reducing transfer shock through faculty collaboration: A case study, *Community College Journal of Research and Practice,* 18, 189-199; Hills, J R, (1965), Transfer shock: The academic performance of junior college transfer, *Journal of Experimental Education, 33,* 201-215; Lanaan, F S (2001), Transfer Student Adjustment, *Transfer Students: Trends and Issues, New Directions for Community Colleges, Number 114, Jossey-Bass Higher and Adult Education Series,* 5-13*.*

[12] SWOP Medien und Konferenzen, (2009), Master Studie 2009: Qualifikation & Berufseinstieg: Wie Studierende ihre Zukunft planen, Berlin, SWOP.