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L&RS NOTE

STEM in schools: the introduction of Coding and Computer science/ICT to the curriculum

25 August 2017

The *Programme for a Partnership Government* (2016) commits to introducing a coding course for the Junior Cycle and introducing ICT/computer science as a Leaving Certificate subject. This *Note* considers the type of supports teachers and students may need in order for these subjects to succeed and reviews similar initiatives in other jurisdictions.

Arising from the research, a number of **key policy areas** have been identified, such as:

- concerns have been expressed that schools may not have the time, resources, or expertise to roll out coding and computer science at second level;
- there is little pedagogical research to guide teachers and those designing curriculum;
- females are less likely than males to pursue STEM subjects at third level, or work in the STEM sector;
- there has been a decline in the number of students studying engineering; and
- the means by which policymakers determine whether the introduction of computer science/ICT to the school curriculum, has been successful, is unclear. For instance, will it be through: take-up rates, performance in exams, follow-through to third level or an increase in those pursuing STEM-related careers?

Glossary

Algorithm: An algorithm is a sequence of steps designed to accomplish a specific task. Algorithms are translated into programs, or code, to provide instructions for computing devices. [1]

Information and Communications Technology (ICT): ICT relates to using technology for access to information through communication. ICT includes a range of hardware and software devices and programmes such as personal computers, assistive technology, scanners, digital cameras, multimedia programmes, image editing software, database and spreadsheet programmes. It also includes communications equipment such as the Internet, email and video conferencing.[2]

Computer science: Computer science is the study of how computers work. It involves the design and development of all types of software from operating systems and phone apps to interactive games and other forms of interactive technology.[3]

Coding/computer programming: Coding and computer programming are often used interchangeably and refer to the process of developing and implementing instructions which enable a computer to perform tasks and solve problems. There are several different programming languages.[4]

Digital Literacy: the basic skill or ability to use a computer confidently, safely and effectively, including: the ability to use office software such as word processors, email and presentation software, the ability to create and edit images, audio and video, and the ability to use a web browser and internet search engines.[5]

Contents

Introduction

In considering Government plans to introduce coding and ICT as subjects in secondary schools, this *Note* will provide an overview of Ireland's take-up of Science, Technology, Engineering and Mathematics (STEM) subjects at second and third level. It will also provide data on Ireland's performance in these subjects.

In 2009 the L&RS published Spotlight: Science and Maths Education in Ireland: Provision, Participation and Achievement. That publication highlighted low numbers of students taking higher level mathematics at second level. However, since that *Spotlight* was published, there has been an increase in the number of students taking higher-level mathematics, as well as more students studying science at third level. This *Note* updates many of the tables in that previous *Spotlight* to reflect this change. The *Note* also looks at the introduction of computer science/ICT to schools in Ireland and other countries; as well as the supports available to teachers in Ireland and internationally.

Over the last decade, the Irish Government, along with Forfás (which has been integrated into the Department of Jobs, Enterprise and Innovation) and the Expert Group on Future Skills Needs (EGFSN)[6] have highlighted the importance of developing (STEM) related skills, to meet the demand for jobs in these areas and attract foreign direct investment.

In 2014 the then Government launched a three year strategy to deliver an increase in STEM subjects.[7] At the launch of the National Skills Strategy 2025 the then Taoiseach said:

> "The ability to attract new jobs, and having our people fill those jobs, is dependent on having a well-educated, well-skilled and adaptable work force. This National Skills Strategy aims to provide an education and training system that is flexible enough to respond to a rapidly changing environment…"

The Action Plan for Education 2017[8] sets out a number of actions to further improve Irish students' performance in mathematics, including:[9]

- introducing coding and computer science throughout the school curriculum;
- a comprehensive National Policy Statement on STEM Education in schools; and
- new measures to upskill mathematics teachers.

Existing skills shortage

While progress has been made in attracting students to STEM subjects at second and third level, a skills shortage in the labour market remains, particularly in the area of ICT. On 6th May 2017 the *Expert Group on Future Skills Needs* published its *Vacancy Overview 2016* which found that 35% of all difficult to fill vacancies in October 2016 were for the Information and Communication sector and mainly for professional roles in software development.[10]

The STEM Education Review Group, which was led by led by Professor Brian MacCraith and included experts in STEM education, as well as industry figures, reported its findings in 2016.[11] The report states:

> "Without an effective national policy on STEM education to secure and sustain a sufficient supply of high-quality scientists, engineers, technologists and mathematicians, there are serious concerns that Ireland might lose economic competitiveness and fail to realise its potential as a nation."

The European Commission reports that there will be an estimated 825,000 ICT job vacancies in Europe by 2020.[12] As such, many European countries are increasingly introducing Computer science and/or ICT to the school curriculum.

This *Note* is structured as follows:

- International context
- Performance of Irish students in mathematics and science
- Participation in STEM subjects in post-primary schools and third level in Ireland
- Demand for third level places in STEM subjects 2007-2017
- Points required to study Computer science/ICT at third level
- Non-progression rates in STEM subjects at third level
- Gender participation in STEM subjects
- Introducing coding at Junior Cycle and computer science as a Leaving Certificate Subject
- Capacity among Irish teachers to teach coding, Computer science and ICT
- Supports for teachers in Ireland and internationally
- Conclusion

1. International context

Computer science is described as an "autonomous" scientific discipline which pre-dates computers.[13] It should be distinguished from digital literacy, ICT and programming.[14] Programming is, however, part of computer science. In the 1970s, where schools in the USA and Europe did teach computer science, they mainly focused on programming. When computers became more complex, schools moved towards ICT and how to use computer applications.

An increasing number of countries around the world are introducing coding to schools.[15] Israel, one of the first countries to do so, introduced Computer science to secondary schools in 1995 (though it had been on the curriculum in some form since the mid 1970's).[16] A 2015 survey[17] of 21 countries found that coding is already integrated in the school curriculum of 16 of those countries.[18] Of the surveyed countries: only Belgium Wallonia, the Netherlands and Norway have no plans to integrate coding in the school curriculum.

The authors of the 2015 report note that the rationale for integrating coding/computer programming in school curricula is twofold:

- to equip all students with important skills in today's digital society and
- to respond to the lack of IT-skilled labour force in Europe.

While most countries integrate coding/computer programming at lower or upper secondary school; ten of the surveyed countries integrate (Estonia, France, Israel, Spain, Slovakia, England) or will integrate (Belgium Flanders, Finland, Poland, Portugal) coding/computer programming at primary level. In England, (which introduced computing in 2014) and Slovakia, coding is a compulsory subject in primary education.

In a recent review of the provision of computer science courses at upper secondary level in other countries, Keane and McInerney (2017) write:

> "Success in other jurisdictions has only followed after the distinction between CS (involving programming and rigorous analytical thinking, with a consistent set of core principles) and Information Communications Technology (typically involving the use of computer software) has been made clear."

Keane and McInerney (2017) also write that the use of ICT in teaching methods is sometimes confused with computer science . In order to avoid confusion the authors reference the work of Simon Furber which recommends disaggregating the term ICT into a framework of computer science, information technology and digital literacy.

How is coding/computer programming integrated in the curriculum?

The European Schoolnet[1] (2015) report found that 13 countries integrate coding in a general ICT/technology course; while 12 countries from the Schoolnet (2015) survey have established a specific coding/computing subject.

However coding is increasingly integrated in mathematics (Denmark, Estonia, Finland, Slovakia, Spain and France).[19]

As noted by the *Economist* (2014)[20] teachers and those designing curriculum have little pedagogical research to guide them. This means that it is not necessarily clear what is the best way to teach computer science. Gal-Ezer et al. (1995) write that while technology changes, the ideas and principles of Computer science, generally, do not. For this reason, they argue that any education programme must be based on the science.[21]

Box 1: Case study – Computing curriculum England

Computer science became part of the school curriculum in September 2014. In the UK (England), computing is a separate subject in school curricula but schools may teach it as an integrated subject or stand-alone.[22] The Department for Education (UK) describes the aims of the national curriculum for computing as follows:

Key Stage 1 (5-6 year-olds):

Pupils should be taught about algorithms and how to implement them, as well as how to create and debug simple programmes. They should also be taught to use logical reasoning to predict the behaviour of simple programmes and use technology in a safe way (including where to go if they have concerns about online technologies).

Key Stage 2 (7-11 year-olds):

Students should be taught to create and debug programs and solve problems by decomposing them into smaller parts. They should learn how to use search technologies effectively and learn how results are selected and ranked. In addition pupils should be taught to use a variety of software to design programs, systems and content for analysing, evaluating and presenting data and information.

[1] European Schoolnet is the network of 31 European Ministries of Education, based in Brussels. As a not-for-profit organisation, they aim to bring innovation in teaching and learning to key stakeholders: Ministries of Education, schools, teachers, researchers, and industry partners.

Key Stage 3 (11-14 year-olds):

Students should be taught several key algorithms that reflect computational thinking (for example, ones for sorting and searching) and use logical reasoning to compare the utility of alternative algorithms for the same problem. In addition, pupils should be taught to use two or more programming languages to solve a variety of computational problems. Students should also learn about simple Boolean logic [for example, AND, OR and NOT] as well as binary numbers.

Key stage 4 (14-16 year olds):

All pupils should be taught to develop their capability, creativity and knowledge in computer science, digital media and information technology. They should also develop and apply their analytic, problem-solving, design, and computational skills.

Students at key stage 4 and beyond may choose to pursue formal qualifications, for example the new computer science GCSE.[23]

Source: Department Education UK. (2013)

2. Performance of Irish students in mathematics and science

The OECD (2015) Universal Basic Skills report[24] ranks Ireland 11th highest (of 31 high income countries) based on its average score for science and mathematics (512). The top five countries are Korea (546), Japan (542), Finland (532), Estonia (531), and Switzerland (523). The data is based on performance in Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS).

PISA assessment

The Programme for International Student Assessment (PISA) is an international survey which tests the skills and knowledge of 15-year-old students in science, reading and mathematics. The survey is carried out every three years and the 2015 report was published in December 2016. The performance of Irish 15 year olds was higher than the OECD average in science, reading and mathematics. However, the gap between the performance of boys and girls in mathematics and science is widening.

Box 2: Key findings of the PISA 2015 survey [25]

- In reading, Irish students ranked 3rd out of 35 OECD countries, 2nd among EU countries, and 5th out of all countries participating in PISA 2015
- In science, Irish students ranked 13th out of 35 OECD countries, 6th among EU countries and 19th out of all countries participating in PISA 2015
- In mathematics, Irish students ranked 13th of 35 OECD countries, 9th among EU countries and 18th out of all countries participating in PISA 2015.
- All three test domains (reading, maths and science) showed some gender differences in results, with girls performing better than boys in reading and boys performing better than girls in mathematics and science

TIMSS assessment

TIMSS is an international comparative study of mathematics and science achievement at primary (Fourth class) and post-primary (Second Year) levels. The 2015 TIMSS assessment (assessment takes place every 4 years) report was published on November 29th, 2016.[26]

Performance - fourth class in primary school in TIMSS

Pupils in Ireland achieved a mean score of 547 in **mathematics**, which was significantly above the TIMSS “centrepoint” (which is set at 500).

In **science**, pupils in Ireland achieved a mean score of 529, which was significantly above the TIMSS centrepoint.

Performance - second year in secondary school in TIMSS

At second year the mean **mathematics** score of students in Ireland was 523 (significantly above the TIMSS centrepoint of 500).

Second Year students in Ireland had a mean **science** score of 530 (significantly above the TIMSS centrepoint of 500).

Box 3: Key Findings of the TIMSS 2016 report[27]

The key findings of the report include:

- Irish fourth class students ranked 9th out of 49 countries in maths (up from 17th out of 50 countries in 2011).
- Irish fourth class students ranked 19th of 47 countries in science (broadly consistent with 22nd position out of the 50 countries that participated in 2011).
- Irish second year students ranked 9th of 39 countries in maths, (there is no recent study with which to compare this).
- Irish second year students ranked 10th of 39 countries in science (there is no recent study with which to compare this).

3. Participation in STEM subjects in post-primary schools and third level in Ireland

A *Programme for a Partnership Government* (2016) proposes to introduce coding as a course in the junior cycle and computer science/ICT as a leaving certificate subject. As these are new to the Irish curriculum, it is useful to look at the participation and performance of existing STEM subjects at Junior and Leaving Certificate level, to ascertain the demand and capacity among students and teachers. Furthermore this section looks at the take-up of STEM subjects at third level in order to gain an insight into students' interest in these subjects.

Participation in STEM subjects for the Junior Certificate

Table1 shows the take-up of some Computer science/ICT-related subjects at Junior Certificate level. Data from the table is taken from the Post Primary Online Database (PPOD), which records subjects taught in a school rather than subjects examined. Table 1 shows growth across all subjects from 2011-2017 (with the exception of computer studies). The numbers of students taking these subjects are relatively small, however, as they are not available in many schools. For instance in 2017, five schools offered computer science, while nine schools offered computer applications, two schools offered informatics/systems and technology and nine schools offered computing. Far more students took computer studies, which was available in 299 schools in 2017.

Table 1: Pupils taking Computer science/ICT-related subjects (Number) by Junior Certificate 2011-2017

	2011	2012	2013	2014	2015	2016	2017	% increase/ decerease 2011-2017
Computer Studies	53,928	53,916	54,594	54,428	61,113	59,898	53,511	-0.8%
Computer Science	74	80	254	465	928	972	745	907%
Computer Applications	1,304	928	1,231	1,239	1,475	1,577	1,348	3.4 %
Informatics/ Systems & Technology	161	--	32	147	320	458	323	101%
Computing	482	598	562	615	1,018	1,329	1,436	198%

Source: CSO/Department of Education and Skills (2017)

While science is not a compulsory subject in the Junior Cycle, 90% of students take it.[28] Table 2 shows the level at which students took Junior Certificate **science** from 2011-2016. The data shows a small growth in the number of students taking higher level science, from 75% in 2011 to 79% in 2016.

Table 2: All Pupils taking Science for Junior Certificate

	2011	2012	2013	2014	2015	2016
Science						
Higher level	38,072 (75.3%)	39,990 (76%)	42,423 (78.7%)	42,821 (78.2%)	42,658 (78.6%)	43,898 (79.1%)
Ordinary level	12,485 (24.7%)	12615 (24%)	11,488 (21.3%)	11,936 (21.8%)	11,632 (21.4%)	11,573 (20.9%)
Total	**50,557**	**52,605**	**53,911**	**54,757**	**54,290**	**55,471**

Source: State Examinations Commission (2016)

Table 3 shows the level at which Junior Certificate students took **mathematics** from 2011-2016. The table shows an increase of 9.5 percentage points for students taking higher level mathematics during this period.

Table 3: The level at which Junior Certificate students took mathematics 2011-2016

	2011	2012	2013	2014	2015	2016
Maths						
Higher level	25,554 (45.6%)	27,913 (48.1%)	30,500 (51.6%)	32,041 (57%)	32,535 (56%)	32,830 (55.1%)
Foundation level	4,407 (7.9%)	4,211 (7.2%)	3,901 (6.6%)	3,532 (6.3%)	3,484 (6%)	2,978 (5%)
Ordinary level	26,064 (46.5%)	25,945 (44.7%)	24,687 (41.8%)	24,047 (43%)	22,856 (39.4%)	23,781 (39.9%)
Total	56,025	58,069	59,088	56,025	58,069	59,589

Source: State Examinations Commission (2016)

Participation in STEM subjects for the Leaving Certificate

Table 4 shows an increase of just over 14 percentage points in those taking higher level mathematics from 2011 to 2017. This may be due, at least in part, to the Government's introduction of bonus points for honours maths from 2012. However, this growth was most pronounced from 2011-2014 and has remained steady since.

Table 4: The level at which leaving certificate students took mathematics 2011-2017

	2011	2012	2013	2014	2015	2016	2017*
Maths							
Higher level	8,235 (15.8%)	11,131 (22.1%)	13,014 (25.6%)	14,326 (27.4%)	14,691 (27.4%)	15,198 (28%)	16,395 (29.9%)
Foundation level	6,249 (12%)	5,395 (10.7%)	5,677 (11.2%)	5,628 (10.8%)	5,613 (10.5%)	6,478 (11.9%)	5,936 (10.8%)
Ordinary level	37,506 (72.1%)	33,917 (67%)	32,165 (63.2%)	32,428 (62%)	33,266 (62.1%)	32,549 (60%)	32,334 (59.1%)
Total	**51,990**	**50,443**	**50,856**	**52,328**	**53,570**	**54,225**	**54,665**

Source: State Examinations Commission (2016)
* 2017 data is provisional

4. Demand for third level places in STEM subjects 2007-2017

The following tables are taken from the Central Applications Office (CAO) and show applications for undergraduate courses in Irish Higher Education Institutions (HEIs). Each table shows data for Level 8 (Degree) and Level 7/6 (Diploma/Certificate) courses in science as well as engineering/technology. It is worth noting that, for the purposes of data collection, some IT courses come under engineering/technology, while others come under science/applied science categories. Furthermore there are some IT courses which are categorised as business.

Table 5 shows a gradual increase in applicants for science/applied science degrees from 12.9% in 2005 to 15.3% in 2017. A much greater increase has occurred in applicants for certs/diplomas in science/applied science from 9.1% in 2005 to 21.7% in 2017.

Table 5: Applicants to Science and Applied Science courses as a proportion of all applicants 2007-2017

Applicants to Third Level - Degree / Level 8			
	Applicants - All Level 8 Courses	**Applicants Science and Applied Science**	**Science and Applied Science Applicants as a % of all Applicants**
2017	350,521	53,787	15.3
2007	316,083	38,012	12
Applicants to Third Level - Diploma /Cert Level 7/6			
2017	117,132	25,475	21.7
2007	163,978	17,674	10.8

Source: CAO 2017

In contrast to the increasing number of applicants for science, Table 6 shows almost no increase in applicants for level 8 engineering/technology, from 2007-2017, and a fall of 2.7 percentage points in applicants for level 7/6 engineering/technology courses from 2007-2017.

Table 6: Applicants to Engineering/Technology courses as a proportion of all applicants 2007-2017

Applicants to Engineering/Technology - Degree / Level 8			
	Applicants - All Courses	**Applicants Engineering/Technology**	**Engineering/Technology as a % of all Applicants**
2017	350,521	34,850	9.9
2007	316,083	30,281	9.6
Applicants to Engineering/Technology - Diploma /Cert Level 7/6			
2017	117,132	25,825	22
2007	163,978	40,451	24.7

Source: CAO 2017

5. Points required to study Computer science/ICT at third level

The following is a snapshot of the CAO Round 1 points required in order to secure a place on some computer science and related courses in 2017. While it may not be representative of all courses on offer, it provides some idea of the number of points required for these courses.

Box 4: Points required for some computer science-related courses

Level 8 computer science-related courses in 2017 (round 1 offer)

Maynooth University: Computer science through Science – 350

University of Limerick: Electronic and Computer Engineering - 413

National University of Ireland Galway: Computer science and IT – 400

Trinity College Dublin: Computer science – 467

University College Cork: Computer science - 419

University College Dublin: Computer science – 477

Level 7/6 computer science courses in 2017 (round 1 offer)

Institute of Technology Carlow: Software Development - 262

Cork Institute of Technology: Software development – 270

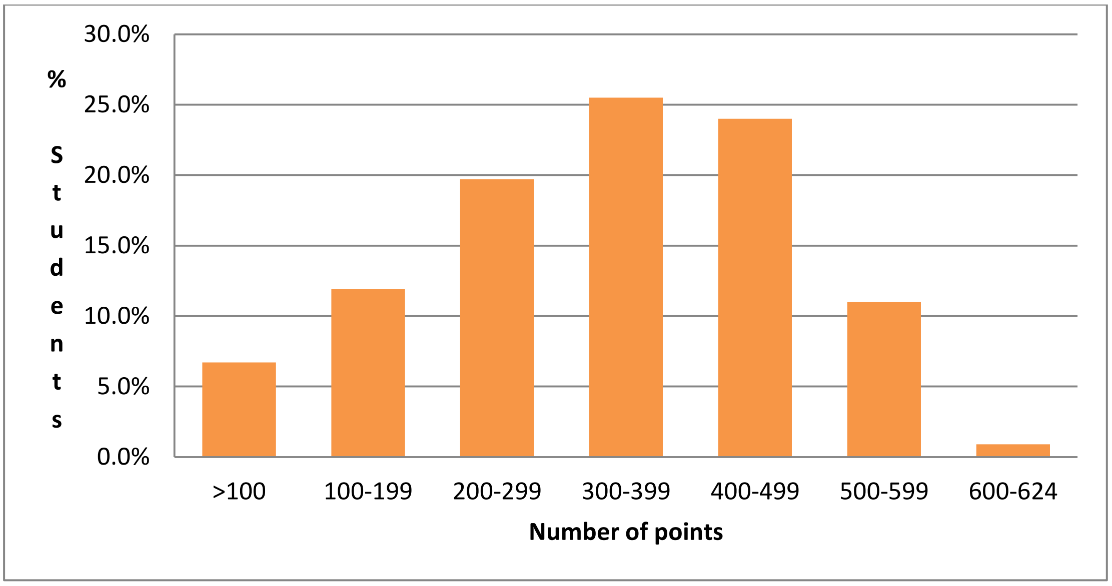
Institute of Technology Blanchardstown: Computing (Information Technology) - 195

Institute of Technology Tallaght: Computing - 200

Source: CAO (2017)

Figure 1 shows that 36% of students in 2017 achieved more than 400 points, while 12% achieved more than 500 points in their Leaving Certificate. Most level 8 computer science courses require more than 400 points, meaning only about a third of those sitting their leaving cert would be eligible to secure a place on these courses. The points for level 7/6 courses is more achievable, as it is possible to secure a place with around 200-300 points, a level reached or surpassed by the majority of those who sat their leaving certificate in 2017.

Figure 1: Number of points achieved in the Leaving Certificate 2017

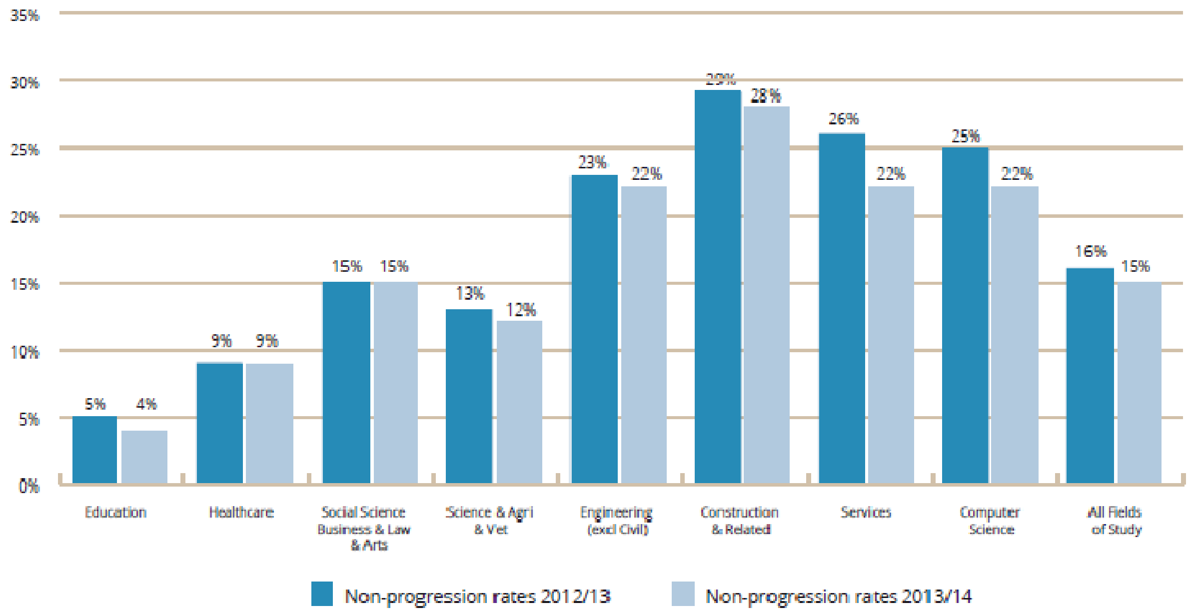


Source: CAO (2017)

6. Non-progression rates in STEM subjects at third level

A report released by the Higher Education Authority (HEA) in April 2017 showed that computer science and engineering have some of the lowest progression rates (i.e. did not progress beyond first year) of full-time undergraduate new entrants.[29] In 2012/13 non-progression for computer science was 25% (average non-progression rate was 15%). This had fallen to 22% in 2013/14. For engineering (not including civil engineering), the rates were 23% and 22% respectively. The study also found that, in general, males were 1.3 times more likely than females not to progress.

Figure 2: Non-progression rates by field of study 2012/13 vs 2013/14



Source: HEA 2017

7. Gender participation in STEM

Although access to higher education is roughly equal between men and women (see Table 7), the statistics show that females are far less likely to enrol in fulltime ICT- related courses. In 2014/15, 71% of all undergraduate new entrants to technology disciplines (science, ICT and engineering) were male compared to 42% of all other disciplines.[30]

Table 7: Breakdown of Participation by Men and Women in Higher Education

Academic Year	Male %	Female %
2014/15	50%	50%
2005/06	46%	54%

Source: Written reply to PQ (31394/15) 22nd September 2015

Table 8 (overleaf) is taken from the HEA 2015/16 data. The table shows that while there are 10,670 people studying ICT only 1,730, or 16%, of these are women.

Table 8: Number of people enrolled in full-time ICT-related courses, by sex (2015/16)

	Universities			Institutes of Technology			Totals		
	M	F	T	M	F	T	M	F	T
Information and Communication Technologies (ICTs)	3,286	732	4,018	5,654	998	6,652	8,940	1,730	10,670
(0610) Information and Communication Technologies (ICTs) not further defined or elsewhere classified	2,163	500	2,663	1,700	388	2,088	3,863	888	4,751
(0611) Computer use	5	3	8	1,402	267	1,669	1,407	270	1,677
(0612) Database and network design and administration				387	76	463	387	76	463
(0613) Software and applications development and analysis	808	177	985	2,165	267	2,432	2,973	444	3,417
(0688) Interdisciplinary programmes and qualifications involving Information and Communication Technologies (ICTs)	310	52	362				310	52	362

Source: HEA 2015/16 data

Women are also under-represented in computer science and ICT related careers,[31] as well as other STEM-based careers.[32] A report following a survey by Accenture (2014) *Powering economic growth; Attracting more young women into science and technology* states:

> "One crucial problem identified by this study is that parents, teachers and students may be uninformed about career opportunities available in STEM sectors."

In order to broaden participation by women in STEM, a number of campaigns have been launched. Women in Technology and Science (WITS) has identified four actions:[33]

- Advance women's leadership and participation in decision making - local and national;
- End the gender pay gap and deliver decent work for women;

- Make early years education and childcare a priority; and
- Strengthen social protection, training and employment supports.

However, care should be taken when considering initiatives at school level, so that they do not inadvertently re-inforce gender stereotypes. Passey (2016) writes:[34]

> "…an evaluation of a scheme in 2005 to provide after-school clubs for girls to engage them in computing (Fuller et al. 2013) suggested that this had reinforced existing gender stereotypes and expectations, concluding that the initiative was "unlikely to have a significant or sustained impact on what remains an occupational and subject area divided by gender" (p.499)."

8. Introducing coding at Junior Cycle and computer science as a Leaving Certificate Subject

Junior Cycle

The National Council for Curriculum and Assessment (NCCA) has developed a short course on coding, which is available to schools for their Junior Cycle programme on an optional basis. Schools may choose to include a course developed by the NCCA or another course, developed by the school itself or another organisation, under guidelines set by the NCCA. [35]

Each short course requires one hundred hours of student engagement and assessment will be classroom based. As part of this classroom assessment, students, working as a team, will develop a final software project.

The coding course has three inter-connected strands:[36]

- Computer science introduction,
- Let's get connected and
- Coding at the next level.

Junior Cycle for Teachers (JCT) is the Department of Education and Skill's support service for teachers to support the implementation of the new Framework.

Leaving certificate

In advance of the new Leaving Certificate computer science subject, due to be introduced on a phased basis, to schools in September 2018; the National Council for Curriculum and Assessment (NCCA) have published a *Draft Specification for consultation* . The document outlines the rationale for introducing computer science as a core subject and what the objectives of the course will be. It also provides information on how the course will be assessed.

9. Capacity among Irish teachers to teach Coding, Computer science and ICT

Of all OECD countries, Ireland has the highest rate of working time spent teaching.[37] In Ireland, for the school year 2014/2015 in the case of primary schools, 17% of compulsory instruction time was allocated to mathematics (OECD average is 15%), while science accounts for 4% of instruction time (OECD average is 7%)[38]. However, the Department of Education and Skills (2015) cautions against comparing countries, as:

> "(a) intended instruction can deviate significantly from actual instruction time and this deviation may not be the same across countries and (b) the exact interpretation of 'instruction' may not be consistent in every case."

As coding and ICT are not routinely taught in schools at present, there may be an issue with capacity (in terms of time as well as expertise), should these subjects be rolled out, as part of the curriculum.

The STEM Education Review Group (2016) states that initiatives are required to ensure that subjects such as physics and chemistry are taught by teachers with a teaching qualification in these subjects. However this could be difficult in the area of computer science/ICT, where there is a shortage of graduates and remuneration in the ICT sector is at the higher end of the jobs market. A recent HEA report ,which looked at graduates' salaries, found that:

> "Overall, Agriculture, Forestry, Fisheries & Veterinary and ICT Honours Bachelor Degree graduates are the highest earners, with 29% and 27% of such graduates earning €33k or over respectively."[39]

In addition the Information and Communication sector enjoys higher average weekly earnings (€1,094.84 per week) compared with (€912.95) per week in the education sector. These 2017 figures are preliminary estimates taken from the Central Statistics Office (CSO) *Earnings and Labour Cost Quarterly*.

A problem for the roll out of computer science and ICT in schools, therefore, is that there may not be sufficient numbers of qualified teachers. Table 9 is taken from the STEM Education Review Group (2016) and shows the number of computer studies teachers currently registered with the Teaching Council (580).

Table 9: Number of STEM teachers registered with the Teaching Council

Subject	Number of teachers currently registered on the basis of qualifications in that subject (2014)
Agricultural Science	729
Applied Mathematics	420
Biology (Science)	3,694
Chemistry (Science)	2,305
Computer Studies (IT or ICT)	580
Construction Studies (Technology & M.T.W)	1,352
DCG (Technical Graphics)	1,215
Engineering (Metalwork/Technology)	769
Mathematics	5,171
Physics (Science)	1,197
Physics and Chemistry (Science)	24
Technology	159

Source: STEM Education Review Group (2016)

A recent report by the House of Commons Science and Technology Committee shows that only one third of the UK's ICT teachers have a "relevant qualification" and that many teachers are struggling to implement the curriculum. The report also highlights the difficulty in attracting those with computer science qualifications to teaching.

10. Supports for teachers in Ireland and internationally

Ireland

As a means of preparing teachers for the junior cycle short course in coding; the Department of Education and Skills, in collaboration with the Irish Software Engineering Research Centre and Intel, devised a pilot project with participating schools entitled "Exploring Coding." According to Junior Cycle for Teachers (JCT), teachers will:[40]

> "• Participate in a two-year programme of CPD, involving six core CPD events;
>
> • Have access to various elective CPD events;
>
> • Contribute to an online community of participating teachers; and
>
> • Share their experiences with the JCT short courses team, thereby informing the development of further supports for teachers."

PACT initiative Maynooth University Computer science Department

The PACT initiative at Trinity College (Programming + algorithms => Computational Thinking) is a partnership between researchers in the Department of computer science at Maynooth University and teachers at selected post-primary schools around Ireland.

The PACT team prepares materials which are then delivered to secondary students. The programme teaches the fundamental principles underlying computer science, in order to equip second level students with transferable skills which are useful to many computer/ICT-related courses at third level.[41]

PACT has identified three "key levels of understanding":

- **Programming:** this introduces some of the basic challenges of the discipline.
- **Algorithms:** involves studying solutions in computational terms.
- **Computational thinking:** in scientific terms this is the study of problems in computational terms.

While programming is integral to computing:

> "…the PACT programme aims to highlight how the underlying principles of algorithms and computational thinking are both more fundamental and more durable."

The Israeli computer science Programme introduced in 1995, similarly focused on the fundamentals of computer science and academics involved in the PACT initiative refer to Gal-Ezer et al.'s (1995) paper. See Box 5.

Box 5: Underlying Principles of Israel's 1995 computer science Programme[42]

- Computer science is a fully-fledged scientific subject. It should be taught on par with other science subjects.
- The programme should concentrate on the key concepts and foundations of the field.
- Two different programmes are needed. The first programme would be less in-depth, for students with a general interest in computer science. The second programme would be for those with a more specific interest in computer science.
- Each of the two programmes should have required units and electives. Electives would be for less crucial aspects.
- Conceptual and experimental issues should be interwoven throughout the programme (subjects which belong in the classroom rather than the laboratory).
- Students should learn one programming language first, as a "mother tongue" but then learn a radically different programming paradigm, this encourages different ways of algorithmic thinking.
- A well-equipped and well-maintained computer laboratory is mandatory. Schools must allow adequate "screen-time" for students.
- New course materials must be written for all parts of the programme. Course materials should be designed by industry computer scientists, computer science teachers and researchers in computer science education.
- Teachers must have adequate qualifications to teach computer science. In Israel it is mandatory to hold a degree in computer science.

Professional Development Service for Teachers (PDST) - Technology in Education

PDST Technology is part of the national support service, the Professional Development Service for Teachers, which operates under the aegis of the Department of Education and Skills. PDST, which is managed by the Dublin West Education Centre, promotes and supports the integration of ICT in teaching and learning in first and second level schools.

In reply to a parliamentary question dated 16/12/2016 the Minister for Education and Skills, Mr. Richard Bruton, T.D. stated that, as part of the PDST Technology in Education, 5,800 teachers (primary and post-primary) received ICT training in 2016.

Trinity Access 21 (TA21) programme

Trinity Access 21 (TA21) programme is a three year project, funded by Google, which helps teachers to better teach Science Technology Engineering and Maths (STEM) subjects, and in particular computer science.[43]

TA21 was developed by Trinity Access Programmes, education innovators Bridge21 and Trinity's School of Education. Google provided €1.5m in funding for the project, along with other resources and facilities. There are 16 participating schools and the project is specifically targeting efforts to improve the teaching of STEM subjects in DEIS schools. It is intended that over three years, in excess of 1,000 teachers will undertake a certified course in 21st Century Teaching and Learning.[44]

The TA21 first report was published in 2016. The report showed that 485 teachers participated in STEM/computer science workshops in the first year of the programme. The report also identified a number of barriers to more widespread teaching of STEM/computer science. These were:[45]

> "•Class times: teachers state they are too short for technology mediated learning to become embedded in the classroom.
>
> •Teaching to the test: teachers do not have the authority or time to adapt the junior and senior cycle curriculum to incorporate STEM/CS content.
>
> •Resources: schools do not have the technology available to bring STEM/CS into the classroom."

International examples

The European Schoolnet (2015) report states that 13 of the countries which include coding in their curriculum also offer in-service and/or pre-service to support teachers (Austria, Bulgaria, France, Estonia, Hungary, Ireland, Israel, Malta, Poland, Portugal, Slovakia, Spain, England). The report notes that most countries have "bottom-up" initiatives to support teachers, such as summer schools and coding clubs.[46]

This section looks at specific international examples of initiatives designed to provide teachers with resources and/or increase access for students to ICT-related learning.

TEALS

In the USA TEALS pairs computer science professionals with teachers.[47] The initiative was started in 2009 by a Microsoft employee who ran the programme in his spare time. The initiative is now supported by Microsoft as part of its *YouthSpark* initiative, which aims:

> "…to increase access for all youth to learn computer science."

Teachers TryScience

Teachers TryScience is a website that provides lessons, teaching strategies and resources, for STEM subjects.[48]

all you need is {C<3DE}

The European coding Initiative, 'All you need is {C<3DE}', was created in June 2014 under the auspices of the European Commission, to promote coding and computational thinking among students and teachers. It is supported by partners from the technology industry, including Facebook, Microsoft and Samsung, as well as not-for-profit organisations including CoderDojo, Code.org and European Schoolnet.[49]

Further examples can be found at the STEM Alliance website

In addition a paper by Passey (2016) provides a useful overview of how thirteen countries are approaching the provision of computer science within the compulsory education sector.[50]

Conclusion

As the Government has committed to rolling out a coding course for the Junior Cycle and introducing ICT/computer science as a Leaving Certificate subject, this *Note* looked at the current take-up of STEM subjects at both post-primary and third level. Over the past number of years there has been an increase in the percentage of students taking up science and applied science at third level. In addition there has been an increase in the percentage of students taking higher level mathematics at both Junior Certificate and Leaving Certificate level.

Ireland's performance in TIMSS, shows above average performance among Irish students in mathematics and science, as well as improvements among Irish primary students in mathematics since 2011.

However, there is also cause for concern. For instance, over the past ten years there has been a decrease in the percentage of students enrolling in engineering/technology courses at third level. Engineering also has a relatively high non-progression rate among undergraduates, as does computer science.

In addition, concerns have been expressed that schools may not have the time, resources, or expertise to roll out coding and computer science at second level. To help address this, industry and academics have teamed up with teachers, on a pilot basis, to prepare materials for students.

Another cause for concern is that females are less likely than males to pursue STEM subjects at third level, or work in the STEM sector. If Ireland is to maximize its opportunities in this sector and attract investment, it cannot afford such a gender gap to continue.

The key challenges for policymakers are therefore:

- Designing and embedding an effective computing curriculum at all levels and resourcing it;
- Addressing the gender gap;
- Progression rates at third level;
- Supporting teachers and harnessing learning from international examples;
- How to determine if the introduction of computer science/ICT to the school curriculum has been effective - will it be through take-up rates, performance in exams, follow-through to third level or an increase in those pursuing STEM-related careers?

[1] This definition is adapted in from that provided in the the NCCA Leaving Certificate Computer science: Draft Specification for consultation.

[2] National Council for Curriculum and Assessment (NCCA). *ICT (Information and Communications Technology) (2016)*. Accessed on 16 November 2016 at http://www.ncca.ie/en/curriculum_and_assessment/ict/

[3] Technology Schools.org. (2016). *What is the Difference Between Computer science and Computer Information Systems Majors?* Accessed on 24 July 2017 at http://technologyschools.org/what-is-the-difference-between-computer-science-and-computer-information-systems-majors/

[4] European Schoolnet. (2015). *Computing our future: Computer programming and coding - Priorities, school curricula and initiatives across Europe.* Accessed on 14 September 2016 at http://fcl.eun.org/documents/10180/14689/Computing+our+future_final.pdf/746e36b1-e1a6-4bf1-8105-ea27c0d2bbe0

[5] This definition is attributed to Simon Furber 2012, as cited in the Keane and McInerney 2017 paper.

[6] The Expert Group on Future Skill Needs (EGFSN) advises the Irish Government on current and future skills needs of the economy and on other labour market issues that impact on Ireland's enterprise and employment growth.

[7] Science Foundation Ireland. (2014). *Three-year plan to deliver increase in uptake of Science, Technology, Engineering and Maths – Minister Bruton.* Accessed on 8 August 2016 at http://www.sfi.ie/news-resources/press-releases/three-year-plan-to-increase-in-uptake-of-stem.html

[8] https://www.education.ie/en/Publications/Corporate-Reports/Strategy-Statement/Action-Plan-for-Education-2017.pdf

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[13] Gal-Ezer et al. (1995). A High School Programme in Computer science. Accessed on 19 September 2016.

[14] Mooney et al. (2014). PACT: An initiative to introduce computational thinking to second-level education in Ireland.

[15] European Schoolnet. (2015). Computing our future: Computer programming and coding - Priorities, school curricula and initiatives across Europe. Accessed on 14 September 2016.

[16] Gal-Ezer et al. (1995). A High School Programme in Computer science. Accessed on 19 September 2016.

[17] Ibid.

[18] These are: Austria, Bulgaria, the Czech Republic, Denmark, Estonia, France, Hungary, Ireland, Israel, Lithuania, Malta, Spain, Poland, Portugal, Slovakia and the UK (England). In addition Finland and Belgium Flanders have plans to integrate coding in the curriculum.

[19] Ibid.

[20] The Economist. (2014). *A is for algorithm*. April 26th 2014.

[21] Gal-Ezer et al. (1995). A High School Programme in Computer science. Accessed on 19 September 2016.

[22] European Schoolnet. (2015). Computing our future: Computer programming and coding - Priorities, school curricula and initiatives across Europe. Accessed on 14 September 2016.

[23] Ibid.

[24]The authors of the report define basic skills as "…the acquisition of at least Level 1 skills (420 points) on the OECD Programme for International Student Assessment (PISA)."
(Annex B), Table B.1, p.97

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