Upper secondary education in Ireland: a case study

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This report forms part of a collection of six case studies commissioned by the Royal Society in 2017 examining upper-secondary education reform in different jurisdictions. The case studies are designed to give the reader an understanding of the trends in upper secondary curriculum reform and, in particular, the recent moves that certain jurisdictions have made towards a broader and more balanced curriculum.

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Chapter 1. Introduction

The history of Ireland is closely entwined with that of Britain, and it might be assumed that on both islands education evolved along parallel if not identical lines. However, this is not the case. Although Ireland, meaning the present Republic of Ireland, assumed autonomy as the Irish Free State in 1922 and full independence in 1937, Britain and Ireland continue to share a commensal if not symbiotic relationship in matters of education.

There is a staff-room addage which claims "wait 20 years and the new thing in Britain will be in Ireland". Whether meant unkindly or not, there appears to be some truth in it and specifically the structure and methodology in primary education, the use of Anglo-centric textbooks, the role of continuous assessment in schools, and the small-scale implementation of British educational projects belie a dependence that few natives here would admit. Of course, wait 20 years, and if the thing proves to be a mess, one might have a lucky escape.

In this overview, I will attempt to align the development of the education system of the Republic of Ireland with the UK, noting specific peculiarities. I will focus on mainstream science education rather than include vocational education in the technological subjects. I will present the Irish education system as a balance point between societal pressures, with the government emerging as a proactive force or reactive force of change and development as opposed to the care-taker role it tended to adopt in former times. Government policy in education exists because the civil service, parents and teachers insist on it, and some might suggest in spite of it. Ireland achieves a relatively high quality output for its captial investment, but such a mismatch can only be a stop-gap rather than long-term policy. I highlight the issue of so-called free education at second and third level, and that issue, combined with curricular reform, needs to be assessed on the back of the basic question posed to society in general: "what do you want from the compulsory education system?"

Chapter 2. Brief Outline of Science Education in Ireland

An in-depth historical account is not provided here as it is beyond the scope of this work, however both detailed accounts and general surveys do exist: Balfour (1903); Kerr (1950); McElligot (1966); Kelham (1968), McElligot (1981) and Quane (2003).

2.1 Primary science education in Ireland

Schooling has always been conducted in two phases on these islands: (i) primary, and (ii) secondary (i.e. 'post-primary' in Ireland). Prior to the establishment of the national school system in Ireland by the Liberal government in Westminster in 1831, primary education had been provided solely by church-related agencies, i.e. Roman Catholic teaching orders or Anglican bodies with or without some government aid. Later, as part of this innovation, a system of model schools, mechanics schools and science schools was set up providing initial teacher training, vocational (for school teachers and apprentices) education and in-service teacher training respectively. Those deemed exceptional in their training in the model school could then complete two years apprentice teaching before proceeding to a central model school in the capital (Ó Buachalla, 1988 pp. 23-24), science education was a central aspect of this training. The introduction and execution of the 1831 Act was controversial and, in the end, did not achieve the goals intended due to religious and political differences.

In 1897, a vice-regal commission was set up, with the Earl of Belmore as chairman, "*to enquire and report with a view to determining how far and in what form manual and practical instruction should be included in the educational system of primary schools under the Board of National Education in Ireland*". Members of the commission visited Britain, Germany, Holland, Denmark and Switzerland to study the practical work being done in the schools in those countries. Their report, published in 1898, shaped the pattern of education in Ireland for the next quarter of a century. The influence of Henry Edward Armstrong and his "Heuristic Method" was to become evident through the work of William Mayowe Heller, appointed to effect the proposals of the Belmore Commission in Ireland. A new primary programme was implemented in 1900. It had proposed that agriculture, since it did not properly belong to primary education, should be replaced by a course of elementary science for rural schools, especially as the experts who appeared before the commission described it as "quite valueless". The theory of

agriculture that had been taught in schools since 1873 was replaced in 1907 by a scheme of nature study which, in turn, made way for Rural Science and Horticulutre in 1912. This was followed by changes in the teacher education colleges to train teachers in these new subjects.

2.1.1 Political autonomy

The most radical change came with a complete overhaul of education with the Education Act of 1924 following independence. In 1922, the Minister for Education of *Saorstat Eireann* replaced the Boards of Commissioners for National Education, Intermediate Education and Endowed Schools. In 1924, the present Department of Education was set up and a new programme for schools, based on the recommendations of the *Dail* Commission on Education, was put in place. *Gaeilge* was made compulsory in schools at primary and post-primary; however, in order to make room for it in the school day, elementary science was made optional. This had the obvious effect of allowing teachers to opt out of teaching a subject they felt ill-prepared to teach. The 1971 primary curriculum attempted to reinstate science as a mainstream subject but little training or funding was provided to schools or teachers so only a few dedicated teachers taught the curriculum as written. The vast majority of teachers in primary school taught environmental studies or nature study however. The 1971 curriculum was revised in 1999 and implemented officially in 2003.

2.1.2 Age of transfer

Because the age of beginning schooling and transfer to secondary schooling is not aligned to Britain, the term 'elementary education' might refer to upper primary or lower secondary in Ireland or compulsory education until 16 years old. Children in Ireland begin school at 4 years old, practically this means that they must have turned four by June of the year they wish to enrol. However, the upper limit is their 6th birthday, so it is possible to have a cohort in any school year with an age range of more than 12 months. Transfer is at 12 or 13 years old, by which time British children have been well settled in to secondary school. The effect of this difference in starting on science attainment awaits research. Such research would have to factor in the type of assessment that takes place prior to transfer and this is particularly important in NI where the eleven-plus / transfer test has been replaced by an alternative. Similarly, some countries do require children to sit a primary school certificate of some sort at 12 years old (e.g., Japan, Singapore) or

a consultative process examining the child's abilities (e.g. Germany). However, Ireland abolished the primary certificate in education.

Although most schools are in the free (state) education scheme and operate an open enrolment policy within catchment areas, entrance exams are held either in feeder primary schools or on arrival in secondary school. Before 1967, the Primary Certificate in Education might have served the same function. These are usually sat in English, Gaeilge and Mathematics and the results permit the school to place students in sets for these three compulsory subjects[1], but the students have classes in their base class-group based on alphabetical surname listing. Subjects such as science are not compulsory, however more than 90% of school children take Junior Certificate Science.

2.2 Secondary science education in Ireland

Irish secondary education has been described as "*a record of poverty, of abused endowments and of numerous inquiries preceding tardy reform*". By the 1870s, the British government may have been conditioned "*towards a policy of minimal involvement as regards secondary education*" (Ó Buachalla, 1988) following the difficulties arising from introduction - and throughout the development - of the national school system due to the continuing religious and political controversies. The Kildare (1869) Commission recommended the inclusion of scientific subjects, an idea earlier presented in the Clarendon (1861) and Taunton (1864) commissions in Britain. Instead, a Department of Agriculture and Technical Instruction was established in 1899 (Mac Cartáin, XXX) under the Technical Instruction Act of the same year, which served as a base from which funding for vocational subject grants might be obtained.

The Department of Science and Art (SAD) in South Kensington was founded in 1859, where a system for promoting science teaching was devised by J. Donnelly and Henry Cole. Examinations in practical science were sat in London (with a centre opening in Dublin in 1863; however, Kelham (1968) describes how, since 1836, provincial towns and cities were visited by state-subsidised science lecturers, some incorporating terminal examinations. Kelham (1968) points out that in Ireland, most of the science

[1] Contrast with the UK, where English, science and mathematics are the compulsory or 'core' subjects. This reflects the problem science has had in Ireland as being promoted to the expense of the Irish language.

instruction for these examinations was carried out in the national and district model schools in a part-time mode of delivery (SAD, 1867).

2.2.1 Intermediate Education Act

In 1878, the Intermediate Education Act established a board of commissioners of intermediate education for Ireland, which detailed rules, examinations and awards for seven subjects at three grades. It established a system of public examinations on the basis of which prizes, exhibitions and certificates would be awarded to students; it would also make payments of fees to school managers relative to the examination results of their students who had complied with certain rules; this remained the case until 1924. Besides this system, students could also enter the examination under the Science and Art Department (Kensington, London); however these were considered much easier than the Intermediate examination (McCrea, 1989 p23).

Ó Buachalla (1988) comments that the scheme of secondary education introduced under the Intermediate Education Act of 1878 "*did little to improve the quality or extend the geographical provision of secondary education in Ireland*". In effect, so long as the school complied with the examination rules, they could operate as they wished. Examinations and results became the central concern of all, both teachers and students and their parents, a situation that exists in part to this day with teaching to the exam and choosing subjects at leaving certificate in order to maximise the matriculation points acquired. Schools selected students for presentation to examination and since there was no provision in the Act regarding school accreditation or teacher qualifications there was a rapid rise in the number of small academies.

2.2.2 The Butler Act

Whereas in the UK, there was a move to improve uptake in secondary education and to widen its provision to include girls and the working classes in the 1940s, culminating in the Education 'Butler' Act of 1944, Ireland waited until the 1960s to attempt the same, at which point some divergence between Ireland and the UK becomes apparent.[2] It is a

[2] The Butler Act sharply distinguished between primary and secondary education at age 11 and ended the traditional all-age (5-14) elementary sector, enforcing the division between primary (5–11 years old) and secondary (11–15 years old) education that many local authorities had already introduced. It abolished fees on parents for state secondary schools (Bateson, 1999; Jeffereys, 1984). Irish primary schools continued and continue to retain the elementary age-range with a slight change (4/5 - 12/13). In Ireland, primary

matter of speculation to consider how the Butler Act affected policy direction in Ireland. One unforeseen effect was the divergence of the Northern Ireland and the Republic of Ireland education systems, another would be the eventual loss of a textbook market in the UK to Irish secondary schools.

In the 1960s**,** the Intermediate Certificate examinations became open to all schools in the secondary education sector under the optimistically named 'Free Education Scheme' whereby second-level fees were abolished. As a result of this new move, new courses and syllabi were issued during 1965/66 school year to become effective in September 1967 to be in place for the free education scheme's first examination in 1968. The separate science subjects were dropped in favour of a common science course. In time, this new Intermediate Certificate course in science became viewed as difficult, exclusive and did not provide all students with the general education it had hoped to achieve. The children of these first 'free' education secondary level students would later be those who would sit the new Junior Certificate exam from 1995.

2.3 Participation rates in secondary education in Ireland

It should be pointed out that participation in secondary education had been increasing due to the improved financial environment in Ireland in the early 1960s (Figure 1.), but following the introduction of the free education scheme, the recession of the 1970s eroded the impact of the scheme whereby 'voluntary contributions' by parents were required to finance schools, thus we see a levelling off of participation rates throughout the 1970s.

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schools are still termed 'National Schools' and secondary education is still referred to as 'Post-primary' emphasising the feature of primary education as not merely the first part of education but the most significant. Until its abolition in 1967, the Primary Certificate in Education was the main, and for many, only terminal examination sat by all children. Secondary schools also issued scholarship examinations, a small number of fee-paying schools continue to do so in specialist areas (e.g., St. Finian's College, Mullingar in Music) and grants are available from religious minority charities or through trustees e.g. Protestant Orphan's Society, Sons/Daughters of the Clergy.

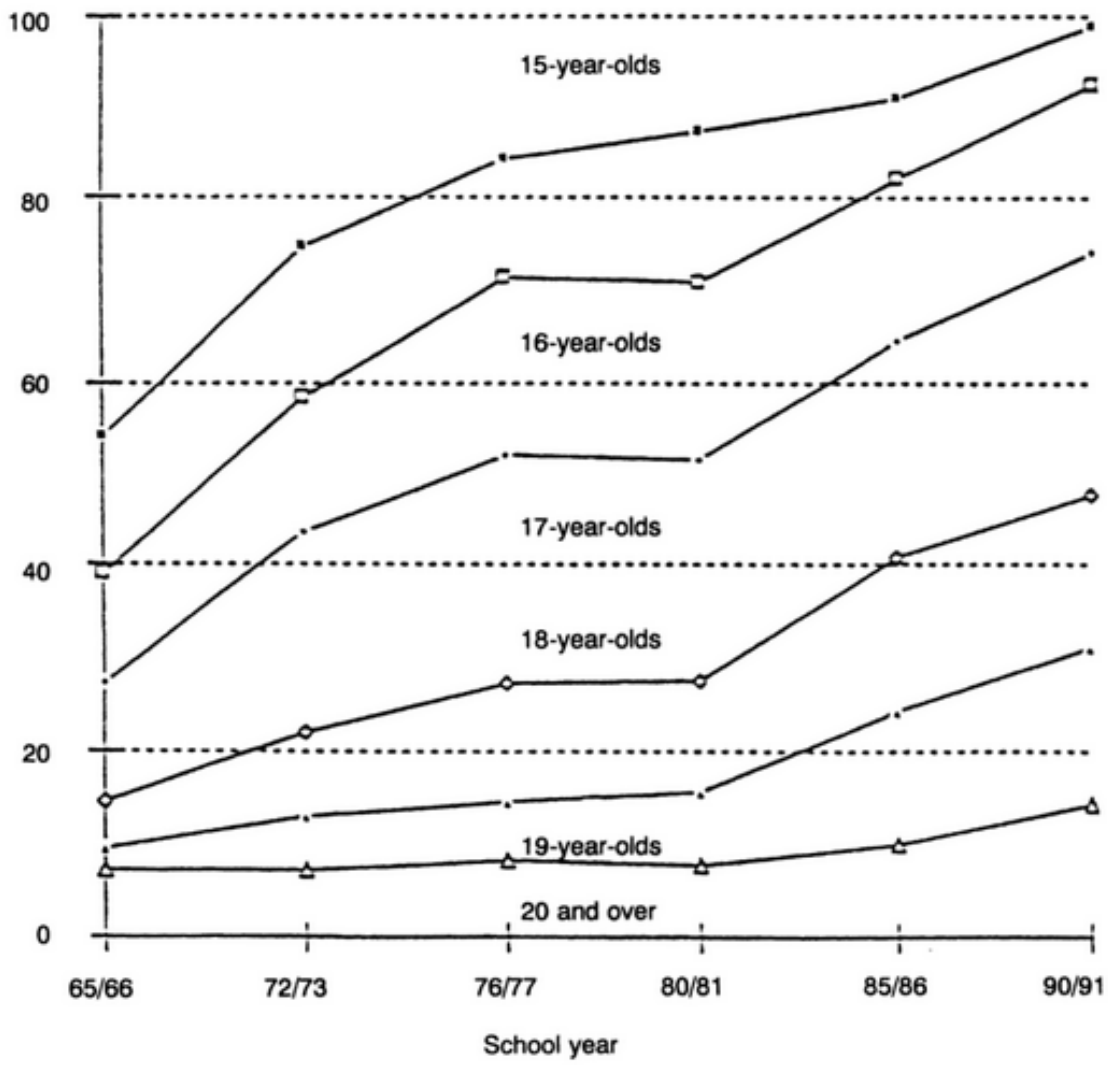


Figure 1. Estimated rates of participation in full-time education for various age groups, 1965-1990 (Taken from Coolahan, 1995)

If, on the one hand, a contributary causal link is made between the 1944 UK Act and the 1967 Free Education Scheme in Ireland and the subsequent primary curriculum reform in Ireland[3], then a link between the 1988 UK Education Reform Act and the repeal of the Intermediate Education Act in Ireland and the roll-out of the junior-certificate programme might also be suggested. A revised junior post-primary programme was redesigned in

[3] The revised primary curriculum of 1971 reintroduced physical science as an option for 5th and 6th class. This has been researched by the author and it appears that the objectives leaned heavily on the Nuffiled Primary Project. Teacher training institutions amended their courses accordingly, but teacher uptake was minimal and little instruction in the physical science in primary schools actually took place. Thus, when children began secondary school, science was studied *ex novo*.

the early 1990s. In 1992, the Junior Certificate examination was first examined and the science course preceding it, which still exists, was a common science course greatly simplified in content with the intention of improving skills and emphasising one form of the scientific method. Many teachers did not make the transition from the heavily content-driven intermediate certificate course to the process-driven junior certificate course well. Furthermore, many teachers have taught the junior certificate course more as the intermediate course was taught to them. An attempt to rectify the reliance on rote learning, prescriptive and expositional approaches was made by including an assessed practical component. In 2005, the revised junior certificate course was first examined. It is not clear how successful this revised course has been as it has not been formally reviewed in its totality outside of annual inspectorate reports. Meanwhile, perceptions in the media of a content-laden course with intense terminal exams favouring rote-learning have led to calls for reform.

The PISA teachers' questionnaire examines teachers' view on the revised junior certicate syllabus and from that linkages between the PISA science framework and science teaching in Irish schools can be determined (Eivers, Shiel and Cheevers, 2006). Eivers, Shiel and Cheevers (2006) found that the revised junior certificate syllabus represents a closer alignment with the concept of scientific literacy as defined in the PISA framework. However, Earth & Space systems - a major category of science knowledge represented in the PISA 2006 framework - is considerably reduced in the revised syllabus whereas it was a popular option in the optional modules pre-2003. 'Earth science' is absent from the primary science curriculum. Irish students, however, do relatively well in this section in PISA because of the coverage in primary and junior certificate geography.

Chapter 3. The current situation

3.1 The curriculum as it is implemented by school type

Although in the past there was a strong difference between types of schools, this has diminshed of late and in particular since the economic crash following the 2008 financial crisis. Formerly, the endowed schools sometimes termed 'grammar schools' or schools run by the religious orders operated a loose selection process. Protestant schools (mainly Anglican, then Presbyterian, Methodist and Quaker) operate as individual instutions with loose association; however, many of these too have entered the 'free education' scheme. The catholic religious orders have been replaced by 'education trusts' and the orders themselves take a downgraded role in the running of the schools with lay principals and chaplains. There is a great deal of emphasis put on the 'ethos' of a school, which is dependent on the patron of the school. Table 1. lists the diversity of school patronage in Ireland.

Table 1. School type, patronage and by whom funded.

School Type	Patron	Funding
Community College or Vocational Schools (*Meanscoil*)	formerly VEC, now ETB	Free Education Scheme with 93% government funding.
Voluntary Schools with a variety of titles such as: "College", "Grammar School", "Cathedral School"	Catholic or Protestant churches' representatives e.g., bishop	Free Education Scheme with reduced funding 90% of salaries and 95% of other costs. Difference in funding met by fees and 'voluntary' contributions.
Community School (*Pobalscoil*)	Local community representation	Free Education Scheme and 'voluntary' contributions.
Gaelcholáiste	*An Foras Pátrúnachta*	Free Education Scheme and 'voluntary' contributions.
Educate Together	Educate Together patron with school community representation	Free Education Scheme and 'voluntary' contributions.
Comprehensive School	Local community representation	Free Education Scheme and 'voluntary' contributions.
Grind School	Fully private full-time offering leaving certificate tuition	Fee-paying
Private School	Catholic or Protestant churches' representatives e.g., bishop	Fee-paying

I have neglected to differentiate schools which specialise in the vocational subjects since these have been incorporated into general schools. Each county had a Vocational Education Committee (VEC) and second level schools were known as the 'Tech'. Such schools typically accepted children from working class backgrounds with a view of an education leading to apprenticeships. In 2014, the VECs were replaced by Education Trust Boards (ETBs) and operate like the community / comprehensive schools, offering both academic and vocational education.

In Table 2. the current structure of the Irish education system and how it maps to that in Northern Ireland (NI) is outlined and its fit to the European Qualifications Framework (EQF) is mapped in Table 3.

Table 2. Comparison of the cohorts in the Republic of Ireland and Northern Ireland

Child's Age	RI	NI	Examination in RI
11 - 12+	Sixth Class (Primary)	Year 8	No formal examination
12 - 13	First Year	Year 9	No formal examination
13 - 14	Second Year	Year 10	No formal examination
14 - 15	Third Year	Year 11	Junior Certificate Exam
16 - 17	Transition Year[4] or Fifth Year[5]	Year 12	No formal examination
17 - 18	Fifth Year or Sixth Year	Year 13	1. Leaving Certificate
			2. Leaving Certificate Applied
			3. Leaving Certificate Vocational
18 - 19	Sixth Year	Year 14	1. Leaving Certificate
			2. Leaving Certificate Applied
			3. Leaving Certificate Vocational

[4] It is a peculiarity of the Irish education system that an elective year separates the junior and senior end of schooling. It is somewhat confusing as it labelled 'Transition Year' when 'transition' also refers to the transfer between primary and secondary school.

[5] Secondary education is thus for all at least five years, or six if transition year is completed.

Table 3. The fit of the EQF to mainstream schooling examination

European Qualifications Framework (EQF)	Mainstream Schooling Examination
Level 1	
Level 2	Junior Certificate
Level 3	Leaving Certificate
Level 4	Leaving Certificate

3.2 Matriculation & Retention

Earlier, I mentioned the increasing participation in secondary education. The same picture, though lagging, is also true for participation at third level. It is an expectation that educated teenagers go to university or "college" regardless of specific vocational directions they might otherwise entertain. As with the secondary school system, there are no fees in third level institutions, however there is a significant annual registration fee (currently up to 3,000 Euros) which some families find prohibitive, but which are partly off-set by the third level bursaries scheme for students from poor backgrounds and for Irish Travellers. Getting to college might be a societal expectation, but completion of the degree course is another. Overall, drop-out rates in Ireland have remained relatively steady - and relatively high - in recent years, despite the rapid expansion of the higher education system.

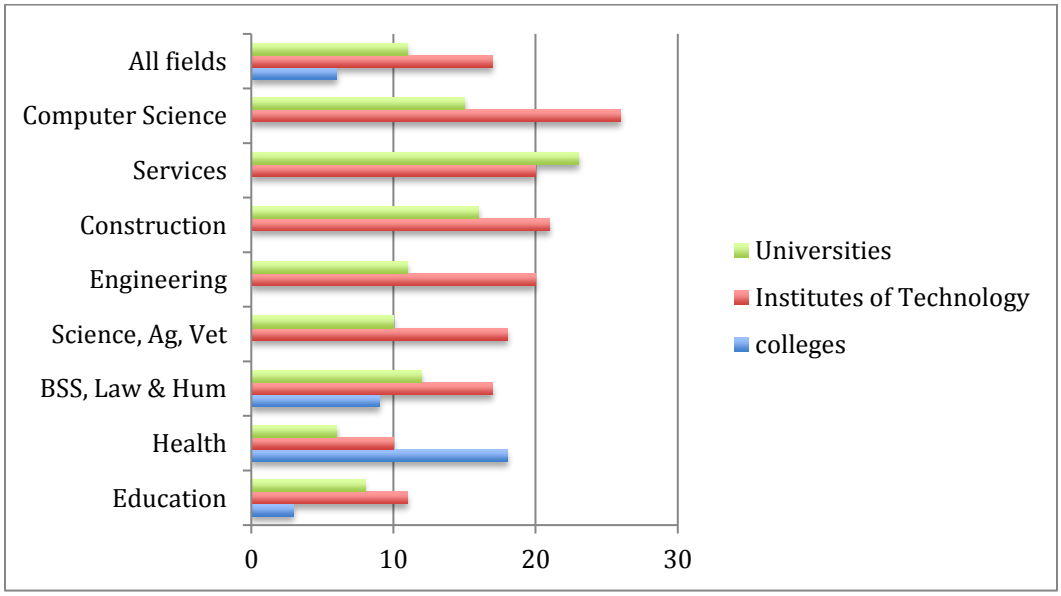


Figure 2. Percent of cohort drop-out rates

Drop-out rates are usually attributed to, among other things, socio-economic background, choosing the wrong course, financial difficulties and health or medical issues.

Nevertheless, Ireland has one of highest proportions of young people in Europe going into higher education, with almost 60% of all school-leavers attending universities or institutes of technology. In England & Wales, this figure is 48%[6]. However, in stark contrast, there has been a dramatic fall in those doing apprenticeships or training. Concern has been expressed that some students who are totally unsuited to higher education are being shoe-horned into universities by their parents due to persistent belief that university education guarantees employment. In the 1960s, completion of secondary education was considered and encouraged in order to retain students in schools and Government policy was framed according to the perceived relationship between length of time in education and prospects of employment. However, it has always been the case that Ireland educated youth have enjoyed better prospects abroad than at home. The Central Applications Office (CAO) determines the total points based on the six best leaving certificate grades that a candidate requires for entry to third level.

[6] UK Statistics Office: https://www.gov.uk/government/statistics/participation-rates-in-higher-education-2006-to-2015

Table 4. Equivalence of leaving certificate grades, CAO points and UCAS tariff points

LC Higher Grade (up to 2016)	CAO Points	UCAS Tariff Points	LC Higher Grade (post 2016)	CAO Points	UCAS Tariff Points
A1	100	90			
A2	90	77			
B1	85	71			
B2	80	64			
B3	75	58			
C1	70	52			
C2	65	45			
C3	60	39	A1	60	39
D1	55	33			
D2	50	26	A2	50	26
D3	45	20	B1	45	20
			B2	40	14
			B3	35	7

3.2.1 Bonuses

From 2017, a new system (Figure 4.) readjusting the CAO points downwards had some notable effects, including a record 36% sitting the higher level mathematics partly owing to the 25 extra bonus points available to those sitting higher maths. The maths bonus had been initially framed as a response to the low numbers taking higher level mathematics. Concerns had also been expressed on the predictability of exam questions, particularly in areas which had not experienced syllabus reform within a thirty year time span; and whether students were simply predicting questions learned by rote pre-prepared responses, choosing not to study certain areas; e.g. ecology and genetics in biology[7].

[7] Anecdote: a newly qualified teacher of biology on appointment was presented with a chart of all questions in leaving certificate biology (1967 - 1993) and was encouraged to prepare the students in a suggested number of areas. This approach would be encouraged by the main subject body: the Irish Science Teachers' Association (ISTA) which continues to hold 'exam meetings' in all science subject areas.

In addition, if the leaving certificate is sat through the medium of Irish - regardless of whether the student is a native speaker or living in the *Gaeltacht* or not - 10% extra points are awarded for selected subjects excepting Irish and Maths, and 5% for language and a further selection of subjects.

Increasing numbers of Irish students are applying to UK HEIs, particularly in Northern Ireland. While the numbers of students presenting the Irish Leaving Certificate may be small in comparison with GCE A Level, it is nevertheless important, in the interests of widening participation in both countries, that the Irish qualification is understood and accepted for entry to HE in the UK. The admission of the Irish Leaving Certificate to the Tariff is designed to support this aim. Table 4. converts Irish Leaving Certificate (ILC) grades to UCAS points. It sets out the recommended allocation of UCAS Tariff points to the ILC Higher and Ordinary Level grades.

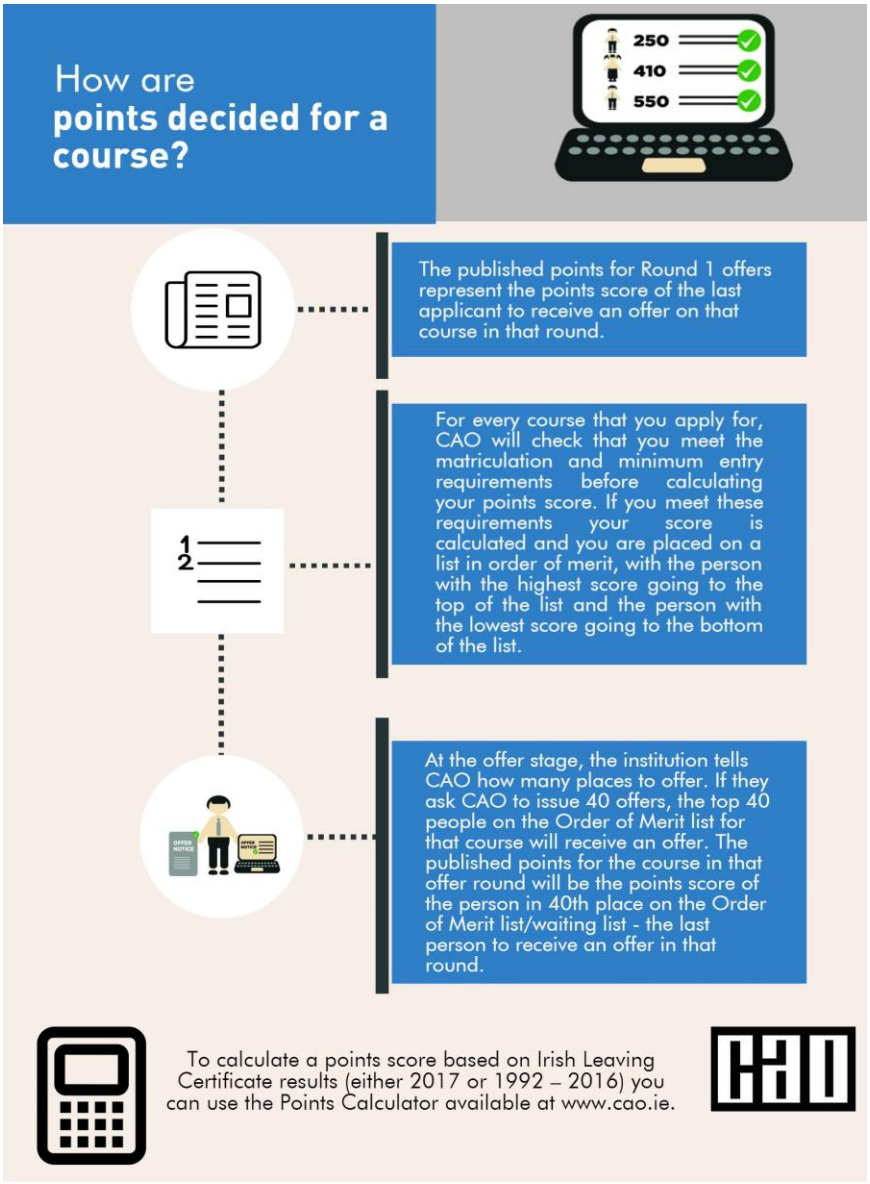


Figure 3. CAO graphic on how points are calculated for course entry (taken from CAO, 2017).

Higher Level Grade	Points	Ordinary Level Grade	Points
H1	100		
H2	88		
H3	77		
H4	66		
H5	56	O1	56
H6	46	O2	46
H7	37	O3	37
H8	0	O4	28
		O5	20
		O6	12
		O7	0
		O8	0

Table 4. CAO graphic on new 2017 grades to points chart

3.3 Syllabus Revision

During the period 1967 to the 1990s, there was very little syllabus revision so that in Biology, for example, the same textbook and content had been examined in 1995 as in 1967. However, once syllabi were recognised as unfit for purpose for the modern era, an on-going revision of syllabi has been happening, so much, it has been claimed, as to cause 'revision fatigue' among the teaching population. Currently, Ireland is in a phase of revision with the ILC course in Biology revised for examination in 2004, Physics-Chemistry in 2002, and Physics in 2004. In all of the new syllabus revisions, Science, Technology and Society (STS) "*plays an integral part of the syllabus so that students can be aware of the principles of the applications of* [science] *in the everyday world*". However, it has been suggested that teachers who have had no education in the philosophy of science are poorly prepared to teach such an aspect.

3.4 Time allocation

Physics has 180 hours of instruction, including practical work. In biology, the time allocation is also 180 hours of class contact time (the equivalent of 270 class periods of

40 minutes or five class periods per week). Many schools only provide four or, in the worse cases, three periods per week. Teachers are expected to split the science courses in terms of time allocation into pure science, science applications and science for citizenship (Figure 5).

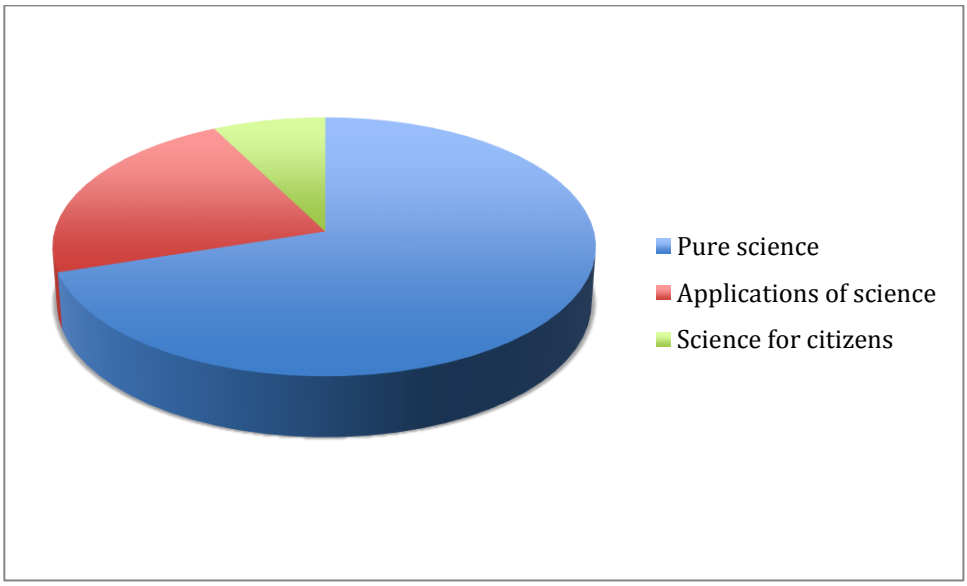


Figure 5. Time allocation for the three main elements of science at leaving certificate

3.5 Guidelines / Specifications

Rather than provide an in-depth analysis of the syllabi in chemistry, physics and biology, I will endeavour to provide a series of snapshots to highlight specific issues of concern.

In terms of a snapshot in physics, there was some attempt to modernise the Physics syllabus with the inclusion of particle physics, according to the Zweig (1964a, 1964b) model (Figure 6.). However, as this is an advancing field of research, the material presented in the teachers' guidelines of 2004 were most likely in need of updating before the course was implemented.

TABLE 2. BETTER-KNOWN MEMBERS OF THE PARTICLE ZOO

Class	Name	Symbol	Mass (*mass of electron = 1*)	Mean life	Year of discovery
	Neutrino	ν	$< 10^{-3}$	stable	1956 (predicted 1931)
LEPTONS	Electron	e	1	stable	1897
	Heavy Electrons — muon	$\mu^- \mu^+$	207	2×10^{-6} s	1937
	Heavy Electrons — tau	$\tau^- \tau^+$	3500	10^{-12} s	1975
	Pi meson	$\pi^+ \pi^-$	273	2.6×10^{-8} s	1947
MESONS		π°	264	8.4×10^{-17} s	
	K meson	$K^+ K^- K^\circ$	$\approx$.970		1947
	Proton	p	1 836	$> 10^{32}$ yrs	1897
	Neutron	n	1 839	960 s	1932
BARYONS *Hyperons* — Lambda		Λ°	2 183	2.6×10^{-10} s	1947
Sigma		$\Sigma^+ \Sigma^- \Sigma^\circ$	2 327	approx. 10^{-10} s	1953
Chi		$\Xi^+ \Xi^- \Xi^\circ$	2 573	approx. 10^{-10} s	1954
Omega		Ω^-	3 272	approx. 10^{-10} s	1964

Figure 6. Example of content from Physics guidelines for teachers

In terms of a snapshot in biology, there has been some attempt to move away from textbooks and to resolve specific issues with the biology syllabus, namely:

- *the need to give a greater vocational orientation to the curriculum*
- *the needs, not only of students who proceed to higher education but also of those who enter the workforce directly on completion of the Leaving Certificate*
- *the particular needs of those students who present at Ordinary level*
- *the perception that the previous Biology course was too long and too broad*
- *the necessity to modernise Biology, e.g. the inclusion of contemporary biological issues and technology and the highlighting of its scientific nature*
- *the need to reduce the overlap in content between the Biology and the Agricultural Science syllabi.*

(NCCA :2002 2)

Additionally, in the biology guidelines, it is specifically stated that: "*one of the primary objectives in the production of these detailed guidelines is to allow the teaching of the course to be syllabus led rather than textbook led*" (NCCA, 2002: 3), a feature mentioned elsewhere in this report, thus reflecting a known difficulty in the teaching of science in schools.

1.3.4 BIOMOLECULAR SOURCES AND THE COMPONENTS OF FOOD

DEPTH OF TREATMENT

Carbohydrates

Carbohydrates contain the elements carbon, hydrogen and oxygen. The smallest unit of a carbohydrate is called a monosaccharide.

Two monosaccharides can join together to form a disaccharide. Many saccharides can join together to form a polysaccharide e.g. starch. Test for and list the sources of carbohydrates.

Fats and oils (lipids)

Fats contain the elements carbon, hydrogen and oxygen but in a different ratio to carbohydrates. Fats are solids at room temperature.

The basic unit of fat is called a triglyceride.

A triglyceride is made of three molecules of fatty acids joined to one molecule of glycerol.

Oils have the same basic structure as fats but contain different types of fatty acids and remain in a liquid state at room temperature.

Phospholipids are fat-like substances where one of the fatty acid groups in the triglyceride is replaced with a phosphate group.

Test for and list sources of lipids.

Proteins

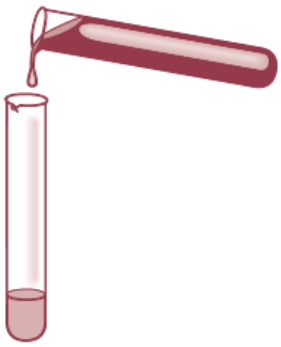
Proteins contain the elements carbon, hydrogen, oxygen and nitrogen. In addition they may also contain sulphur, sometimes phosphorus or other elements.

The smallest unit of a protein is called an amino acid. There are twenty common and several rare amino acids found in proteins. Many more amino acids are known to occur free in different cells and tissues but not in proteins.

Test for and list sources of proteins.

Vitamins

Vitamins differ chemically from each other and are required in only small quantities. They may be referred to by letters or by names based on their chemical structure. Refer to water-soluble and fat-soluble, with one example of each.



ACTIVITIES	SUGGESTED RESOURCES
Food Tests	Variety of food samples Recording chart Test tubes Heat source Dropping pipettes Spatula
*Teacher demonstrates positive test for food biomolecules. Students then test a variety of foods for the presence/absence of food biomolecules. The use of a control should be stressed in each test for the following:	
Carbohydrates	Glucose, Benedicts or Fehlings solutions Starch suspension (starch, NaCl, water), iodine solution
Monosaccharide (reducing sugar) glucose, Benedicts or Fehlings tests	Fat source, Sudan III or brown paper and heat source
Polysaccharide iodine test	10% Sodium hydroxide or Potassium hydroxide solution 1% Copper sulphate solution
Fats brown paper test or Sudan III test (caution, toxic)	Protein source e.g. egg albumen suspension.
Proteins biuret test	Dichlorophenol indophenol solution (DCPIP)
*Vitamin C DCPIP test	Vitamin C source e.g. lemon or orange juice.

Figure 7. Complete leaving certificate specification for biomolecules and components of food (NCCA, 2002: 12).

Figure 7 and 8 provide a snapshot of the difference in depth between leaving certificate and A level biology. In A level biology, all biological molecule classes are covered including DNA/RNA and minerals as it applies to the structure and composition of living things. In the biology leaving certificate, by contrast, only the biomolecules as they relate to nutrition are dealt with at this point, with DNA/RNA mentioned later but again only with a brief coverage. It would seem, that this difference reflects the original

purpose of each exam system - leaving certificate as a general end point of education giving broad outcomes for school leavers; and A level as a means to enter university along the lines of the A levels completed. A leaving certificate student might study one science subject but pursue a university course in general arts or a humanity subject. To conclude therefore, leaving certificate science subjects are comparable in terms of breadth, i.e. the range of topics covered; but not comparable in terms of depth, i.e., the detail of the topics covered.

3.1 Biological molecules

All life on Earth shares a common chemistry. This provides indirect evidence for evolution.

Despite their great variety, the cells of all living organisms contain only a few groups of carbon-based compounds that interact in similar ways.

Carbohydrates are commonly used by cells as respiratory substrates. They also form structural components in plasma membranes and cell walls.

Lipids have many uses, including the bilayer of plasma membranes, certain hormones and as respiratory substrates.

Proteins form many cell structures. They are also important as enzymes, chemical messengers and components of the blood.

Nucleic acids carry the genetic code for the production of proteins. The genetic code is common to viruses and to all living organisms, providing evidence for evolution.

The most common component of cells is water; hence our search for life elsewhere in the universe involves a search for liquid water.

3.1.1 Monomers and polymers

Content	Opportunities for skills development
The variety of life, both past and present, is extensive, but the biochemical basis of life is similar for all living things.	
Monomers are the smaller units from which larger molecules are made.	
Polymers are molecules made from a large number of monomers joined together.	
Monosaccharides, amino acids and nucleotides are examples of monomers.	
A condensation reaction joins two molecules together with the formation of a chemical bond and involves the elimination of a molecule of water.	
A hydrolysis reaction breaks a chemical bond between two molecules and involves the use of a water molecule.	

Figure 8. Introductory specification for biological molecules in AQA AS/A biology (2017).

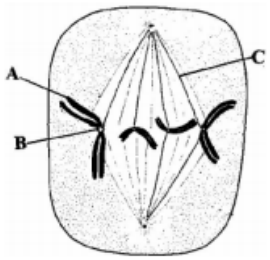
3.6 Policy shift: content to skills

One of the most significant trends in science education in Ireland has been the shift from content (the learning-off of large quantities of factual knowledge) to skills (the application of smaller quantities of knowledge, including relating to the everyday world) in terms of policy. Such policies have not been met with universal approval. In practical terms, this has meant a reduction in depth and breadth of the material to be studied for a leaving certificate examination. Demands for courses to be less rote-oriented and more 'practical', by which is meant 'useful', have seen syllabus reviews reduce the number of topics or the depth at which the topics are treated. This can be perilous, since leaving certificate biology, for example, is not as deep and broad in content as A level biology in the UK. If we examine any topic, e.g., Kreb's Cycle, in leaving certificate biology, it is treated somewhat circumspectively, and a general and singular figure of the number of molecules of ATP is provided. In A level biology, Kreb's Cycle - depending on the option - can involve understanding and applying knowledge of carboxylic acids and the numerous chemical reactions yielding varying amounts of ATP and that the system is dynamic rather than a fixed cycle of set steps.

One way to examine differences in depth and breadth is to look at the questions posed in exams since syllabi do not explore the depth of treatment very often. Figures 8 to 12 compare two sub-topics in biology between higher level leaving certificate and the AQA specification for AS/A level. The sub-topics are cell division and cellular structure. The leaving certificate question tends to seek recall of factual knowledge and the AS/A level question tends to seek descriptive responses with some degree of application. A similar picture is observed in chemistry and physics.

Q3 2007

3. Study the diagram of a stage of mitosis in a diploid cell and then answer the questions below.



(a) Name A, B and C.

A .....B .....C .....

(b) What stage of mitosis is shown? ....

Give a reason for your answer. .....

(c) What is the diploid number of this nucleus which is undergoing mitosis? .....

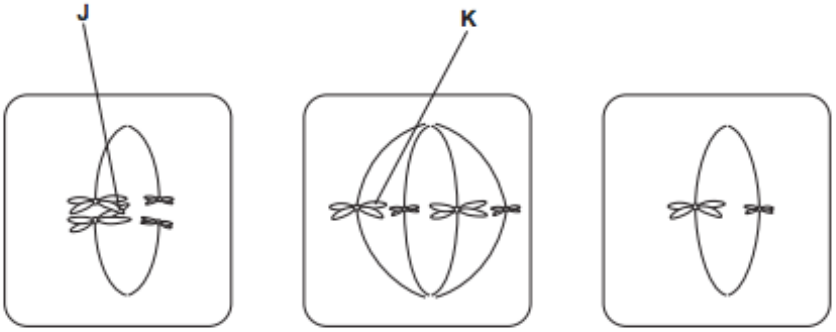
(d) Give a role of structure A. .....

(e) Some cells in the human body undergo meiosis. Give one function of meiosis .....

Figure 9. Higher level leaving certificate question on cell division

5 **Figure 4** shows three cells, **B**, **C** and **D**, from tissues in the same organism. Each cell is in a stage of either mitosis or meiosis.

Figure 4



5 (a) Complete **Table 3** with a tick if the cell shows the feature.

[2 marks]

Table 3

	Cell B	Cell C	Cell D
homologous chromosomes are present			
a stage of mitosis			

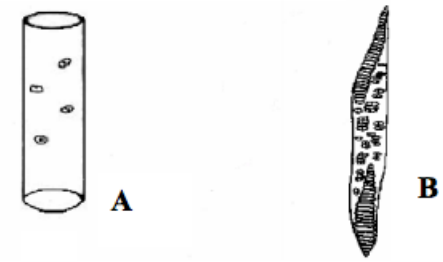
5 (b) Describe and explain the appearance of chromosome **K** in cell **C**.

[2 marks]

Figure 10. AQA AS-A level question on cell division

Q 6 2007

The diagrams represent two forms of a vascular plant tissue, as seen under the microscope.



(a) Name this vascular tissue

(b) Identify the two forms of this tissue.

A..... B .....

(c) The walls of A and B are reinforced with a hard material. Name this material .....

(d) Where precisely is this vascular tissue found in the stem of a young dicotyledonous plant?

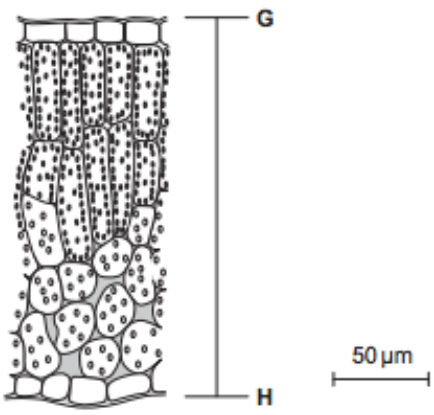
(e) Name another vascular tissue .....

Figure 11. Higher level leaving certificate question on cellular structure

outside th box

6 A scientist examined the structure of mustard plant leaves. He viewed temporary mounts of leaf tissues with an optical microscope. **Figure 6** shows a drawing of typical results.

Figure 6



6 (a) Describe how temporary mounts are made.

[2 marks]

1 6

Figure 12. AQA AS-A level part of a question on cellular structure (first part)

Chapter 4. Future directions

Whereas practical examinations have been a part of the UK A level system for many decades, practical exams in Ireland have been viewed with a certain ambivalence owing in part to the fact that no laboratory technical support is available to teachers except in fee-paying schools or through the community employee scheme. Teachers have resisted practical examinations using the issue as leverage to obtain practical support. In addition, the teachers' unions have also delineated a policy that teachers do not examine their students' own work. In the UK context, there is a clear distinction between the teacher invigilating and examining a practical examination. Many secondary schools, although admittedly not all, in the UK have multiple laboratory technicians, and some have one for each of the main science disciplines.

4.1 Practical Examinations in science

The National Council for Curriculum and Assessment (NCCA) has prepared new specifications for Leaving Certificate Biology, Chemistry and Physics. These specifications envisage that the Leaving Certificate examinations in these subjects will include an assessment of students' practical science skills by means of an externally assessed laboratory-based practical examination. Practical examinations would be a popular recourse with students and consistent with diversifying teaching, learning and assessing methods, but it is unclear what exactly might be assessed - an issue that is undergoing research in a number of institutions.

The proposal is that the practical examination will be of 90 minutes' duration and attract 30% of the overall marks for the examination. Candidates will be assessed in two ways. First, an external examiner directly observes the candidates performing the activities and marks them on this. Secondly, the work they generate during the examination is marked later by another examiner.

The Department of Education and Skills has asked the State Examinations Commission to carry out, in consultation with the NCCA, a trial of the proposed model of practical assessment. The purpose of the trial is to assess the feasibility of including this model of externally examined practical examination in the Leaving Certificate examinations in biology, chemistry and physics on the introduction of the new specifications.

4.2 General Science at Leaving Certificate level?

Prior to the economic crisis of 2008, there was a proposal to have a general science leaving ceritifcate subject, however this was shelved and, as we have seen, there has been some account of the idea that, for many students, the leaving certificate is their final terminal examination and this is, for some, an unhealthy, unduly stressful and traumatic experience. In a recent small-scale study comparing stress[8] levels in final year RI and NI students found high levels of stress (mean score of 28.73) and with RI students displaying slightly higher stress levels (mean score of 32.01) than NI students (mean score of 28.73). A larger-scale study in the 1980s (Cohen and Williamson, 1988) found the mean score to be 19.62, suggesting that stress levels may well have increased.

4.3 Compulsory science at all levels?

Science, according to the Rules (2004), is to be offered against a third language, other than Irish and English, or a subject of the Business Studies Group of subjects. However, science is not compulsory at any level. In contrast to many other European countries, science subjects are not made available to all students at upper secondary level in Ireland. The vast majority of schools provide biology for the Leaving Certificate but a significant minority of schools do not provide physics and chemistry.

Some schools might offer a science course in the Transition Year after the Junior Certificate, and many schools offer a taster model of short 6 week courses. According to the Clerkin (2013), 81% of all schools offer a transition-year programme – rising to 83% among non-designated disadvantaged schools – but among designated disadvantaged schools it is 76%. Even though a school runs a transition-year programme, it does not mean that all eligible students take it. There is a 54% uptake among students in all schools, compared with 44% of students in schools in disadvantaged areas. Schools in the Vocational Education Committee (VEC) - now Education Trust Boards (ETB) - sector, which have greater concentration of pupils suffering disadvantage, are least likely to offer the programme. If these figures are split by patronage, 57% of VEC schools ran transition year in 2010/11, compared with 91% of secondary schools and 88% of

[8] Using the Generalised Self-efficacy scale (GSES) by Schwarzer et al. (1992); the perceived stress scale (PSS) by Cohen et al. (1983), the Self-esteem scale (SES) by Rosenberg (1965), and the Coping scale (COPE) by Carver et al., (1989).

community and comprehensive schools. Transition year is an opportunity to mitigate lacunae in the scientific education of students where teachers felt such exist, e.g. enhancing work on ecology or genetics, which also serve to provide a foundation for the leaving certificate.

Smyth and Hannon (2007) hypothesised that the way in which schools structure the subject choice process at upper secondary level would also influence science take-up. They used three measures relating to subject provision in the school: i) whether Physics is provided, ii) whether the combined subject Physics-Chemistry is provided, and iii) whether any science subject has been dropped by the school in the previous 5 years. These measures yielded an insight into the alternative choices available to students. As well as measures relating to subject provision, measures of subject "packaging" were also used. Firstly, whether science subjects clashed in a subject set, that is, students were expected to choose between two or more science subjects, was expected to impact on their final choices. Secondly, the extent to which biology take-up was facilitated by the school, either by making it a compulsory subject or by offering it in a number of different subject sets, was taken into account. Finally, whether the guidance counsellor in the school had a science background was expected to influence the advice they gave to students on subject choice and hence actual patterns of subject take-up.

Smyth and Hannon (2007) found, in keeping with expectancy value theory (see Eccles, 1994) subject take-up is influenced by the extent to which the student *values* different subject options and the extent to which the student expects to achieve success in that subject. Thus, students are more likely to take science subjects if they find them interesting and useful and if they do well in science and are less likely to take the subjects if they find science difficult. However, Smyth and Hannon (2007) found that a focus on individual student attitudes is not sufficient to explain variation in take-up patterns since important differences are found between schools in the proportion of students taking science subjects at upper secondary level. Smyth and Hannon (2007) also found that science subject choice reflected a school's decision about whether to provide a subject or not, along with school organisation and process, at both lower and upper secondary levels.

4.4 Continuous Assessment (CA)

Although CA was enshrined within the UK Education Reform Act of 1988, CA did not enjoy an in-depth roll-out in Ireland. Some science courses in schools offering rural science transitioning to Junior Certificate Science employed teacher-assessed projects. In the mid-1990s, all schools could avail of this procedure, but few did. Practical lab notebooks where supposed to be compiled and made available for inspection for Leaving Certificate chemistry but marks were not awarded for this work. In the recent reforms in science, it was suggested that teachers would mark the lab notebooks at junior certificate level and in chemistry initially, with a distant prospect of the biology and physics. However, teachers, through the unions, refused to mark the lab notebooks. Instead, set designated practicals were to be completed, typically a set of 13 practicals in each of the science subjects, but concerns were raised from a number of quarters when lab notebooks were found to be identical within groups of students suggesting that the material recorded had been cribbed from some common source and that the students had not actually performed the practicals. Again, and as mentioned elsewhere, there is a move toward practical examinations, which the DES has suggested would be marked by class teachers. Again also, teachers have refused to do this. Practical examination tasks as they are currently framed appear to test procedural knowledge / ability more than the skill of inference or interpretation.

However, alternatives to the mainstream leaving certificate and the intense set of terminal examinations, invariably termed the 'rat-race' or 'trial by ordeal', do exist. The Leaving Certificate Applied, which carries additional modules presented in a CA format, is currently a model of the future. Where students are below the levels of attainment expected to complete the mainstream leaving certificate, the Leaving Certificate Applied (LCA) is an alternative. Modules in horticulture and technology are available for those who chose to do so. If the student continues to the mainstream leaving certificate, a third lower level of content is available in English, Irish and Maths, but no such provision is available in science. Furthermore, in schools that offer it, students may mitigate some of the intensity of the mainstream leaving certificate by engaging in a higher level of CA through link modules and reducing the burden of examinations; this programme is the Leaving Certificate Vocational (LCV).

4.5 Textbooks

Text-books have always been purchased by families and, in order to be used by siblings, parents are loathe to see changes in the suggested texts (Cooney/Carey, 1993). Socio-economic status has an effect on educational attainment where textbooks is the single biggest outlay for families. Book Rental Schemes[9] are used to mitigate the burden on families. In theory, teachers decide what texts to use. In practice they are subject to a variety of parental, school and marketing pressures which are all designed to influence them in different directions, rather than quality of conversion from syllabus to classroom or a particularly teaching methodology. It was estimated that "*if the Irish Department of Education were to spend the equivalent figure as their UK counterparts on new school books, the figures would be IR£5.3m at primary level and IR£5.6 at post-primary level*" (Cooney/Carey, 1993)

4.6 Realingment of values to further, vocational and higher education

Based on what we have seen, there is a need to re-evaluate vocational education and release the burden on further and higher education. Vocational education has suffered from lack of investment but also political will and support. Policymakers tend view education through the lens of their personal history, which is often fairly privileged. This provides a false overview which downplays the value of vocational education. I would hope that a reassessment of vocational education would alleviate drop-out rates at third level and provide students the freedom to pursue subjects in school or courses in further education that are aligned to abilities and potential of the student.

4.7 Future directions in STEM

Whereas there is universal acceptance in Irish society for the need of students to learn mathematics, science lags behind in sentiment. Mathematics is held as a difficult subject and therefore success in this subject has added value. The 25 CAO point bonus is self-

[9] Rental schemes work on the following basis: Books are owned by the school where students hold books for one year or for an examination cycle. Students are required to keep the book in good condition and at year's end books are surrendered back to the school for recycling. Books are replaced and decisions to change books are co-ordinated by the rental scheme manager and a mixture of second hand and new books is used. Payments of the rental can be at one stage or in two or more phased payments depending on the school in question. The parents' representative group usually operates the scheme.

limiting because internal adjustments will have to offset the advantage accrued when numbers reach a desired level. This will herald a drop off in attainment in higher level mathematics since students' choice for sitting subjects and levels are really parentally decided. Physics has traditionally failed to attract students, with chemistry not far behind because it is deemed more difficult to accrue CAO points, a fact bourne out by research.

The Examinations Commission needs to ensure that, in a exam system where all subjects have the same or a neutral level of difficulty or 'load', no one subject is advantaged over another. However, syllabi tie the hands of the examiners. Syllabi are written by multi-stakeholder committees in the NCCA in which teacher representatives from both secondary teacher unions and the subject organisation tend to seek overinclusion of material because of pride in their subject. Some of these points are mentioned in the interviews carried out on key stakeholders; I have transcribed one of these, found as an appendix, which acts as a summary of a repeated picture among experienced science educators who have worked in third level.

As the school and university populations continue to grow (Figure 7.), resourcing science will be additionally challenging where, in spite of the recovery from the fincial crisis of 2008, the greatest issue for teachers is pay restoration. Science syllabus and examination development will always be used as a both a carrot and a stick. Figure 7. does not show typical sequential population trends since migration - both emigration by Irish families and immigration from the EU and beyond, including asylum seekers, has some considerable effect on the numbers - note the levelling off 2008 - 2011 where we saw parents making the hard choice to emigrate due to unemployment in the financial crisis (DES, 2013). It is projected that numbers will continue to rise regardless of emigration[10]; however, as recruitment is problematic and relates to pupil-teacher ratio at first and second levels, additional strain in the system will be experienced.

[10] It has been projected that there will be net immigration in 2018; since 2008, migration was emigration, at which point in time, Ireland had the highest population since the Great Famine (1845 - 1849).

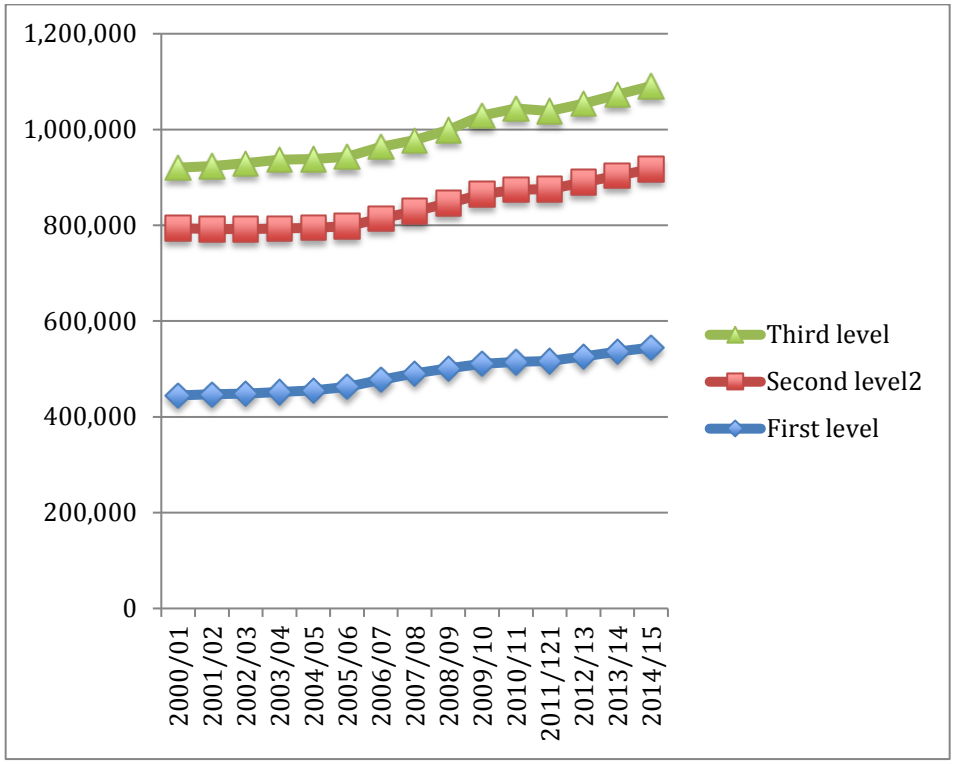


Figure 7. Numbers of students in full-time education at all three levels.

Chapter 5. Conclusion

I have attempted an overview of the history, main features, current issues and future or possible future directions of the Irish education system with particular reference to science.

I have also attempted to highlight the depth and breadth of the leaving certificate with reference to A levels - a difficult task since they have had different historical developments - the former leaning to generalisation, the latter to specificity. Generalisation is perhaps a feature of a small country having a small education system since specialist coverage in all areas is impossible. Thus all primary teachers are generalists regardless of their background or ability or understanding of science. Similarly, secondary teachers of science rely on their primary degree and their own school experience to cope in the classroom.

The leaving certificate pre-1967 may have been comparable to the equivalent A level at that time, however, anecdotal evidence suggests a closer similarity to the former O Levels. Not only is the time allocation much less for leaving certiciate subjects (typically 4 periods of 40 minutes), the range of sub-topics with major themes do not match, and the depth of delivery/experience is so much greater in A levels.

The leaving certificate replaced the matriculation exams set directly by universities and the CAO points system has seemed to many to operate a form of tyranny over the Irish education system, in a way UCAS points do not, again because of the direction the older teenager takes. In bygone years, the leaving certificate was sat in four or five subjects without extra non-examinable subjects. As the latter were introduced, and the university requirements increased because of increased expectations of going to university, more subjects were required (currently 6).

In summary, the main issues affecting education policy and practice reform in Ireland are:

1. The examination system at Leaving Certificate level and how students matriculate
2. The resistance to reform in general, and particularly at the Junior Certificate level
3. Financing the education system - "free education"
4. Textbook provision and use and the issue of rote learning

5. Time allocation for the science subjects

6. Resource allocation for the science subjects

7. Participation at third level, and the need for renewal of the vocational sector

8. Practical assessment, and to what purpose is it put, and the lack of technician support.

And finally, since this will determine how to address the previous 8 points:

9. The country needs to come to agreement on what education is for.

Ultimately, the success, perceived or otherwise, of the education system in Ireland is down to the hard-work and determination of the teachers (See Appendix). Science teachers have to do all their laboratory preparation themselves as well as lab management and procurement often under a difficult financial environment.

Intellectual ability needs to be viewed as something different from memory exertion and university education should be viewed as a means to generate excellence and expertise rather than a rite of passage or an experience to have.

Critiques of measures to ensure fairness in the examination system have drawn claims of dumbing-down (See Appendix) but, ultimately, society must decide what it wants to be the outcomes or objectives of science education both in school and in university. Demarcating societal policies is a difficult process but necessary if the state is to continue having oversight in the educational sphere in the 21st century as opposed to the care-taker role adopted throughout most of the 20th.

I would say, in closing, that the same issues have been experienced in the UK over the last 100 years, and, therefore, some sharing of that experience for mutual benefit would seem desireable if not essential.

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Appendix – Sample interview with key stakeholder

Q. What in your opinion is the most pressing issue(s) facing secondary school science reform in Ireland?

Subject1: Lack of vision and "joined-up thinking" within the civil servants in DES tasked with leading education policy. NCCA comes up with excellent proposals, support groups such as PDST/JCT await for sign-off to commence teacher CPD, long delays and lack of action and sign-off by DES to transform proposals to concrete policies.

Q. What is the singular most important policy document (as expressed by any document having come from a government department) concerning secondary school science in Ireland?

Subject1: With all due respect to Dr MacCraith and his STEM Education Review Group, I suspect that history will teach us that its message and vision did not gain traction within DES. Ironically, in terms of teaching and learning, the JCT Key Skills Framework will possibly have greater impact on post-primary science education in the long-term. Ironical because technically, the NCCA is not a government Department and the document is aimed towards all learning - not simply STEM.

Q. What in your opinion are the reasons for the delay in reform of secondary school science?

Subject1: The said fact of life is that reform in Irish post-primary schools is assessment-driven. Rather than trying to change this we should accept what we cannot change and reform assessment to measure what is important in terms of STEM education. However this would require a major dislodgement of institutional inertia from DES and to take on the political challenges of teachers' unions. As seen with Junior Cert reform, these are major challenges. However well meaning, a small increase in funding and token teacher CPD will not deliver the reform required.

Q. What in your opinion would be the best way to resolve the issues listed in the previous question?

Subject1: Firstly, I would generate national debate on the need for STEM competences among our young people. Once there is national consensus on the needs and competences required it is easier to argue for the institutional changes needed to enable the required achievements. Unions may walk outside schools decrying what they view

as "dumbing-down" of subjects. It is less media-friendly to strike with placards opposing "Critical Analysis" and "rational Thought"

Q. What for you is the most significant document (from whatever source) in relation to secondary science?
Subject1: In recent years, as stated earlier: Key Skills Framework for JCT

Q. What role have you had in secondary school science?
Subject1: Teacher of secondary science at junior level, Teacher of one or more science subjects at senior level, Science teacher educator at third level, Member of national (i.e., government endorsed or funded) committee concerned with curricular reform)

Q. What do you think is the most accepted methodology of teaching science in Ireland today?
Subject1: Alas, didactic is the most accepted. Especially by most parents and a surprising number of pupils.

Q. What do you think is the methodology with the greatest 'traction' in the teaching & learning of science? (i.e., the contribution a teacher brings to the classroom)
Subject1: While not a methodology, passion for Science and enthusiasm to lear are vital. I am a methodological agnostic and freely borrow from guided discovery to didactic as the situation requires. One must be nimble and humble in the classroom and use whatever methodology will work best in that given situation.

Q. What is the most positive aspect of learning secondary science in Ireland today?
Subject1: For some lucky students, the skill and passion of their teachers.