Report of the STEM Review

SCIENCE TECHNOLOGY
ENGINEERING MATHS

Department of Education
www.deni.gov.uk
AN ROINN Oideachais
MÁNNYSTRIE O Lear

Department for Employment and Learning
www.delni.gov.uk

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

Report of the STEM Review

September 2009

Contents

1 Foreword 4

2 Executive Summary 8

2.1 Business must take the lead in promoting STEM 12
2.2 We must alleviate key constraints in the STEM artery 13
2.3 There needs to be increased flexibility in the provision of STEM education 14
2.4 Government must better coordinate its support for STEM 15

3 Introduction 18

3.1 The Global Challenge in STEM 21
3.2 STEM and the Programme for Government 23
3.3 STEM and the Business Community 24
3.4 Background and Remit of the STEM Review 25
3.5 Methodology 25
3.6 Understanding STEM Supply and Demand 27
3.6.1 The Education Artery (STEM Supply) 29
3.6.2 The Economic Model (STEM Demand) 31
3.7 Audit of Existing Government Initiatives in Support of STEM 33

4 Global Perspective 34

4.1 Global Concerns over increasing mismatch in STEM supply and demand .. 35
4.2 The Recommendations of the MATRIX Review 38
4.3 Gender Imbalance 41
4.4 Addressing the Challenge of STEM 43
4.4.1 Republic of Ireland 43
4.4.2 Scotland 44

5 Review of the STEM Education Artery 46

5.1 Key Stages 1 and 2 47
5.2 Key Stage 3 49
5.3 Key Stage 4 and GCSEs 52
5.4 Post Compulsory Education 60
5.4.1 Post-16 and A - Levels 60
5.4.2 Further Education 66
5.4.3 Apprenticeships 73

5.5 Higher Education – First Degree 75
5.6 HE Postgraduate 82
5.7 STEM Migration Loss 85
5.8 Careers Education, Information, Advice and Guidance in Post-Primary Schools 88
5.9 Specialist Schools and Further Education Centres of Excellence 90
5.9.1 Specialist Schools 90
5.9.2 Further Education Centres of Excellence 91
5.10 Step-Up Programme 92

6 Further Constraints in the STEM Artery 94
6.1 Society's viewpoint 95
6.2 Business viewpoint 96
6.3 Coordination of STEM within Government 97
6.3.1 The STEM Review and MATRIX, the NI science Industry Panel 98
6.4 The Relative Attraction of the Public and Private Sectors 99
6.4.1 Comparing Benefits and Opportunities 100
6.5 STEM Market Failure 102
6.6 STEM Teacher Supply 102
6.6.1 Initial Teacher Education 103
6.6.2 Teacher Shortage 104
6.6.3 Distribution of STEM Teachers 105
6.7 Continuous Professional Development 107

7 Analysis of Projected Supply and Demand 110

8 Recommendations of the STEM Review 118
8.1 Business must take the primary role in promoting STEM 119
8.2 We must alleviate key constraints in the STEM artery 122
8.3 There needs to be increased flexibility in the provision of STEM education 125
8.4 Government must better coordinate its support for STEM 127

Annexes **130**

Annex 1: Terms of Reference for the STEM Review 131

Annex 2: STEM Subjects within Schools, Further Education and Higher Education 132

Annex 3: Membership of the STEM Review 138

Annex 4: Audit of Existing STEM Initiatives in Government 142

Annex 5: The Development of the NI Curriculum, 1989 - 2007 157

Annex 6: GCSE and A-Level, STEM Entries and Results in Selective and Non-Selective Schools 160

Annex 7: Subject Combinations Chosen at A Level, 1995 - 2005 162

Annex 8: STEM Enrolments and Qualifications in Further Education, 2001/02 & 2006/07 164

Annex 9: Higher Education Entrants and Retention 166

Annex 10: Initial Teacher Education and Supply 170

Annex 11: Local STEM Innovators 173

Annex 12: Abbreviations 174

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

This Review of STEM (Science, Technology, Engineering and Mathematics) was commissioned by the Department for Employment and Learning (DEL) and the Department of Education (DE) in spring 2007. The review panel was asked to examine the issues related to STEM and make recommendations to ensure the future success of STEM education within this region.

I would like to thank the panel members for the time and commitment they have shown in addressing these issues. They gave generously of their time to attend many meetings and seminars. Many panel members also took it upon themselves to delve deeper than was expected and put considerable efforts into preparing work for the other panel members.

I would especially like to thank Alan Blair for his commitment and dedication in finalising this report. Without his constant drive this report would not be possible.

The panel took upon itself to go beyond its initial terms of reference which had specified a review of STEM in schools and further education. By expanding the remit to include universities, this permitted the entirety of STEM education to be reviewed. In particular, the Review could then focus on the importance of the STEM artery to addressing the principal goal of the Programme for Government viz. growing a dynamic, innovative economy.

We moved from the traditional perspective of viewing STEM education as a pipeline to considering it as an artery with many branches. The word "artery" better conveys a sense of vitality and represents the many dimensions of STEM education.

In producing our Review we have consulted many organisations, including companies, professional bodies, trade associations, universities, colleges, schools and government departments. We have moved beyond our region to consult with our nearest neighbours in the UK and Ireland. We have collected their views about opportunities and constraints and listened to their experiences to help us draw up our recommendations.

The Review has built upon what we believe is an evidence-based appraisal of our STEM artery and, as you shall see, the STEM artery in this region has many strengths. There are trends however that we must seek to change.

We are releasing this report at a time of upheaval in the world economy. In the past, there have been upheavals such as the 'Telecoms bust' at the turn of the century.

Although the telecom companies picked themselves up relatively quickly, there continued to be a negative impact on uptake of careers in engineering which can still be seen today. More than ever we need to view this upheaval as an opportunity for the economy and for our pupils. Let's make sure when the dust settles we are in a stronger position to avail of the opportunities that will undoubtedly come for the STEM economy in the coming years.

Together with my colleagues I earnestly commend these recommendations for implementation.

DR HUGH CORMICAN
Chair, STEM Review

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

We might look at the introduction of the personal computer in the 1980s or the growth of the World Wide Web as ushering in the modern technological era but one thing is clear, as a society we are increasingly dependent upon technology and our economy reflects a growing dependence on technology based businesses.

Barriers of distance have been eroded; we live in a global society and our local businesses compete in a global economy. We are challenged daily by reports of climate change, and by moral dilemmas on stem cell research, genetically modified food, human variants of BSE and renewable energies.

As a society, we will rely increasingly on a good education in science, technology, engineering and mathematics (STEM) to help us understand all of these issues and to manage the rapid rate of technological change which we see around us.

As an economy, we are trading on a world stage against countries which have been pursuing the growth of STEM over an extended period of time. Our challenge is no different; we need a workforce with STEM qualifications if we are to sustain growth in our economy.

But we face a major hurdle. Like many other developed countries, our young people are increasingly disengaged from STEM which manifests itself in reducing enrolments in courses in those STEM subjects which will be critical to our future economic growth. We refer to this phenomenon as STEM fatigue and we see evidence of it from the early years of primary school and continuing throughout post-primary schools, further education colleges and universities. The natural consequence is a reducing flow of those who are qualified in STEM subjects at all levels into our workforce.

Against this backdrop, the Department of Education and the Department for Employment and Learning commissioned the STEM Review in 2007. The Terms of Reference were set broadly enough to permit an investigation of all the major issues currently impinging upon STEM education in the primary, post-primary and tertiary education sectors. The principal directive for the Review was to produce recommendations which are to promote sustained economic growth. This economic imperative was reflected in the membership of the various working groups which, in addition to a strong educational representation, comprised senior private sector representatives, industry representative bodies and Sector Skills Councils.

The Review is strongly evidence-based; we have consulted not only with the other regions in the United Kingdom, but also with the Republic of Ireland to gain from their experience in STEM. We have been guided on key issues by our working groups and have compiled a considerable body of evidence on each issue, as a basis for our conclusions and recommendations. The STEM Review complements the work of MATRIX, the Northern Ireland Science Industry Panel; close communication has been maintained between the two programmes.

Throughout the Review, we have considered the education system using the analogy of a STEM artery and sought to identify the constraints and losses at each stage in the artery. In addition to the general decline in uptake in STEM subjects, we have identified subtleties unique to our situation. For example, there is little planning at the primary/post-primary school interface in STEM which impinges upon pupils' progression at Key Stage 3. Furthermore, the relevant continuing professional development (CPD) undertaken by teachers and lecturers appears to be very limited. From a careers guidance perspective, insufficient time is allocated to planning for or providing careers guidance in the majority of schools.

While the uptake of STEM subjects within further education (FE) has increased overall, there is an ongoing decline in certain STEM subjects which will be important for economic growth. There are concerns about the success rate in certain STEM subject areas within FE, while the gender imbalance in engineering is markedly worse than the UK average.

Our performance in science at GCSE level in international student assessments is good, when compared with other countries, yet we have the largest spread between the higher and lower performing pupils of any country assessed. There has also been a significant change over this past decade in the way in which young people are combining STEM subjects at GCE A-level reflecting a cultural bias towards professions such as medicine. The uptake of physical sciences at GCE A-level is declining at a time when the other UK regions are responding to the recommendations of the Sainsbury Review for an increase.

Between 10% and 18% of STEM students at our local universities drop out at the end of the first year and migration loss remains a major issue with around 26% of NI domiciled students who graduate in STEM courses in the UK each year choosing not to live and work here following graduation.

STEM has not been as high on the policy agenda here as in other regions of the UK, and in the Republic of Ireland (RoI). To achieve our goals, as set out in the Programme for Government, this will need to change.

Perhaps most concerning is the potential shortfall in the workforce which we have identified from our examination of supply and demand. Despite the present recession, and the relatively low forecast growth, there appears to be a significant shortfall in the supply of those qualified in STEM subjects when set against the likely demand. The situation may be masked to some extent by the relatively higher numbers in medicine-related subjects by comparison with the low proportions in the core sciences, mathematics and engineering. The lower numbers in these subjects will present a particular barrier to growth within the Private Sector. Of concern also is the uptake of Level 3 apprenticeships in STEM areas which remains low.

In response to the challenges, we present our Vision, together with the recommendations which we believe will underpin its realisation.

Vision

Our Vision must inspire and energize us throughout our journey. It must open our eyes to what is possible and it must serve as the reference against which we will judge our progress and eventual success. We therefore offer the following as our Vision for STEM.

Vision

Empowering future generations through science, technology, engineering and mathematics to grow a dynamic, innovative economy.

We now present the 20 Recommendations which will support us in achieving this Vision. The recommendations are aligned under 4 major imperatives:

1. Business must take the lead in promoting STEM.
2. We must alleviate key constraints in the STEM artery.
3. There needs to be increased flexibility in the provision of STEM education.
4. Government must better coordinate its support for STEM.

2.1 Business must take the lead in promoting STEM

Business must take the lead role in firmly establishing STEM as the centre of a global innovative economy. Government, universities, FE colleges and schools need to support the initiatives but only business can provide the credible and strategic leadership to achieve the goals.

Recommendation 1 – Establish a business-led STEM framework

Business should develop and lead a framework of stakeholders which will engage directly with schools, FE colleges, universities and government to focus on growing the STEM artery across the education service and the promotion of STEM within our society.

Recommendation 2 – Develop a clear STEM careers path

Business, in conjunction with the Sector Skills Councils, professional bodies, DEL and DE need to develop and promote clear career paths for STEM students. Linking formally with the Careers Advisory Service, the pathway should identify the benefits of taking up apprenticeships, graduate and postgraduate education and the career opportunities available within the private sector.

Recommendation 3 – Introduce prestigious STEM scholarships

Business, professional bodies and DEL should introduce prestigious scholarships in STEM subjects for students entering FE and HE, targeted at retaining our most able STEM students following graduation.

Recommendation 4 – Address gender bias

Business, in conjunction with Sector Skills Councils, and in partnership with schools, colleges and universities, must address the issue of gender bias, particularly the disparity between the physical sciences and engineering on the one hand and the life sciences on the other.

Recommendation 5 – Develop regional STEM links

The framework to engage business should include mechanisms to join with STEM businesses in neighbouring regions and especially on the island of Ireland, to create a critical mass of larger businesses to promote STEM. In support, links should also be developed with DETI.

2.2 We must alleviate key constraints in the STEM artery

It is clear that we are in the fortunate position of having a strong education system. However, a number of constraints need to be addressed;

Recommendation 6 – Address the disparity in STEM performance amongst schools

There needs to be action focused on improving the performance of our poorer performing pupils in STEM, particularly in science and mathematics. Improving pupils' mathematical knowledge and the application of their mathematical skills will be a prerequisite.

Recommendation 7 – Support primary school teachers in teaching the area of learning, The World Around Us

As a matter of urgency, there needs to be a programme of support for primary school teachers to ensure they develop the confidence and enthusiasm to teach science in ways which motivate and engage pupils.

Recommendation 8 – Review developments in mathematics in relation to STEM provision

There is a need to review whether or not current initiatives are adequately addressing the development of mathematical knowledge and the difficulties experienced by many young people in applying their mathematical skills, which hinder their progress in science, engineering and technology. In particular, DE, DEL and CCEA should review how ongoing developments in GCSE mathematics will impinge on the provision being offered by schools, FE colleges and training organisations.

Recommendation 9 – Make STEM learning more enquiry based

Young people's STEM learning in schools, FE colleges and training organisations needs to be much more investigative and enquiry-based than it is now. The relevance of STEM in everyday life should be emphasized by all the key interests.

Recommendation 10 – Improve planning at the Key Stage 2 / Key Stage 3 interface

Post-primary schools and their feeder primary schools need to plan jointly to ensure that there is improved continuity and progression from KS2 to KS3, so that the teaching of STEM builds effectively upon the children's earlier learning.

2.3 There needs to be increased flexibility in the provision of STEM education

The provision of STEM education, more than any area, needs to be flexible to meet the changing demands of technology in the society and the workplace. We make the following recommendations:

Recommendation 11 – Increase the focus on the core sciences and mathematics subjects

STEM teaching resources, scholarships and grant assistance should be focused on the core STEM courses, viz physics, chemistry, biology, and mathematics to provide maximum flexibility and efficiency later in the STEM artery, to meet the changing demands of the economy. In addition, postgraduate subjects such as medicine should consider the implementation of a graduate stream to allow easier transfer from core science courses.

Recommendation 12 – Facilitate easier two-way transfer between FE & HE

Our local universities and FE colleges should introduce mechanisms to permit easier two way transfer, thereby allowing students additional time and space to choose between academic, technician, or apprenticeship style courses and providing alternative choices in the event of non-continuation; courses must sit within the qualifications and credit frameworks.

Recommendation 13 – Reduce barriers to obtaining support in STEM

Government, in conjunction with FE and HE, should review the financial support for students both full-time and part-time on all STEM courses.

Recommendation 14 – Develop a STEM CPD framework

There needs to be a clear CPD framework related specifically to STEM, which continues to update teachers, lecturers and support staff on STEM developments and issues globally and to promote best practice in respect of curriculum, pedagogy and assessment.

Recommendation 15 – Increase the emphasis on STEM CEIAG

There needs to be more resources allocated by business and government to Careers Education, Information, Advice and Guidance (CEIAG) for STEM. In support, formal links should be created between the business framework and the Careers Advisory Service.

2.4 Government must better coordinate its support for STEM

Although government has recognized the importance of STEM, its approach lacks coordination. We recommend the following actions:

Recommendation 16 – DE and DEL, supported by other relevant Government departments, should develop a clear STEM strategy & vision

Building on the Executive's Programme for Government to create a dynamic, innovative economy, DE and DEL, supported by other relevant departments, should develop a clear strategy for STEM recognizing the critical role of STEM and the skills required for sustained economic growth.

Recommendation 17 – DE and DEL, supported by other relevant Government departments, should introduce cross-departmental structures to help develop appropriate STEM strategies and policies.

The structures should include a Chief STEM advisor who would carry the educational responsibilities of a Government Chief Scientist and a National STEM Director.

Recommendation 18 – Develop a more proactive approach to managing STEM supply and demand

Government needs to be more proactive in managing the supply and demand of skills in relation to economic needs. To assist in this, DEL supported by other relevant departments should develop appropriate systems to better assess the flow of skills into the workforce at the various qualification levels, including the application of ongoing foresight.

Recommendation 19 – Increase the number of applications for physical sciences and mathematics places in Initial Teacher Education courses

DE, in partnership with Initial Teacher Education institutions, should continue to seek to increase the number of students entering Initial Teacher Education courses in the physical sciences and mathematics. Further research is required into the issue of STEM subjects which are taught by teachers without appropriate specialist qualifications.

Recommendation 20 – Expand the capacity to respond to critical skills shortages as they arise

DEL, in conjunction with business, should continue to develop and build upon its current initiatives to tackle skills shortages. This should include the application of foresight and knowledge of important emerging market opportunities.

If we are to bring about meaningful change, it is critical that the above recommendations receive the full support of the key stakeholders. Furthermore, those stakeholders must take the lead on certain recommendations as identified below.

Lead Stakeholder	**Recommendations**																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Business	■	■	■	■	■															
DE						■	■	■	■	■	■			■	■	■	■		■	
DEL								■	■		■	■	■	■	■	■	■	■		■
Other Government Departments																■	■	■		■

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

STEM is an acronym of science, technology, engineering and mathematics. Since these are subjects which can be interpreted broadly we offer, by way of guidance, a definition of STEM which we have set within the three main contexts of this review.

- **STEM in Education** begins with the early development of mathematical and scientific ideas in pre school education which are built upon in primary and post primary education. The pupils in the post primary sector all study mathematics to age 16 while they may choose from a variety of inter-related science/technology courses. Throughout, pupils are provided not only with knowledge of the subjects, but also develop investigative and problem-solving skills and an understanding of their application in the real world and their impact upon society. From post-16 through to tertiary level, young people are offered a wide portfolio of qualifications to meet their personal aspirations.

- **STEM in Society** is concerned with equipping the public with sufficient knowledge and understanding of issues relating to STEM so that they are enabled to make informed judgments on the many technological challenges facing them. It is important that they understand the contribution of STEM to everyday life and to the local economy through a vibrant private sector which offers rewarding career opportunities for young people. Society needs to be well informed of the possible uses of new technologies and the accompanying ethical and moral issues. As our politicians face the challenge of making decisions on emerging technological issues such as climate change, genetic testing, nuclear power, genetically modified food, cloning and embryo research, they need to consult and engage the electorate in an informed debate.

- **STEM in the Economy** is concerned with having sufficient people with the skills and knowledge required to grow STEM based businesses, leading to future economic growth and prosperity.

Barriers of distance have been eroded and our local businesses now compete in a global economy against countries which have much experience and expertise in growing STEM based businesses. A strong, STEM educated workforce will be fundamental to growing our economy for the following reasons:

1. Economic studies conducted before the information technology revolution, have shown that the vast majority of growth in per capita income is due to technological change[1].

1 R. M. Solow, Technical Change and the Aggregate Production Function, (The Review of Economics and Statistics 39, 1957) 312 – 320.

2. Studies have also highlighted how companies with qualified scientists and engineers in senior positions tend to invest in projects which bring a longer term benefit and have better performance[2].

3. The opportunity to attract Foreign Direct Investment (FDI) will be enhanced by a society with a work-force with good qualifications in STEM subjects.. Multinational companies cite access to qualified personnel as a major factor in developing off-shore operations[3] and this past decade has seen a move from traditional, capital-based investment to a more knowledge-based investment providing access to intellectual property[4].

However, like most OECD countries, we face a fundamental challenge; that of declining interest in, and uptake of, STEM subjects amongst our young people. As we will show, this decline begins in the latter years of primary education and continues through post-primary and tertiary education. It manifests itself in reducing enrolments in particular subjects at post primary level, and is creating a potential shortfall in the supply of those with STEM qualifications at the various levels required for the growth of the economy.

We must find ways to attract our young people into STEM education and ultimately into STEM careers. We must also provide a STEM education which fulfils three main functions if it is to equip citizens to be active members of the society in which we live:

- All pupils need to be equipped with the knowledge, skills and aptitudes required to engage purposefully with the science-related issues they will encounter as individuals and as citizens in a society increasingly shaped by scientific and technological advance; we term this 'STEM literacy'.

- Many pupils need to gain the further and higher education STEM qualifications and the world class skills required in an increasingly STEM-based business environment.

- A significant number of young people need to gain the education and world class skills required to invent and create STEM businesses here, and to help grow a dynamic and innovative economy.

---

2 H.C. Tan & D. Bosworth, Scientists and Engineers dynamic activities and business performance, (Manchester school of Management).

3 Booz, Allen & Hamilton, The Globalization of White Collar Work, 2007, *http://www.boozallen.com/media/file/Globalization_White_Collar_Work_v4.pdf*

4 J.P. Graham & R.B. Spaulding, Understanding Foreign Direct Investment, 2004, *http//www.going-global.com/articles/understanding_foreign_direct_investment.htm*

Figure 3.1 Functions of a STEM Education

In this Review, we examine the many issues which shape our STEM education and offer recommendations which will support the aspirations of a developing economy and guide STEM education through the coming decade.

3.1 The Global Challenge in STEM

The pace of economic and business change continues to accelerate rapidly around the world. Furthermore, we are seeing an eastward shift in economic strength which now threatens the traditional power base of the European Union, USA, Canada and Japan.

Goldman Sachs[5] projects that within 40 years the economies of Brazil, Russia, India and China (the so called BRICs) collectively could be larger than the combined strength of the former G6 nations– the United States, Japan, UK, Germany, France and Italy. Furthermore, India's economy could be larger than Japan's by 2032, and China could reach parity with the USA by 2041.

Technology, both as an enabler and as a product, will be at the heart of such growth and the rise in STEM education within these countries is on a staggering scale. China is expanding its university system and in 2004 awarded 2.1 million degrees of which 23,000 were doctorates, with a large proportion in STEM. In 2003, India awarded 13,700 doctorates with 40% of these in science and engineering. Collectively, Brazil, Russia and China turned out 90,000 PhDs in 2004 compared with 180,000 in the other OECD countries. China and India are investing heavily in their research base[6]; China's science spending trebled since 1998. In 2005, there were 1.1 million researchers in China, representing a growth of almost 60% in 5 years; investment in fields such as nanotechnology and stem cell research is already yielding results.

However, the quality of the education systems within China and India is forecast to remain behind that of the USA and the UK which, according to the Global Talent

5 Goldman Sachs, "Dreaming with the BRICs: The Path to 2050", Global Economics, Paper 99 (October 2003)

6 NESTA, Embracing the "threat" of India and China, 2006, *http://www.nesta.org.uk/embracing-the-threat-of-india-and-china/*

Index[7], are ranked first and second respectively in the world. Looking at several elements of that global ranking, compulsory education within the UK remains strong, while the quality of universities remains largely static in most countries. Indeed, we have to go to 153rd place in the world ranking of universities[8] before we find a university in China or India. However, there are already indications that the huge investment which China has made in higher education and in science will change this ranking markedly in coming years.

The significant economic growth in these developing countries provides opportunities and threats for our economy. On the one hand, it provides vast and growing trading opportunities from which we have the potential to benefit. However, it also highlights the pace at which the global economy is shifting towards a knowledge base and how quickly many of our trading partners are gearing up to profit from the opportunities presented by this global economy.

While we might view our relatively small size as a weakness, it does provide a unique opportunity to become efficient in implementing and managing the changes necessary to grow our economy. STEM will be at the heart of any growing economy of the future and unless we aggressively pursue a coordinated STEM agenda, we will fall behind.

Conclusion 1 – Compete Effectively

We are competing in a global economy against other major economies which are already implementing their respective STEM strategies. We need to use our small size to our advantage through an efficient approach to STEM which follows a clear direction in support of the economy and engages all key stakeholders.

7 Heidrick & Struggles, Global Talent Index – 2007-2012, http://www.weknowglobaltalent.com/gti/window/gti/

8 Shanghai Jiao University, Top 500 World Universities, 2004, http://ed.sjtu.edu.cn/rank/2004/top500list.htm

3.2 STEM and the Programme for Government

The Programme for Government (PfG)[9] has set "growing a dynamic, innovative economy" as its top priority and it articulates the actions necessary to achieve this and its other strategic priorities within twenty-three Public Service Agreements (PSAs).

Although STEM is recognized as a key enabler, with some targets featuring throughout the PSAs, the central role which STEM can play and its coordination are not addressed in the PSA document. For example, a key goal of halving the private sector productivity gap with the UK average will rely strongly upon people with the necessary STEM skills.

Gross Value Added (GVA) will be influenced by research and development (R&D), innovation and scientific management[10], all of which require a supply of graduates with appropriate STEM skills. Similarly, the goal of 6500 new jobs, with salaries above the Private Sector Median, implies professional positions, many of which will be filled by applicants well-qualified in STEM. A starting point of our Review, therefore, will be to consider the dynamics of educational supply and economic demand within the context of the PfG.

The STEM Review also links to the Skills Strategy[11] and the Regional Innovation Strategic Action Plan (RISAP)[12]. For example, the Skills Strategy sets a target of 10,000 apprenticeships by 2010; we will review the current position of this later. The Strategy also considers the potential for a graduate sponsorship scheme to retain our best young people, which is also a key recommendation of the Review.

The RISAP is more explicit regarding STEM, as related to Imperative 4 of the Plan. STEM curriculum resources, careers guidance, primary school initiatives and specialist schools are amongst various specific STEM actions which are reflected in the findings of this Review.

The STEM Review strongly complements the work of MATRIX, the Northern Ireland Science Industry Panel. Through its Horizon Programme, MATRIX has examined five key sectors, identifying those technologies and markets that could create significant social and economic benefits for our economy. As STEM will be fundamental to enabling such growth, the two reviews have communicated closely throughout. The economic future presented by MATRIX will not be achieved without the supply of STEM skills and knowledge, while the attraction of young people into STEM education will require a vision of exciting, future career opportunities within a growing economy.

---

9 NI Executive, Programme for Government 2008 – 2011, http://www.pfgbudgetni.gov.uk/index/programme-for-government-document.htm

10 Department of Enterprise, Trade and Investment, NI Economic Bulletin, 2007, http://www.detini.gov.uk/cgi-bin/downutildoc?id=1955

11 Department for Employment and Learning, Skills Strategy for Northern Ireland, 2004, http://www.delni.gov.uk/skills_strategy_for_northern_ireland-2.pdf

12 Department of Enterprise, Trade and Investment, Regional Innovation Strategic Action Plan, 2008 – 2011

The key recommendations of the MATRIX report will be discussed in Section 4.2.

Conclusion 2 – Vision and Strategy

Government requires a coordinated vision and strategy for STEM to underpin the Programme for Government.

3.3 STEM and the Business Community

The private sector has a leading role to play in the implementation of a STEM strategy. This is well understood by the individual companies, business representative bodies and Sector Skills Councils involved in the Review and there is recognition now, more than ever, of the need to grow our supply of STEM skills.

Business must be involved in all aspects of a STEM strategy, from partnering with primary schools to develop the children's interest, through supporting careers guidance, facilitating CPD for teachers and lecturers, developing skills with schools, FE colleges and training organisations and engaging with the universities in joint research programmes. But, as we will see, the business community recognizes that it needs to coordinate better such engagement if it is to be truly effective in growing the supply of young people with STEM qualifications.

There is also a broader aspect, that of promoting STEM awareness across society in general. Business has a key role to play, not least in creating awareness amongst parents of the existence of a vibrant STEM private sector offering exciting career opportunities for their children. Parents' perceptions of the private sector are frequently limited which quickly becomes apparent when discussing their children's choice of subjects and career aspirations.

Conclusion 3 – Business not coordinated

The Business community has a clear role to play in the implementation of a STEM strategy but there is currently no suitable mechanism to coordinate this activity.

3.4 Background and Remit of the STEM Review

Although we have strengths within our education system at all levels, the PfG will place increased demands upon the supply of those who are well educated in STEM subjects. We are operating within a global economy, competing with other countries who are actively examining their STEM policies as they recognize the importance of STEM to their economy. In many cases we are "playing catch up", therefore we must be more responsive in addressing the challenges we face.

However, in common with many western countries we face a fundamental challenge; that of declining interest in, and uptake of, certain STEM subjects by students. As we will show, this decline begins in the latter years of primary education and continues through post-primary and tertiary education, manifesting itself in reducing enrolments and giving rise to a potential shortfall in the supply of people with STEM qualifications at the various levels required for the growth of the economy. This decline will be further exacerbated by the declining age cohort[13]; there will be a reduction of 5% in year 12 pupil numbers between 2007 and 2013.

In response to these concerns, the Department of Education (DE) and the Department for Employment and Learning (DEL) jointly commissioned the STEM Review in spring 2007 with the remit of examining the issues contributing to the decline and to develop recommendations which would guide STEM education into the future. A primary emphasis for the Review was that the recommendations should be guided by the future needs of a growing economy.

The Terms of Reference for the Review, as presented by DE and DEL, are shown in Annex 1. The Steering Group, during its initial meetings, further agreed that

- The Review should include education at all levels from primary to tertiary level, including postgraduate study.
- Subject areas which constitute STEM within the education system should be clearly defined as these would be used as a basis for analysis under the Review (see Annex 2 for agreed list).

3.5 Methodology

The Review has sought to determine if STEM education is well positioned to support the necessary growth in our economy as we look to 2015 and beyond. Where it is not, the key constraints are identified and strong, evidence-based recommendations are presented.

13 Department of Education, Northern Ireland Schools Census, 2006/07

We have drawn upon the PfG, together with other key economic perspectives, as we have attempted to develop a composite picture of future STEM needs within the economy. This picture has been used to assess any potential imbalance in supply and demand for STEM skills.

A substantial database on enrolments, qualifications, exam performance, subject combinations, gender balance, student retention and migration has been developed with support from the statistics staff in DETI, DEL and DE and comparisons have been carried out with other regions where data was available. The data reviewed focused on school, college and university outputs sourced largely through DE and DEL.

The Review has examined key influencing factors such as Initial Teacher Education (ITE), teacher supply, continuing professional development, student attitude, business links, careers guidance and salary levels, with additional research provided by members of the Review. Further research was commissioned with external bodies as necessary.

Since the issues related to STEM are many and diverse, members of the Review have been drawn from a broad cross-section of stakeholders across the public and private sectors. In terms of structure, the Review comprised a Steering Group supported by three working groups as follows.

- Business-Led Working Group
- Government-Led Working Group
- Education and Training Inspectorate-Led Working Group

The membership of the Review is shown in Annex 3.

It was clear from an early stage that we share many STEM challenges with western nations. Since other regions within the UK had already developed their STEM policies, it would be important to learn from their experiences. Understanding the reasons behind the decisions which they took might guide the final recommendations of this Review.

Relationships were established with appropriate bodies such as the Scottish Executive, the National Science Learning Centre and, in particular, the RoI, where Forfás provided advice and guidance about their experiences in the role of STEM in developing the economy. Links were forged with professional bodies in the RoI and in England, and much valuable experience was gained which helped shape the recommendations of this review.

Two STEM workshops were held which brought together all those involved in the Review - an initial meeting in November 2007 and the second in May 2008. These

workshops provided an opportunity to debate key issues within the Review, to seek consensus on the direction being taken and to identify early recommendations.

3.6 Understanding STEM Supply and Demand

The role of STEM in growing a successful economy is undeniable. In Section 3.1, we highlighted the growth in STEM education within Brazil, Russia, India and China; the so called BRICs. The National Governors Association[14] , which is the collective voice of the school governors of the USA, has similarly echoed the critical role of STEM in economic development, stating,

> America's economic growth in the 21st century will be driven by our nation's ability to generate ideas and translate them into innovative products and services. A strong consensus is emerging among scientific, business, and education leaders that America's ability to innovate and compete in the global marketplace is directly tied to the ability of our public schools to adequately prepare all of our children in STEM.

How well does our supply of STEM skills match our future aspirations for economic development?

The All Island Skills Study[15] has examined skills needs in the north and south of Ireland and identified, for example, shortages of engineers of all types and shortages in financial services. These findings are complemented by the report 'Building Ireland's Knowledge Economy'[16] which identifies the need to "attract the necessary extra researchers to perform the increased levels of R&D required in enterprises and in the science base".

Within the UK, the Engineering Technology Board[17] has highlighted the low proportion of intermediate skills in the workforce (the UK ranks 20th out of 30 OECD countries) and expresses concerns about the future source of professional technicians. The outlook is arguably worse for our economy as the report by Oxford Economics[18] identifies that we have even lower proportions of these intermediate skills in our workforce.

SEMTA[19], the Sector Skills Council for Science, Engineering and Manufacturing Technologies, reports that engineering skills at Level 4, and below, are lower here

---

14 National Governors Association, 2007, Building a Science, Technology, Engineering and Math Agenda.

15 Expert Group on Future Skills Needs and Northern Ireland Skills Expert Group, All-Island Skills Study, 2008, *http://www.delni.gov.uk/all-island_skills_study.pdf*

16 Building Ireland's Knowledge Economy, July 2004

17 Engineering Technology Board, 2007, Engineering UK 2007

18 Oxford Economics, 2009, Forecasting Future Skills Needs in Northern Ireland

19 SEMTA, Skills Action Plans by Sector, *http://www.semta.org.uk/about_us/media_centre/skills_action_plans_by_sector.aspx*

than elsewhere. In its report 'Biosciences Gap Analysis – Northern Ireland', SEMTA highlights the divergence of supply and demand here for first degree graduates.

The Institute of Directors[20] has stated, in its briefing paper on education, that many of its members are affected by "shortages of graduates in particular disciplines, particularly the STEM subjects".

The foregoing examples are clear evidence of the shortfall that exists between STEM supply and demand, a shortfall that, in certain sectors, is increasing. In the following sections, we will see that quantifying this shortfall is a difficult process.

The STEM educational supply is highly complex with many influencing factors, constraints and losses along the way. When we include the numbers of courses on offer, the transfer of students between institutions, their movement across subjects and mature entry from the workforce, exact tracking of students becomes increasingly uncertain.

Predicting the STEM demand is extremely difficult when considering the variety of industry sectors within the uncertainties of the economy, the growth potential and the changing skills requirements within each sector.

Bringing these two imprecise pictures together to assess the current position, let alone to project the future supply and demand of STEM skills, is a very challenging undertaking. If we are to manage the process of delivering skills and knowledge to our economy, we must understand the dynamics of supply and demand. The risk of uncertainty in our analysis is, therefore, outweighed by the need to add some colour to the challenges we are facing.

In the following sections, we will consider supply and demand separately. We will then bring these together in Chapter 7 in order to present an overview of the supply - demand balance.

Conclusion 4 - Better STEM monitoring systems required

Matching skills demand and supply implies both a sufficiency of qualification and numbers flowing into the economy. However, on this latter issue of flow, current systems are not adequate to allow an accurate picture of STEM supply and demand requirements to be drawn.

20 Institute of Directors, www.iod.co.uk

3.6.1 The Education Artery (STEM Supply)

The STEM Supply is complex and might be imagined as an artery which, by definition, is a "main channel or highway, especially of a connected system with many branches". Using the analogy of an artery helps convey a feeling of its importance to our modern day society and economy.

A representation of the STEM supply artery is shown in Figure 3.2, with some of the major losses and constraints highlighted.

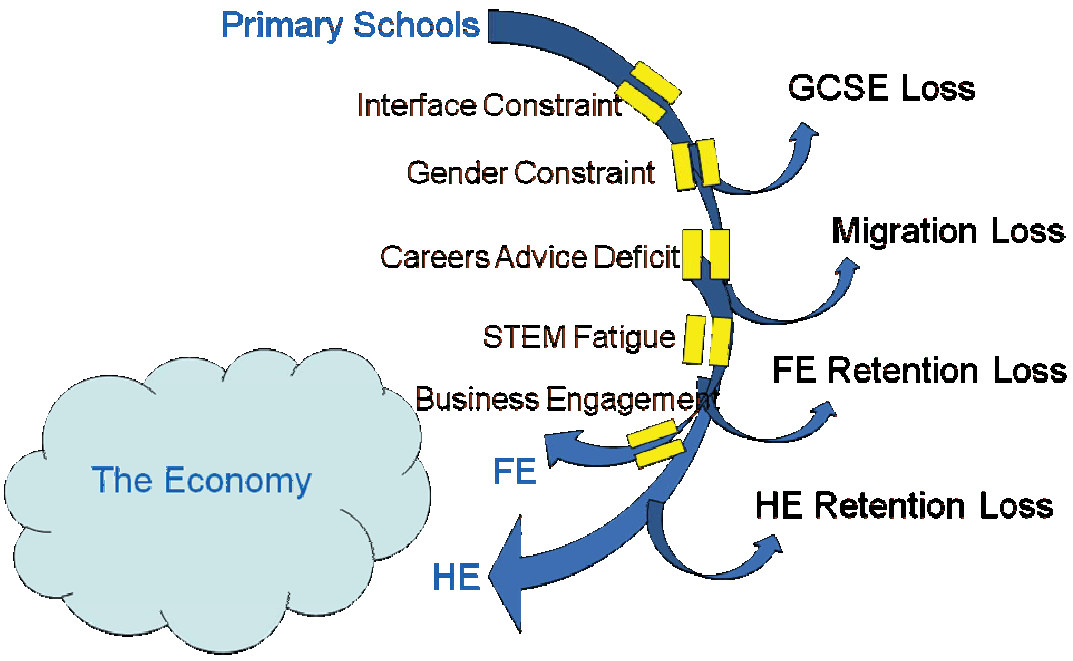


Figure 3.2 STEM Educational Artery

There is a range of comprehensive data on the performance of students at the various stages within the education system and this information is presented in Section 5. However, what has been less easy to quantify, is the flow of students between institutions and those entering the workplace.

For example, students reaching the end of compulsory education at age 16 may choose either to continue in school or commence further education or enter the workplace. Students entering further education may do so at different levels as defined within the National Qualifications Framework[21] (NQF). The following summarises these levels in respect of further education.

21 QCA, Changes to the National Qualifications Framework, 2004, http://www.ofqual.gov.uk/files/nqf_changes.pdf

- Level 1 – equivalent to GCSE grades D – G
- Level 2 – typically a BTEC First Diploma which is equivalent to GCSE grades A* – C
- Level 3 – typically a BTEC National Diploma which is equivalent to GCE A Levels
- Level 4/5 – equivalent to BTEC Higher Nationals / Foundation Degrees

Direct entry to any of these levels is dependent generally upon prior qualifications. For example, entry to a National Diploma in engineering typically requires a minimum of 4 GCSEs at grade C or above including mathematics, English, and one science-based subject, plus one technology-based subject.

But entrants to FE will also include adults from the existing workforce who wish to upskill or who may have been economically inactive for a period of time. Estimating the numbers progressing between levels within FE is further complicated by students leaving and re-entering study, transferring between courses, entering the workforce and, for an increasing number of FE students, entering university here and in GB. To track students effectively is a major challenge and we rely on school leaver data which is at best incomplete. Consequently, predicting the supply of people entering the workplace has a high level of uncertainty.

The Skills Strategy and the PfG both identify the need for a better match between skills supply and skills demand. This implies a need both to match the provision of training and education with business needs and to assess if the numbers flowing into the workplace are sufficient to meet forecast demands of the various business sectors. Such data will permit a better assessment of short and medium term actions in line with a "demand-managed" approach, as opposed to a "demand-led" one.

Within the DEL Research Agenda[22] actions are identified to establish tracking studies for young people aged 16 to 24 and for FE leavers to assess outcomes. This offers the potential for better tracking of FE graduates which, with improved demand forecasting, may permit a better understanding of the dynamics of supply and demand.

As we analyze the STEM supply artery in the following sections, one of the benchmarks we will use will be the relative number of students here compared to those in the UK overall, for given subjects. To benchmark the student numbers we have normalised the figures by adjusting them by the respective population numbers. The population figures we have used are estimates from mid-2007[23] and are shown in Table 3.1.

---

22 Department for Employment and Learning, Research Agenda 2007 – 2009, *http://www.delni.gov.uk/researchagenda0709final.pdf*

23 Office of National Statistics, Population estimates mid 2007 UK, England and Wales, Scotland and Northern Ireland, 2007, *http://www.statistics.gov.uk/statbase/Product.asp?vlnk=15106*

NI	UK
1,759,100	60,975,400

Source: ONS

Table 3.1 Population Estimates, mid-2007

In Section 5, we examine the STEM supply artery in detail and compare it with forecast demand, when we consider the supply – demand position in Section 7.

3.6.2 The Economic Model (STEM Demand)

Whilst we recognize the importance of STEM to the economy, and in particular its role in driving R&D, we need to put a shape to the future need for STEM skills if we are to compare supply and demand.

The PfG sets broad growth targets for the economy, identifying for example Compound Annual Growth Rate (CAGR) targets in the manufacturing and tradable services sectors and, more generally, Business Expenditure on R&D (BERD) targets in Invest NI client companies. Since the PfG was launched, however, the world has entered a period of major economic downturn and the impact of this change upon the growth targets set within the PfG remains to be seen.

The challenge has been to develop a credible picture of demand given the present economic uncertainty. We initially drew upon various local and national economic analyses, in particular the Working Futures Report[24], supported by the Labour Force Survey and the 2001 Census of Population. However, these analyses were developed prior to the economic downturn and hence incorporate growth scenarios which are no longer achievable, at least in the medium term.

A report prepared by Oxford Economics[25] on future skills needs here has recently been completed. Commissioned by DEL, the research is grounded in the present recession and examines the need for skills under two economic scenarios, a baseline scenario and an aspirational scenario. The aspirational scenario is based upon achieving the PfG's target of halving the private sector productivity gap with the UK average (excluding the Greater SE) by 2015. Comparisons are also made with the findings of the Leitch Review[26].

The Oxford Economics report highlights the steady improvement in skills levels over the last decade, which has helped place our economy 'within the pack' of UK regions in terms of graduate concentrations. We are above the Welsh and industrial Midland

24 Institute for Employment Research, University of Warwick, Working Futures Report 2004-2014, Spatial Report, 2006, *http://www.findfoundationdegree.co.uk/wfspatialreport.pdf*

25 Oxford Economics, February 2009, Forecasting Future Skills Needs in Northern Ireland

26 Lord Leitch, Prosperity for all in the global economy – world class skills, 2006, *http://www.hm-treasury.gov.uk/leitch_review_index.htm*

regions, in this regard, but below the RoI, London and countries such as Canada and Finland. It is predicted that the economy will continue to transform towards more 'skills-hungry' sectors and occupations, relying on exports as a source of demand rather than on consumers and government, as in past years. Whereas in recent years people qualified at NQF Levels 4 – 8 (sub-degree, first degree and postgraduate) represented a third of the requirement from education, this will rise to a half in future years.

The Working Futures and Oxford Economics reports both project these future needs by taking account of the forecast expansion of the labour market and also the replacement demand. Replacement demand is much larger than expansion demand, and is that which is required to fill vacancies created by people leaving employment for the following reasons:

- Leavers to death and retirement;
- Leavers to unemployment and inactivity;
- Leavers to other occupations / sectors; and
- Leavers to outward migration.

Table 3.2 summarises the longer term projections of each of the two reports and, as can be seen, the replacement demand is typically much larger than the demand created by any of the possible growth scenarios. The nett annual requirement for people entering employment varies from ~21,000 to ~28,000.

Report	Expansion Demand	Nett Gross Replacement Demand	Nett Requirement from Education & Migrants	Nett Annual Requirement
Working Futures 2004 - 2014	28,000	254,000	282,000	28,200
Oxford Economics Baseline 2010 - 2020	55,700	152,600	208,300	20,830
Oxford Economics Aspirational 2010 - 2020	79,700	157,700	237,400	23,740

Source: (see references)

Table 3.2 Projected Annual Requirements

The Oxford Economics report also considers the short term impact of the downturn. It predicts that, through 2010, there will be a negative annual expansion demand of -2,100 which, coupled with a nett annual replacement demand of 16,700, will give rise to an annual requirement of 14,600. This is significantly lower than the longer term nett annual requirement given by Table 3.2.

The reports also predict the demand for skills, based upon an analysis of the change during the preceding years. The workforce of the future will be significantly more highly skilled than the current workforce and, as may be seen in Table 3.3, the reports generally agree on the projected balance of qualifications.

Qualification Level	Average 2005-2007	Working Futures 2004 - 2014	Oxford Economics Baseline 2010 - 2020	Oxford Economics Aspirational 2010 – 2020
Postgraduate level (NQF 7-8)	7.0%	9.1%	8.8%	9.4%
First Degree and Sub-degree (NQF 4-6)	32.0%	31.0%	41.6%	44.5%
Intermediate a (NQF 3)	21.2%	23.4%	26.0%	26.7%
Intermediate b (NQF 2)	18.3%	22.3%	9.4%	17.6%
Low (NQF 1 and below)	21.5%	14.2%	14.2%	1.8%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: (see references)

Table 3.3 Forecast Annual First Degree Requirement, 2010 - 2020

In Chapter 7 we examine the forecast demand in terms of STEM requirements and compare that to the STEM supply.

Conclusion 5 – Increasing demand for higher level STEM skills

The future economy will be increasingly 'skills-hungry' and the demand for NQF Levels 4-8 will rise from a third of education leavers to a half.

3.7 Audit of Existing Government Initiatives in Support of STEM

If we are to develop effective recommendations within this Review, we must understand the starting position. In other words, which of the existing initiatives within the various government departments currently support the growth of STEM?

Annex 4 presents the results of an audit carried out by DETI for the Review. Included within the data is: the lead government department; the policy or programme name; how the initiative supports STEM; and the level of funding allocated. As we can see, there is a significant level of activity which already exists, and on which we need to recognize and build upon in any future plans for STEM.

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

The pace of economic and business change continues to accelerate rapidly around the world. Furthermore, we are seeing an accelerating eastward shift of economic strength which now threatens the traditional power base of the European Union, USA, Canada and Japan. The development of China, India and Brazil will continue to alter the balance of power as we have already discussed in Section 3.1.

STEM will continue to be at the heart of change, both as an enabler and in the products created. The cost of technology is declining each year, as can be seen in the prices of consumer goods, such as digital televisions and computers. Billions of people can now afford technology; by the end of this decade it is predicted that 2 billion will own mobile phones with web browsers. Furthermore, as a society, we have come to view technological change as the norm and to expect that each new consumer good will provide us with a convenience to further enhance our lifestyles.

Given the increasing role which STEM will play in the world economies, we now examine some of the global issues concerning STEM and look at how some neighbouring countries are presently addressing the challenges.

4.1 Global Concerns over increasing mismatch in STEM supply and demand

STEM jobs are high value adding and are fundamental to the growth of our economy. A recent US Department of Labor study[27] estimated that the STEM workforce accounts for more than 50% of the nation's sustained economic growth. Furthermore, STEM jobs will stimulate employment in other fields, such as business and professional services, further increasing their positive impact on the economy.

Despite the present period of recession, we may look to employment estimates prior to the downturn to compare the growth of STEM occupations, relative to all others. Table 4.1 shows predicted increases in STEM-related occupations for NI[28], the UK[29] and the US[30]. We note from the NI figures that STEM jobs have been estimated to grow on average at around 8 times the rates of non-STEM jobs.

While it may be several years before we move back towards the actual growth figures shown in Table 4.1, the prospect for increasing STEM-related jobs is undeniable.

27 US Dept of Labor, The STEM Workforce Challenge, April 2007, *http://www.doleta.gov/Youth_services/pdf/STEM_Report_4%2007.pdf*

28 Institute for Employment Research, University of Warwick, Working Futures Report 2004-2014, Spatial Report, 2006, http://www.findfoundationdegree.co.uk/wfspatialreport.pdf, (Table 14.2)

29 Institute for Employment Research, University of Warwick, Working Futures Report 2004-2014, National Report, 2006, http://www.findfoundationdegree.co.uk/wfnationalreport.pdf, (Table 4.3)

30 US Bureau of Labor Statistics, National Industry-Occupation Employment Projections 2004-2014, 2004

Projected employment growth in STEM occupations from 2004 to 2014	NI	UK	US
science and Technology Professionals	14%	18%	26%
Health Professionals	14%	28%	22%
sciences & technology Associate Professionals	15%	12%	20%
Health Associate Professionals	22%	8%	29%
All other Occupations	2%	2%	13%

Source: (see references)

Table 4.1 Comparison of Projected Employment in STEM related Occupations

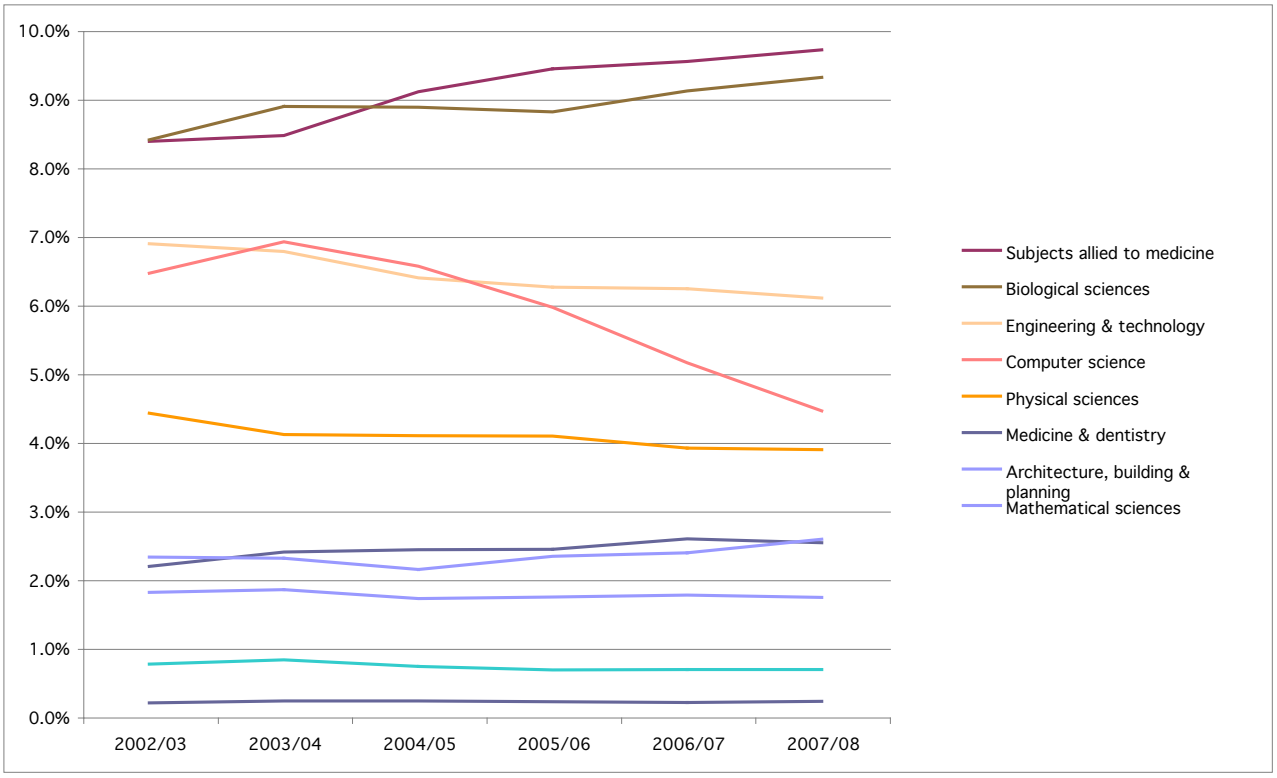
Against the prospect of increasing STEM-related jobs, many western countries are concerned about a weakening of science and technology within their societies which will erode the ability of their citizens to compete for high quality jobs, leading inevitably to a degradation in social and economic conditions.

We have termed this phenomena STEM fatigue, examples of which can be seen in economic powers such as the USA[31] and the UK[32]. The effect of STEM fatigue has been a reduction in the numbers of students enrolling in STEM subjects, at a time when economies are projecting a growth in STEM jobs.

Figure 4.1 illustrates the main changes in UK STEM first degree graduations for the past six years, as a percentage of total graduations. We see that, although the overall number of STEM graduations has only fallen slightly, there are major changes within STEM subjects. While there have been considerable increases in medicine related areas and biological sciences (especially psychology), there has been an equally significant decline in the physical sciences, engineering and computer science.

31 National Academy of Sciences, Rising above the gathering storm: Energizing and Employing America for a Brighter Economic Future, 2007

32 HESA, Students and Qualifiers Data Tables, 2002-2007 *http://www.hesa.ac.uk/index.php?option=com_datatables&Itemid=121&task=show_category&catdex=3*



Source: HESA

Figure 4.1 UK First Degree Graduations for STEM subjects 2003 – 2008

Another indicator of STEM fatigue is the most recent Relevance of Science Education (ROSE[33]) project. Based at the University of Oslo, the project surveyed, by questionnaire, 15 year olds in some 40 countries. What makes this research interesting is that the data shows a strong inverse relationship between the United Nations Human Development Index (HDI) for a country and ROSE's scores for that country. In other words, the higher the level of development of a country, the lower the interest its young people express in learning about science, or following science-related careers.

As the report suggests, there may be a cultural dimension to pupils' disengagement from science. Young people, as they struggle to develop self-identity and social relationships in advanced societies, may perceive that the value systems of science are at variance with the value systems of contemporary youth culture.

33 Relevance of Science Education, http://www.ils.uio.no/english/rose/

Over 800 pupils from schools here answered questions relating to their attitudes to school science and their career aspirations in the sciences. Responses were broadly in line with those for the rest of the UK, Ireland and other participating western countries.

The natural consequence of the factors described will be an increasing gap between supply and demand. Economic growth will either not be achieved at the rate desired or will, most certainly, not be sustainable. Many countries have recognized this and are pursuing STEM strategies aggressively in an attempt to attract more young people into STEM subjects and ultimately STEM careers. Those who do this effectively will reap the benefits to society of sustained economic growth.

Conclusion 6 – Need to address STEM Fatigue

The latest ROSE study shows that there is a cultural dimension to young people's increasing disengagement from STEM which is evident in all developed countries. It is essential that strategies to address this disengagement are prioritized so that greater numbers of young people are attracted into STEM subjects and ultimately STEM careers. Countries that implement effective strategies will achieve and sustain strong economic growth.

4.2 The Recommendations of the MATRIX Review

MATRIX[34], the Northern Ireland Science Industry Panel, was established in 2007 with the primary remit to map out a preferred future for an innovation-based economy, capable of competing with the best in the world. The guidance provided would assist DETI and the DETI Minister in developing policies to maximise the economic return from the exploitation of science, technology and R&D over the next 2 – 10 years.

Following an initial study to assess technology capabilities and potential market opportunities, MATRIX established its Horizon Programme. Five technology sectors were identified which were considered to be of the "highest economic significance in the Regional Innovation Strategy for Northern Ireland", taking account of previous foresight exercises. An expert panel was established in each sector

34 MATRIX, the Northern Ireland Science Industry Panel, http://www.matrix-ni.org/

and recommendations developed to maximise the future "science to market" commercialisation opportunities within each.

The following summarises briefly the key market opportunities and recommendations arising from each of the five Horizon panels.

Life & Health Sciences

- Two overarching opportunities identified; personalised medicine and home-based care.
- Personalised medicine is the use of genetic information to tailor detection, treatment or prevention of disease, while home based care refers to the remote exchange of a patient's data from his/her home to a response centre.
- The global market for personalised medicine is expected to grow to $250 billion.
- The home based care market in the US will be $4.5 billion by 2010, the UK market share being $286 million.

ICT

- Three key focus areas identified: Packaged Application Software; Nearshoring and High Performance Embedded Systems.
- Packaged Application Software provides opportunities in markets such as Global Financial Services and Telecommunications.
- Nearshoring places a focus on decision-making based services as opposed to transaction based services.
- Further development of High Performance Embedded Systems will provide opportunities in a broad range of sectors including Automotive, Aerospace and Security Solutions.

Agri-Food

- Five potential leadership areas identified.
- Differentiated/Functional Food: the use of pharmaceutical techniques to produce food with a health benefit.

- Innovative Process & Packaging: to improve food safety and shelf-life, and reduce preservation costs.
- Enhanced Consumer Knowledge: to provide assurance of quality to the customer.
- Leveraging computational science: to better model food and processes.
- Releasing Embedded Energy in the sector to improve productivity.

Advanced Materials

- Five key areas have been identified which collectively serve to underpin success in other sectors. These are: Biomaterials; Nanostructured Materials; Multifunctional Materials; Composites, and the computational science necessary to model and analyze these materials accurately.

Advanced Engineering (Transport)

- This final area embraces four key market opportunities. These are: environmentally optimal products; design for passenger safety & security; ease of lighter, stronger and more affordable materials; and efficient supply of more complex, customised and innovative solutions, combining products and services.

The MATRIX report served to inform the STEM Review in a number of key areas, not least in confirming that future economic success will be built upon a multidisciplinary approach, which will look at the interactions across traditional business sectors. MATRIX has not attempted to predict the demand for specific future STEM skills, nor is this necessary, since we can see that every sector will require a mix of these skills. However, what is critical is that we develop a solid base of STEM skills, which will support growth of the economy by companies leveraging market opportunities as they arise.

The STEM Review reflects this thinking in its examination of supply and demand for STEM skills. We have not attempted to analyze the situation by individual subject area, for example, the number of chemists required. Rather, using current local and national forecasts of economic growth, we have examined the supply-demand balance of people at specific STEM educational levels, for example the number of STEM graduates required at Level 4.

This approach was discussed in Section 3.6 and will be further expanded upon in Section 7.

4.3 Gender Imbalance

Despite women outnumbering men in education around the western world[35], women are under-represented in STEM subjects, as shown in Table 4.2.

% Females obtaining university first degrees in selected countries and regions	All university first degrees	All STEM	Field of university first degree				
			Sciences	Mathematics/ computer science	Agricultural sciences	Social sciences	Engineering
Japan	38%	23%	29%	24%	45%	27%	11%
Ireland	55%	43%	57%	37%	34%	73%	20%
Northern Ireland	61%	57%	49%	30%	72%	69%	21%
United Kingdom	54%	40%	52%	27%	56%	58%	15%
United States	57%	50%	55%	33%	46%	63%	21%
Europe	55%	39%	51%	32%	47%	57%	20%
World	52%	38%	51%	34%	42%	48%	19%

Table 4.2 Percentage of Females Studying STEM Subjects in Selected Countries and Regions[36]

There are subtleties of gender bias within the STEM subjects themselves, for example, more women choose sciences and social sciences than choose mathematics and engineering. Even the sciences, which collectively show near parity, have an underlying bias, with ~60% of women choosing biological sciences versus 22% choosing physics.

Many scientists agree that what prompts this imbalance is a result of both nature and nurture[37]. It has been variously suggested that boys prefer physics or mathematics which they see as more individual pursuits while girls prefer biology which they see as more collaborative[38]. Alternatively, cultural influences within family, school and society[39] may create negative stereotypes which contribute to girls opting out of STEM subjects and STEM-based careers.

35 Closing the gender gap in education, The Economist, Nov 1st 2007, http://www.economist.com/world/international/displaystory.cfm?story_id=10064829

36 National Science Board, International S&E Higher Education, 2004, http://www.nsf.gov/statistics/seind04/c2/c2s5.htm

37 The New York Academy of Sciences, The Nature and Nurture of Women in Science, 2005, http://www.nyas.org/ebriefreps/main.asp?intEBriefID=445

38 Washington Post, Decoding Why Few Girls Choose Science, Math, 2005, http://www.washingtonpost.com/wp-dyn/articles/A52344-2005Jan31.html

39 H. Zhu, Education & Women's Career Choices, 2006, http://www.wallnetwork.ca/resources/Zhu%20_Women_IT_Education_Career_Choices_WALL2006.pdf

The gender bias appears to start at an early age, with boys and girls showing discernable differences in attitudes even in primary school; girls liking biology-related areas and boys preferring physical science-related areas. Interestingly, girls are generally more positive than boys about science at Key Stage 2[40] but this trend is reversed at Key Stage 3. The bias is masked, to some extent, by a common curriculum until KS4 when pupils start to express their preferences through the subjects they choose for GCSE. We then start to see an increasing bias, as young people progress towards employment.

Not surprisingly, women's representation in the STEM workforce mirrors the decreasing proportional representation in the education artery. A recent survey by the Engineering Technology Board identified that of women who graduate with a first degree in science, engineering or technology, only 27% pursue a career in these fields compared with 54% of male graduates.

Science and research roles attract the majority of women, while only a minority of around 5% choose to work as engineering professionals. The lowest participation by women is in the skilled trades which will be reflected in the uptake of professional and technical qualifications in further education, as discussed in Section 5.4.2.

Conclusion 7 – Need to address Gender Imbalance

Gender bias is a problem shared across most developed economies and considerable female talent is being lost from the STEM artery. This is ultimately leading to low female representation in the STEM workforce, with Engineering attracting the lowest percentage of STEM women professionals.

40 C. Murphy, Primary Science in Northern Ireland – A Position Paper, April 2008

4.4 Addressing the Challenge of STEM

In developing our vision of STEM, we are playing "catch up" with other countries and other regions of the UK. If we consider the USA, the National Governors Association[41] has identified key strategies to promote the uptake of STEM and has initiated various programmes. Closer to home, the RoI and Scotland have developed STEM policies and strategies, together with the supporting infrastructures needed to drive their implementation. In order to learn from their experiences, and to identify any lessons appropriate to our situation here, relationships were established in both cases. The following briefly summarises how each jurisdiction has approached the challenge of STEM.

4.4.1 Republic of Ireland

The RoI has developed a broad Science Strategy[42] for the period 2006 – 2013 which addresses the STEM artery, from the primary years through to industrial research. Key actions include: continuing professional development (CPD); careers guidance; developing teacher networks; and promoting science awareness. Forfás is the national policy and advisory board for enterprise, trade, science, technology and innovation and the relevant powers are delegated through Forfás to its sister agencies:

- Enterprise Ireland - for the promotion of indigenous industry;
- IDA Ireland - for the promotion of inward investment;
- Science Foundation Ireland (est. 2003) - to provide strategic support to scientists, engineers and academic researchers.

Forfás has three key Advisory Councils: the National Competitiveness Council; Expert Group on Future Skills Needs and Advisory Council for Science, Technology and Innovation. This latter group is hosted by Forfás on behalf of the Office of Science & Technology. Its National Integrated Awareness Programme was launched in 2003 and, for 2007; it has a budget of €5M and a team of 8 staff. Key objectives include:

1. To increase the numbers of students studying the physical sciences;
2. To promote a positive attitude to careers in science, engineering and technology; and
3. To foster a greater understanding of science and its value to Irish society.

---

41 National Governors Association, 2007, Building a Science, Technology, Engineering and Math Agenda

42 Committee on Science, Technology and Innovation, Strategy for Science, Technology & Innovation, 2006, *http://www.entemp.ie/publications/science/2006/sciencestrategy.pdf*

4.4.2 Scotland

Scotland's original Science Strategy[43] was launched in 2002, largely as a result of the evolving bias amongst students towards medicine and related subjects. Agencies were tasked with delivering their respective elements of the strategy; a review was carried out in 2004 to evaluate progress. An updated science Strategy was subsequently released in 2005 and it is understood that further revisions are underway.

A Chief Scientific Adviser (CSA) was appointed in 2006, with the task of raising the science base, identifying niche market opportunities and improving the outreach to society, in respect of science. A particular focus of the Office of the CSA has been to engage politicians in the science scene. For example, events have been organised to debate science issues, chaired by Ministers or their representatives.

A key focus for the coming period will be the development of forums to better manage the approach to science funding, bringing together partners such as the Wellcome Trust, Shell, BP and the Royal Society.

43 Scottish Executive, A Science Strategy for Scotland, 2002, *http://www.scotland.gov.uk/Resource/Doc/158401/0042918.pdf*

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

The school curriculum will be at the core of an effective STEM education and we will frequently refer to it in the following sections. Since its introduction in 1989, there have been several major milestones and various amendments to the curriculum. Annex 5 provides a summary of its evolution.

5.1 Key Stages 1 and 2

Primary education is split into three age groups: Foundation Stage, covering years 1 and 2; Key Stage 1, covering years 3 and 4; and Key Stage 2, covering years 5 to 7.

The quality of our primary schools, teachers and education is generally good, despite concerns expressed over funding relative to the rest of the UK[44]. However, research shows a noticeable decline in pupils' interest in science during the primary years, which is a major concern, given that this is a critical time in developing a child's enthusiasm and sense of wonder for science and technology.

The largest research study[45] on pupils' perceptions of primary school science was conducted in 2000/2001, involving over one thousand 8 to 11 year olds from 44 schools here. Key findings included:

- Children in Yr6 and Yr7 complained of not doing enough experiments, doing too much writing and boring and repetitive revision for the Transfer Test;
- Girls were shown to have a more positive attitude to science at Key Stage 2 but this trend is reversed at Key Stage 3; and
- Teachers identified making science more relevant to children's lives as the single most important factor in improving science.

Studies by the Wellcome Trust[46] have revealed that a lack of knowledge, expertise, confidence and training is the most frequently reported issue facing primary teachers in their science teaching. Those who had undertaken professional development were significantly more confident to teach science than those who had not. Teachers here were more negative about the resources for science than teachers in other UK regions.

While these were not extensive studies and were carried out prior to the introduction of the Revised Curriculum, the work of the present review suggests that the issues remain to be addressed. Discussions with Initial Teacher Education representatives

44 NI Assembly Debate, 9 June 2008, http://www.theyworkforyou.com/ni/?id=2008-06-09.10.1

45 C. Murphy and J. Beggs, "Children's perceptions of school science", School Science Review 84, 308

46 Wellcome Trust, Primary Science in the UK: a scoping study, April 2005, http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtx026636.pdf

have confirmed that, year on year, science is the subject which primary school teachers report they have low confidence in teaching.

Changes currently underway will have a significant impact upon children's primary education. First, the Revised Curriculum is in the process of being implemented and will reduce the prescribed content, placing a much greater emphasis on the acquisition of skills and capabilities alongside knowledge and understanding. The curriculum encourages creativity and numeracy; in particular 'Using Mathematics' has been introduced as a cross-curricular skill which will be assessed and reported to parents.

Science will be delivered at the primary level through the learning area called 'The World Around Us', which includes geography, history and science & technology. Primary school teachers indicated previously that this is the area of the curriculum that they feel the least confident in teaching[47], a natural consequence of which is a considerable variation in children's education, given the expansive nature of the subject. This in turn risks a degree of repetition in teaching at Key Stage 3, as we highlight in the next section.

The second major change is the removal of the Transfer Test. This has potential for positive change in the teaching and assessment of primary science, by allowing science to be taught in a way which is more open and less constrained by tests. Removal of the test could provide an opportunity to assess primary science in a more formative manner, which supports learning; provided that the opportunity is taken.

Much useful development work in primary science teaching has been undertaken by the National Science Learning Centre in York University and the Discover Science and Enginering Programme in the RoI. Ways of building upon these initiatives need to be developed.

Conclusion 8 – Need Greater Support for Primary Curriculum

There are major issues relating to the teaching of science and technology in the primary curriculum which need to be addressed. Research indicates that the primary phase is a crucial time, when children develop a sense of wonder and enthusiasm for science and technology: however, currently too many pupils develop negative attitudes to science and practical and investigative approaches are underdeveloped. The "World Around Us" has the potential to make science more relevant and exciting, but the indications are that many primary teachers may lack the knowledge, skills and confidence to deliver a science and technology programme which develops progressively the children's skills and knowledge.

47 AstraZeneca Science Teaching Trust, New Approaches to Primary Science Teaching and Assessment, 2008

5.2 Key Stage 3

Key Stage 3 refers to the first three years of post-primary education here encompassing Years 8, 9 and 10.

There is strong evidence to suggest that Key Stage 3, together with Key Stage 2, is the critical period when a child's attitudes to science[48] are developed. Musgrove and Batcock[49] (1969) showed that one third of students studying science and engineering at the University of Bradford said they had made the choice to study science by the age of 12 and had stuck to it.

The revisions to the curriculum are also being implemented in Key Stage 3, with similar reductions in statutory minimum content and a greater emphasis on the knowledge and skills that young people need to be effective as individuals and citizens in a modern technological society. This change offers an opportunity to combat the stronger decline in liking for science[50] that occurs in Key Stage 3, compared with Key Stage 2.

One cause of decline appears to be the degree of widespread repetition of primary school science teaching occurring in Key Stage 3. Conscious of inconsistencies between primary schools[51], post-primary school science teachers often repeat much of what had already been taught at Key Stage 2 to ensure all children are 'up to speed'. A six-year longitudinal study[52], surveying post-primary teachers' planning for primary/post-primary curricular continuity and progression in 50 schools across Northern Ireland, revealed that little account was taken of, or attempt made to build upon, pupils' earlier learning in science. It will be important that action is taken to address any remaining discontinuities.

We may see from Figure 5.1 that the issue of declining interest is more acute for girls than for boys; by the end of Key Stage 3, boys were found to like science more than girls, while pupils in non-selective schools were found to enjoy science more than those in selective schools. We can see that the subject with the greatest decline in enjoyment at Key Stage 3 is physics.

---

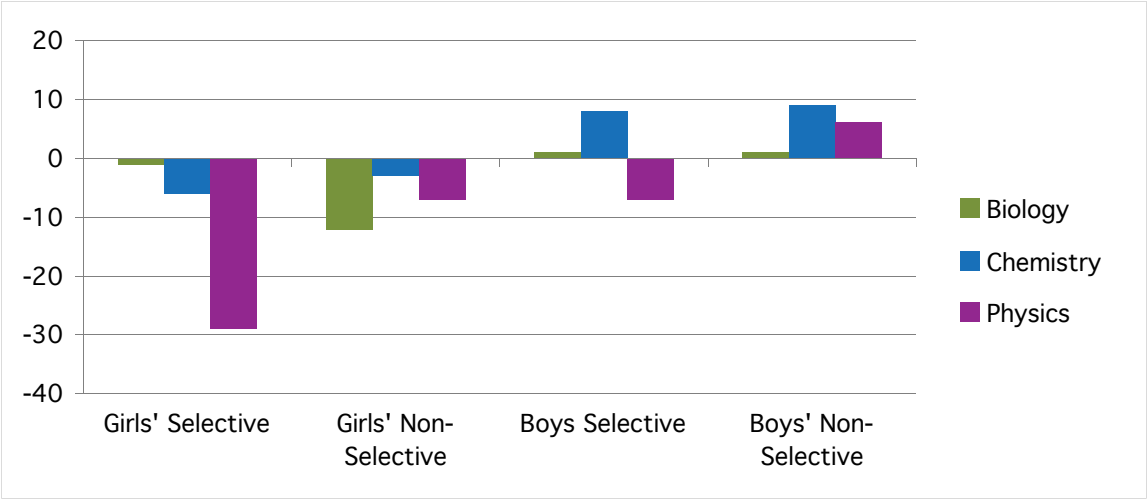
48 C. Murphy, Primary Science in Northern Ireland – A Position Paper, January 2008.

49 F. Musgrove and A. Batcock, "Aspects of the Swing from Science", British Journal of Educational Psychology, (1969)

50 E. Donnelly, 2001, Management of Science Education during Key Stages 2 and 3, MEd Thesis, Queen's University, Belfast

51 CASE Report, Science Education in Northern Ireland's Schools, 2006, *http://www.savebritishscience.org.uk/documents/2006/CaSE0613b.pdf*

52 R. Jarman, 1997, "Fine in Theory: A Study of Primary-Secondary Continuity in Science, Prior and Subsequent to the Introduction of the Northern Ireland Curriculum", Educational Research, 39 (3) 291-310



Source: QUB Dept of Education

Figure 5.1 Change in Enjoyment of sciences from Primary to Secondary Level

Conclusion 9 – Need greater curricular coordination for STEM

There is little joint planning between primary and post-primary schools in the STEM subjects. Consequently KS3 pupils often repeat work which they mastered at primary school, and there is a risk of insufficient emphasis on the relevance of STEM at a time which many consider to be critical in forming a child's interest.

As part of the Numeracy Strategy, which was launched in 2001 within the School Improvement Programme, both primary and post-primary schools were required to appoint a Numeracy Co-ordinator (NC) with responsibility to lead on the aspects of the school's Numeracy Policy, two of which were:

- The responsibility which every member of staff has for developing numeracy;
- The ways in which numeracy is promoted across all the areas of the curriculum.

In 2006, the Education and Training Inspectorate evaluated the Numeracy Strategy[53] and concluded that in a majority of post-primary schools, 'numeracy across the curriculum' was an area for improvement. In particular, the use of examples from science and technology to enhance the teaching and learning in mathematics was underdeveloped.

In 2006, the Inspectorate carried out a review of post-primary mathematics provision[54]. The report concluded that there was a need to use a greater variety of activities and experiences in order to improve the pupil's mathematical thinking and understanding. This report, and a subsequent publication,[55] promotes a pedagogy which is in line with research findings[56]. Namely, mathematics teaching is more effective when it is interactive, problem-based and involving collaborative activities. In addition, when it links mathematics with other subjects, particularly science and technology, using realistic contexts and problems, not only do standards rise but attitudes to mathematics improve[57].

The assessment of the cross-curricular skill, 'Using mathematics,' becomes a statutory requirement in KS3. While the models of how schools will assess this are still developing, the expectation is that evidence in relation to this skill can be drawn from science and technology subjects. Importantly, mathematics teachers will have the responsibility to ensure that their pupils can apply the mathematical skills they acquire in mathematics classes to a range of familiar and unfamiliar contexts, including those relating to STEM.

Conclusion 10 – Greater variety of interaction in mathematics

Mathematics teaching is more effective when it is interactive, problem-based and involving collaborative activities, linking also with science and technology.

53 Education & Training Inspectorate, 2006, The Quality Assurance Report of the NI Numeracy Strategy

54 Education & Training Inspectorate, 2006, Better Mathematics: evaluations and prompts for self-evaluation and improvement in post-primary schools

55 Education & Training Inspectorate, August 2007, Commentary on post-primary mathematics teaching

56 The SCRE Centre, University of Glasgow, November 2006, Review of the NINS: Final Report

57 Black et al, King's college, London, 2006, Survey of Existing research into attitudes to mathematics and related areas

The revisions to the Curriculum, with the emphasis on relevance, employability and economic awareness, could make a major contribution to maintaining pupils' positive attitudes to STEM and promote their achievement. However, this will require issues of continuity and progression in the primary and post-primary curriculum to be effectively managed within the more open framework of the Revised Curriculum.

5.3 Key Stage 4 and GCSEs

Key Stage 4 is Year 11 and Year 12, at the end of which pupils take GCSE examinations. The revisions to the curriculum for Years 11 and 12 became statutory from September 2007 and September 2008 respectively. These revisions are intended to provide a balanced and broadly based curriculum which:

a) Promotes the spiritual, emotional, moral, cultural, intellectual and physical development of pupils at the school and thereby of society; and

b) Prepares such pupils for the opportunities, responsibilities and experiences of life by equipping them with appropriate knowledge, understanding and skills.

Unlike the position with the curriculum in the rest of the UK and Ireland, science has ceased to be a compulsory subject here.

In Figure 5.2, we compare the GCSE STEM entries here with those of the UK overall. We have taken account of the population difference by firstly normalising each set of entries as a percentage of their respective populations (see Table 3.1) and comparing the relative values.

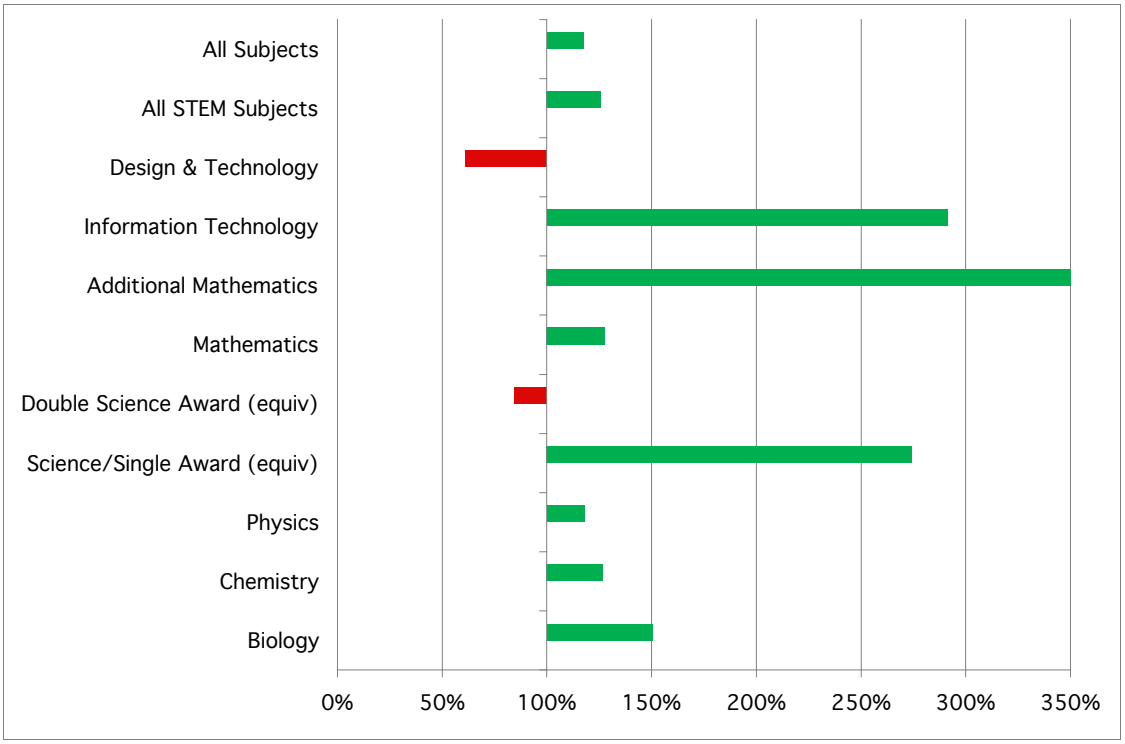
Looking first at 'All Subjects' and 'All STEM Subjects' entries, we can see that there is reasonable parity with the whole of the UK, when we compare entries as a percentage of the respective populations. While proportionately entries here appear slightly higher, there are some major differences within the individual subjects.

The relative entries for design and technology are lower than the UK, which is disappointing given the considerable investment in design and technology resources in schools here. By comparison, the relative entries for information technology are much higher than in the rest of the UK.

Entries in additional mathematics are also much higher here, than in the rest of the UK, but there are indications that the UK numbers are rising, possibly as a result of the Further mathematics Network[58] (FMN). The FMN has 46 centres across England, each

58 The Further Mathematics Network, http://www.fmnetwork.org.uk/index.php

with a local manager who works with local schools and colleges to promote the study of AS/A-level mathematics and further mathematics. The FMN has a focus also on supporting mathematics at GCSE level.



Source: Joint Council for Qualifications

Figure 5.2 NI – UK Comparison of GCSE Entries for STEM Subjects, 2007/08

With reference to Figure 5.2, biology entries here have risen sharply as a result of changes to the curriculum and this is reflected in the entries relative to the UK. Chemistry and physics have also increased but to a lesser extent, while the relative uptake of double award science is lower at around 84% of the UK total. The changes to the curriculum will be discussed in more detail below.

The uptake of single award science here is of particular concern, being almost three times larger than the relative uptake in the UK. While this subject is designed to provide an appreciation of important 'Science and Society' issues, it was never intended to have a sufficient science content to allow pupils to continue into STEM education post-16 in schools or FE colleges. Thus pupils studying this course are a major loss to the STEM education artery and as we see in Table A6.1, single award science is taken predominantly within non-selective schools.

Regarding the 'equivalence' term against double award and single award in Figure 5.2, CCEA is the only awarding body now offering double award science and single

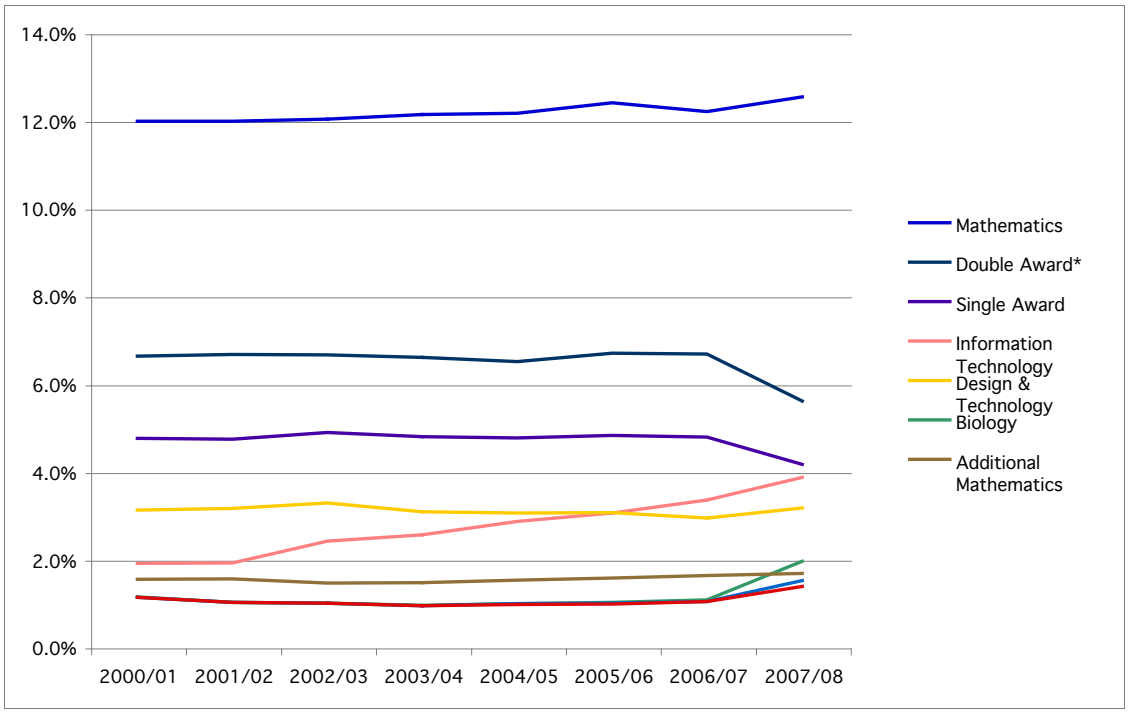
award science at GCSE. AQA (The Assessment and Qualifications Alliance) has replaced its double award science and single award science with a suite of new science qualifications of which science A/B and additional science are the dominant qualifications in the rest of the UK. Science A and B equate to the CCEA single award science while additional science, which must be taken together with science A or B, is the nearest equivalent to the previous double award science. In addition to GCSEs in biology, chemistry and physics, AQA also offers a GCSE in applied science which is described as a vocational path and also a GCSE in additional applied science which is taken with science A or B and which appears to have a vocational context.

The trends in GCSE entries here between the academic years 2000/01 and 2007/08 are presented in Figure 5.3. Subject entries are shown as a percentage of total GCSE entries during any given year to take account of the declining year 12 cohort; entries have fallen by ~7% from a maximum of 195,433 in 2003/04.

With reference to Figure 5.3, between 2000/01 and 2006/07 subject entries followed general trends which saw declines in the individual sciences and also design and technology. Information technology increased substantially during this period.

But it is 2007/08 which is particularly significant as this was the first year pupils took GCSEs following the removal of the requirement to study a balanced science course. In other words, pupils could choose individual sciences whereas they were previously required to study all three sciences, known as the triple award. With reference to Figure 5.3, entries in double award science fell by 16% between 2006/07 and 2007/08, while the entries in biology rose by over 80%. Chemistry and physics rose by 46% and 33% respectively.

Although these increases are at first sight encouraging, it raises the immediate question as to how pupils are combining subjects and what this will mean for progression to further STEM qualifications and ultimately a STEM career. This places an even greater emphasis on ensuring pupils receive sound careers guidance in relation to STEM and the progression routes open to them.



Source: DENI

Figure 5.3 Trends in NI STEM GCSE Entries, 2001 – 2008

Interestingly, the Sainsbury Review[59] noted that the chance of getting an A or B in A-level chemistry increased by 76% for pupils who take three separate science GCSEs rather than studying double award science. This was a factor in the recommendation to Government that it should continue its drive to increase the numbers studying three separate sciences at GCSE.

Table 5.1 compares the GCSE results of pupils here with those of the UK and it may be seen that the quality of our STEM education is good. However, while our achievement rates in biology, chemistry and physics were better than the UK average in 2005/06 and 2006/07, this is not the case for 2007/08. Our performance in biology and chemistry has fallen by around 2% in each subject while the UK performance has improved between 2% and 3% in biology, chemistry and physics. As a consequence, we now lag behind the UK achievement in each of the core sciences.

Single award science remains an issue of particular concern, with 48% of the entrants receiving a grade 'D' or lower.

59 Lord Sainsbury, October 2007, The Race to the Top: A Review of Government's Science and Innovation Policies, http://www.hm-treasury.gov.uk/d/sainsbury_review051007.pdf

GCSE Subjects	NI Results % A*-C	UK Results % A*-C
Biology	90.9%	91.1%
Chemistry	92.4%	94.0%
Physics	91.3%	93.5%
Science/Single Award	51.5%	43.9%
Double Science Award	83.3%	63.6%
Mathematics	61.6%	56.3%
Additional Mathematics	91.7%	68.9%
Information Technology	85.0%	68.3%
Design and Technology	70.3%	61.2%
All STEM	73.3%	63.2%
All Subjects	74.5%	65.7%

Source: Joint Council for Qualifications

Table 5.1 Comparison of GCSE Results, 2007/08

Conclusion 11 – Step change in uptake of individual sciences and double award science

Entries in the individual sciences increased significantly in 2007/08 as a result of the removal of the requirement for a balanced science. Conversely, double award science declined markedly.

The percentage of pupils here achieving grades A* - C in biology and chemistry declined from 2006/07 while the results for the rest of the UK rose by around 3% in each subject in 2007/08.

In comparing the performance of our GCSE students it is worth taking time to consider our standing against an international benchmark. The Programme for International Student Assessment (PISA) is organised by the OECD to survey the educational achievement of 15-year-olds in OECD member countries and other major countries in the world every three years. Science, mathematics and reading are the three subject areas assessed, with each in turn becoming the major subject area for successive surveys. In 2003, the major subject was mathematics while in 2006 it was the turn of science.

In PISA (2006)[60], a total of 57 countries participated including 30 OECD members and 25 European Union members. 107 schools participated from here and the results[61] can be reviewed as a subset of the national results. Looking first at science achievement, and with reference to Table 5.2, pupils here performed well and had a mean score which was higher than the OECD average. Nine of the 57 countries surveyed had mean scores which were significantly higher than the scores of our students.

Student Achievement Category	Science	Maths
No of countries with mean scores significantly higher than NI	9	18
No of countries with scores statistically similar to NI	15	12
No of countries with mean scores significantly lower than NI	32	26

Source: PISA 2006

Table 5.2 PISA 2006

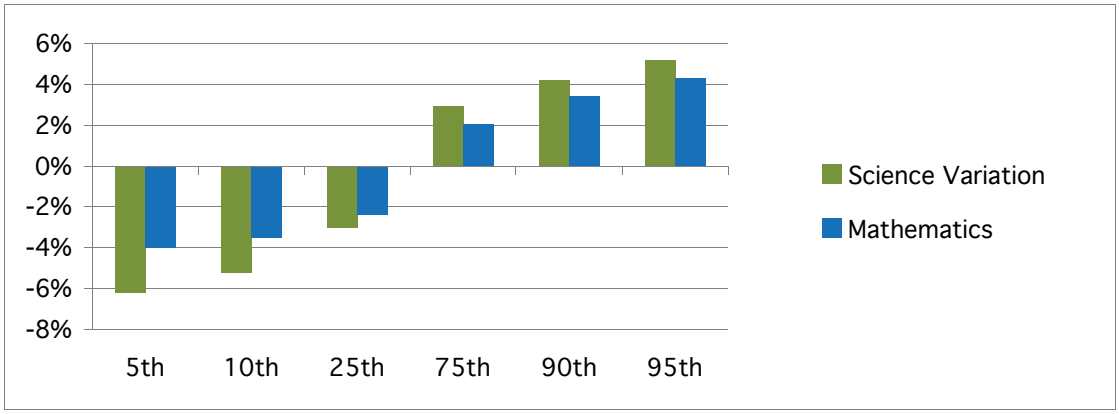
However, while our performance in science was encouraging, we had the highest spread of attainment of all the countries participating, meaning that we have a substantial 'tail' of low-scoring students in science. By comparison, the RoI has a much narrower spread of attainment, being close to the OECD average in science and much lower than the OECD average in mathematics. The spread of attainment in mathematics here was close to the OECD average, but was wider than in other UK regions.

Although a minor subject in 2006, the results for mathematics still provide a valid comparison of achievement in the countries surveyed. With reference to Figure 5.2, the mean score of our pupils was not statistically different from the OECD average and placed us in a group of 12 countries which included the RoI.

Figure 5.4 compares the spread of attainment between our students and those of the RoI in both science and mathematics, the values at each percentile representing the difference in variation from the mean score for each country. Taking science in the 5th percentile for example, the scores of pupils here exhibit a variation from the mean which is over 6% greater than that for the RoI.

60 Programme for International Student Assessment (PISA), 2006, http://www.pisa.oecd.org/

61 Bradshaw et al, 2007, Student Achievement in Northern Ireland: Results in science, mathematics and reading among 15-year-olds from the OECD PISA 2006 study, http://www.nfer.ac.uk/publications/pdfs/downloadable/PISANorthernIreland.pdf



Source: PISA 2006

Figure 5.4 Distribution of PISA Scores of NI relative to Ireland

We can see that while pupils in the 75th percentile, and above, score better than the RoI in science and mathematics, those in the 25th percentile, and below, underscore significantly.

Conclusion 12 – Large spread in STEM performance

The PISA 2006 comparisons shows that while our science performance is strong, we have the largest variation between best and worst performing pupils of all countries surveyed. Although we do not rank as high in mathematics, the spread in our performance is much closer to the OECD average. However, our spread in mathematics is higher than the RoI and also other regions of the UK.

Comparing the uptake of the individual sciences, research[62] has shown that mathematics is a contributory factor in the relative unpopularity of physics and chemistry. Physics was considered difficult by 23% of those interviewed, largely because of the mathematical aspects of the subject. 35% considered chemistry difficult, citing the mathematics but also the chemical formulae and equations. The new strategy for numeracy is intended to address the difficulties which young people experience in progressing in science and technology.

62 R. Jarman, L. McAleese and B. McConnell, 1997, A Survey of Science at Key Stage 4, Queen's University of Belfast

Currently, there is debate nationally over GCSE mathematics and whether all of the statistical subjects should be included or whether there is a need for a double award or a higher mathematics course. While the former consideration is of lesser importance here, it is important that we consider our position and curriculum in regard to the latter consideration, particularly as most selective schools currently offer CCEA's additional mathematics to their higher attaining pupils.

Conclusion 13 – Performance in mathematics is impacting physical sciences

The role of mathematics in the physical sciences is important and the relatively less strong performance in mathematics could be impacting physics and chemistry which are considered difficult due largely to the mathematics content.

In terms of attitudes, pupils generally sustain their level of interest in science from Key Stage 3 to Key Stage 4. However, interest was shown to be significantly higher when courses involved practical work, including undertaking investigations independently of the teacher. NISEF[63] has similarly emphasized the importance of cross-curricular projects to help students relate science to the outside world.

The Review felt it appropriate to consider whether there were obvious trends in lower levels of GCSE performance in areas of social need. Taking guidance from the 2005 Deprivation Analysis[64], it was noted that the correlations between educational access, attainment and income was very high. On this basis, an analysis was carried out of the GCSE grade levels attained in the 57 post-primary schools which ranked highest according to their entitlement to free school meals.

Representing 25% of all post-primary, it transpired that all 57 schools were non-selective. It was therefore considered appropriate to compare the aggregated data for the 57 schools with that of all non-selective schools, to determine if there were any observable differences in attainment.

Double Award science and mathematics were chosen as comparator subjects and the results are shown in Figures A6.1 and A6.2 respectively, in Annex 6, based upon 2006/07 data. As may be observed, while the grade attainment in those schools

63 NI Science Education Forum, May 2005, A Scientific Future for Northern Ireland, Report from the Science Futures Conference

64 Northern Ireland Neighbourhood Information Service, www.ninis.nisra.gov.uk

eligible for free school meals is slightly lower, the difference is no more than 3% to 4% at any one grade. No doubt this difference would have increased had we examined the top 10 schools in receipt of FSM awards, but the intent was to identify if social deprivation was having a marked effect on the STEM supply; this does not appear to be the case.

Conclusion 14 – Areas of social need not showing marked reduction in STEM performance

An examination of the impact of social need, as identified by free school meals entitlement, shows a slightly lower performance in STEM subjects in the 25% of schools reviewed. However, this is not having a marked impact on overall numbers in STEM.

5.4 Post Compulsory Education

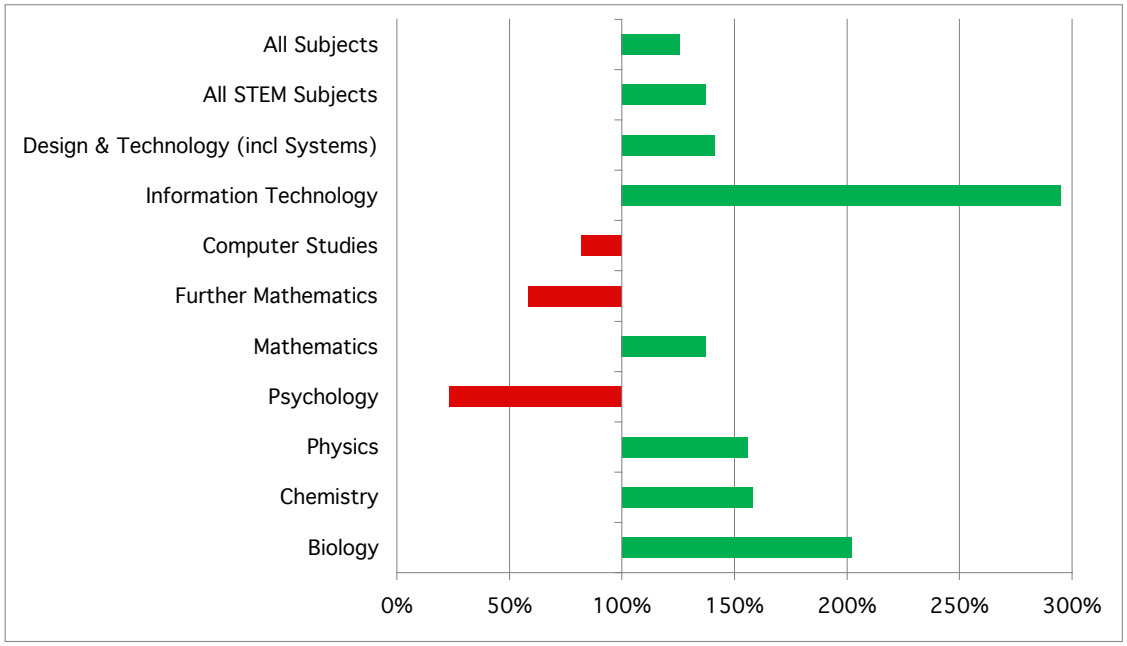
Following completion of Key Stage 4, students may choose from several education paths. They may continue to A-level or vocational courses, transfer to further education or enter the workplace to pursue education through work-based learning and/or an apprenticeship.

The following sections consider the issues associated with each of these paths.

5.4.1 Post-16 and A - Levels

'Post-16' in schools here is considered to be Year 13 and Year 14.

If we compare the uptake of STEM subjects here with the UK as a whole, we may see from Figure 5.5 that, as a percentage of the respective populations, we have a higher proportion of pupils studying STEM at A-level. For example, there are approximately 37% more pupils studying 'All STEM Subjects' here than in the UK as a whole.



Source: Joint Council for Qualifications

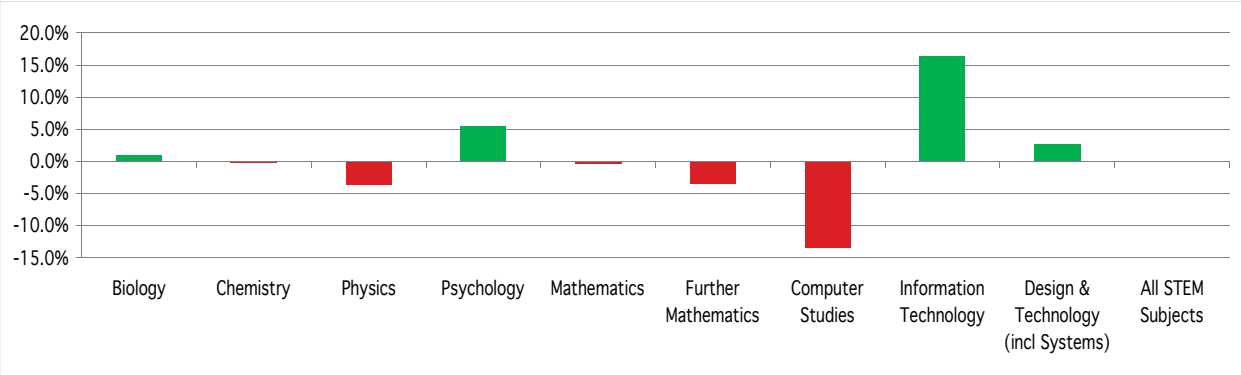
Figure 5.5 NI – UK Comparison of A-Level Entries for STEM subjects, 2007/08

Two subjects in particular are not well represented; psychology and further mathematics. As psychology is a relatively new subject here, the result is not surprising. The relatively low uptake of further mathematics however is a disappointment, considering our strong performance at GCSE, but may be in part due to the increase in entries in the rest of the UK. The Further Mathematics Network within England may be having an impact upon numbers at A-level, with the entries for the UK for 2007/08 showing an increase of ~16% over the previous year. Further mathematics offers a significant advantage to students who study engineering and physical sciences later in university; it is unfortunate that more students do not avail of this subject.

Despite the relatively strong proportions of pupils studying STEM here, the picture is less positive when we look at the annual trends in STEM subject entries in the period 2001 – 2008. Although total STEM entries rose by ~9% during this period, total subject entries increased by the same proportions. It was therefore considered appropriate to examine the change as a proportion[65] of STEM subject entries rather than actual numbers.

65 A-level subject entries in any given year have been normalized against the total A-level entries for that year and the annual change then calculated based upon a "least squares" approach

With reference to Figure 5.6, while the proportion of all STEM subjects has remained relatively unchanged, there are some disturbing trends in individual subjects.



Source: DENI

Figure 5.6 Annual Trends in STEM A-Level Entries, 2001 – 2008

Physics and further mathematics have been declining between 3% and 4% per annum with the largest decline being in computer studies at ~-14%. To put this in perspective, this represents a total decline of ~20% for both physics and further mathematics and ~90% for computer Studies over this seven year period.

By comparison, psychology has been increasing at ~5% per annum with by far the biggest increase being in Information technology at ~16%. Technology subjects have also been on the increase generally at ~3% per annum.

Following an initial rise in the late 1990s, computing subjects have been in sharp decline. Although constituting only 0.4% of A-level subjects studied, computing represents around 4% of the EU's gross domestic product (GDP)[66]. The decline may be explained by the relatively large rise in information technology but these are very different subjects. Information technology concentrates on the application of technology while programming is a major element of computing.

Conclusion 15 – Major decline in STEM subjects at A Level

Physics, further mathematics and computer studies continue to decline at A-level.

66 European Commission, March 2004, Benchmarking national and regional policies in support of the competitiveness of the ICT sector in the EU, http://ec.europa.eu/enterprise/ict/policy/ict-policies/int_rep_fin.pdf

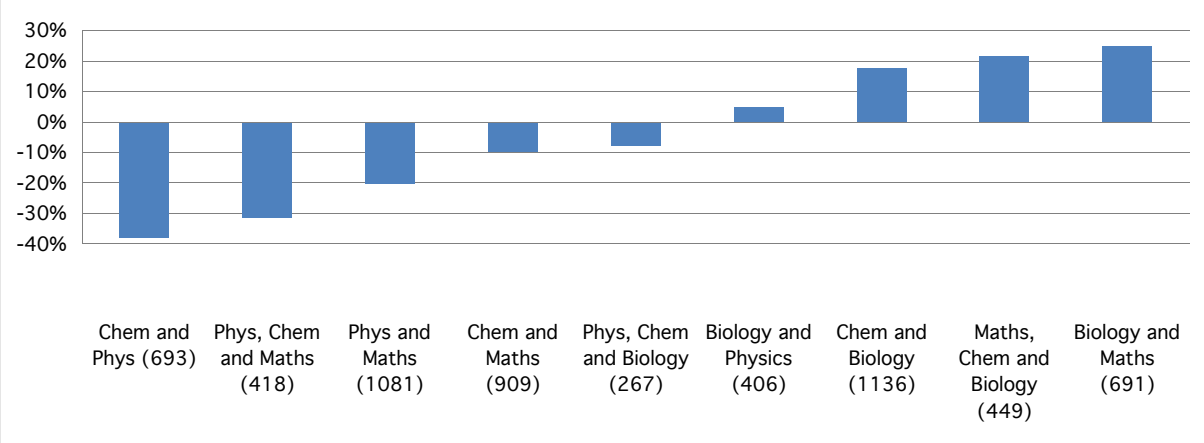
It can be seen from Table 5.3 that our results at A-level continue the trend of GCSEs where we outperform the rest of the UK, with the exception of psychology. The results for mathematics at A-level appear better than at GCSE level, although this is due to the quality of pupils choosing this option, many of whom will have obtained a grade A or better at GCSE and who may also have studied additional mathematics in year 12.

GCE A-level Subjects	NI Results % A-C	UK Results % A-C
Biology	80.9%	69.2%
Chemistry	82.4%	76.3%
Physics	77.6%	70.6%
Psychology	55.6%	67.7%
Mathematics	89.1%	81.3%
Further Mathematics	92.2%	88.9%
Computer Studies	63.3%	59.0%
Information Technology	82.7%	55.8%
Design & Technology (incl Systems)	76.6%	68.6%
All STEM	82.5%	72.7%
All Subjects	84.4%	73.9%

Source: Joint Council for Qualifications

Table 5.3 Comparison of A-level Results, 2007/08

Perhaps less obvious, but of particular concern, this past decade has seen significant change in how students are opting to combine STEM subjects at A-level. Annex 7 presents the numbers of students choosing the various subject combinations in both 1995/96 and 2005/06 and the change during this period is summarised in Figure 5.7. For reference, the figures in brackets show the actual numbers of students choosing each combination in 1995.



Source: DENI

Figure 5.7 Change in Uptake of A-Level Subject Combinations, 1995 - 2005

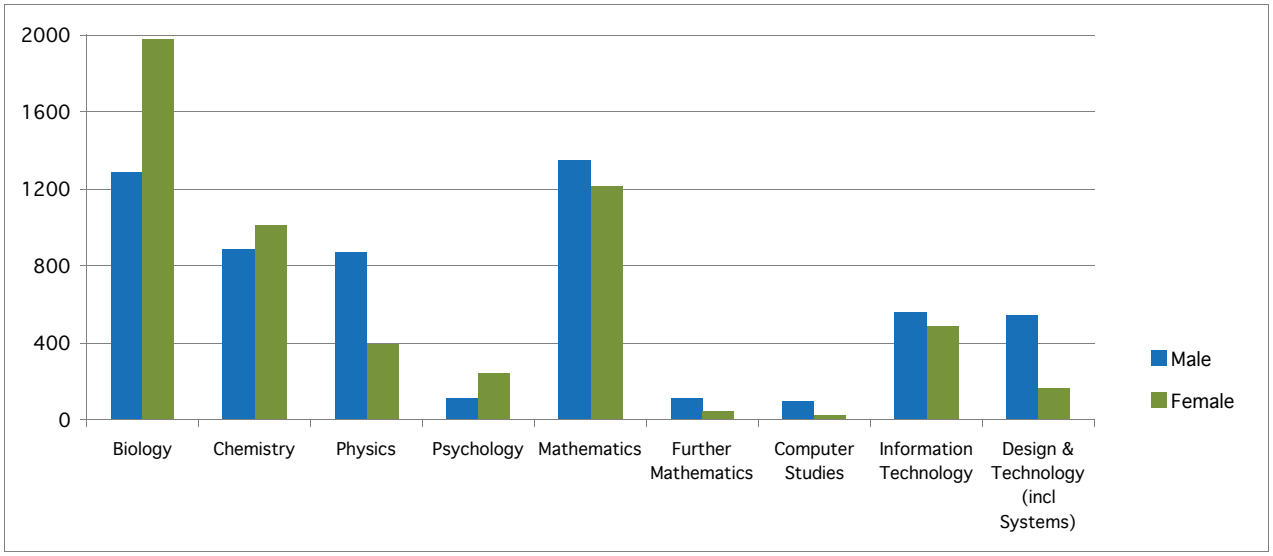
As we see, the biggest decline has been in the combination of the two physical sciences alone or in combination with mathematics. This is closely followed by the combination of mathematics with physics which is of particular concern, since this is a traditional route for those considering engineering.

In 1995, as shown by the figures in brackets, the two dominant subject combinations were physics and mathematics on the one hand, and chemistry and biology on the other, implying a balance between the physical sciences and the life sciences. Since then, the pendulum has swung noticeably towards the life sciences and it is suggested that this again illustrates the cultural bias towards medicine and medicine related careers here.

A factor in this may be gender bias which again appears at A-level as illustrated by Figure 5.8. Girls prefer biology while boys choose physics. Chemistry and psychology tend to attract more girls than boys while entries to design and technology have a strong male bias.

Conclusion 16 - Major shift away from physical science combinations at A-level

This past decade has seen a marked change in how pupils are combining STEM subjects at A-level. There has been a significant shift away from physical science combinations or mathematics and physical sciences, with a corresponding increase in combinations leaning towards life sciences.



Source: Joint Council for Qualifications

Figure 5.8 Gender Bias within A-Levels, 2007/08

There is also a question around the paths of study, post-16, of the significant pool of STEM talent within non-selective schools at GCSE level. With reference to Table A6.1, around 19,000 pupils achieve grade C or better in STEM subjects. If we look at the numbers achieving Grade B or better, this equates to ~1,600 in double award science and ~2,100 in mathematics. Yet when we look at the entries in STEM at GCE A-level in the non-selective sector (Table A6.2), total STEM entries are only 1,412, with biology representing 33% of these.

While these low entries reflect the absence of a sixth form in many non-selective schools here, the question remains as to how many pupils who studied STEM subjects at GCSE in non-selective schools continued to do so post-16. While pupils may transfer to selective schools or further education to continue their STEM studies, there is a concern that we may be losing considerable STEM talent from the artery at this stage.

Conclusion 17 – Non-selective sector pupils in STEM artery post-16

There is a strong STEM pool at GSCE within the non-selective sector with significant numbers achieving Grade B or better in Double Award science and mathematics. However, the absence of a 6th form in many non-selective schools and the resulting low entries at A-level raise questions as to how many of these young people remain in the STEM artery post-16.

In light of this, a review was carried out of the distribution of A-level entries across schools here to determine if a small number of schools were responsible for the bulk of A-level provision in STEM. Currently there are 226 post-primary schools here, comprising;

- 69 selective schools
- 157 non-selective

If we consider A-level entries in physics, chemistry, biology, technology and mathematics, we find that around 20% of the schools here (47 of the 226) account for 70% of the A-levels delivered in STEM subjects. These are all selective schools.

Conclusion 18 – Narrow base of STEM schools offering A-levels

Looking at A-level entries in post-primary schools, 20% of the schools account for 70% of the entries. In line with the previous remarks, these are all selective schools.

5.4.2 Further Education

Further Education in Northern Ireland has been a cornerstone of training for business for many decades, providing the skills demanded by the economy through its broad portfolio of qualifications.

The high quality of the professional and technical training available within further education is also well reflected in STEM provision. A review of science provision[67] in 2003/04 highlighted the quality of teaching, the access courses for adults, the ethos in science classes and the innovative science programmes as key strengths.

Students entering further education may do so at different levels as defined within the National Qualifications Framework[68] (NQF). The following summarises these levels in respect of further education.

- Level 1 – equivalent to GCSE grades D – G
- Level 2 – typically a BTEC First Diploma which is equivalent to GCSE grades A* – C

67 Education and Training Inspectorate, 2003/04, science Provision in Further Education Colleges

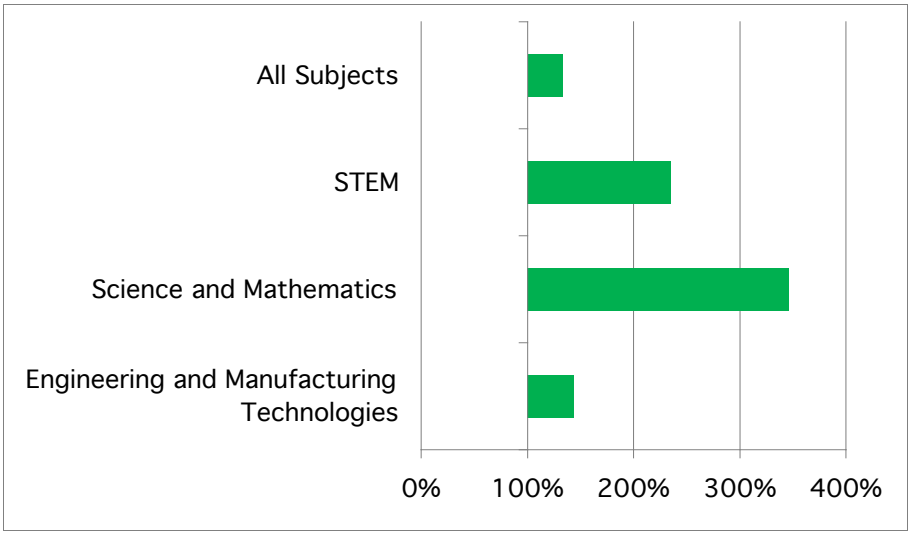
68 QCA, August 2004, Changes to the National Qualifications Framework, http://www.ofqual.gov.uk/files/nqf_changes.pdf

- Level 3 – typically a BTEC National Diploma which is equivalent to GCE A Levels
- Level 4/5 – equivalent to BTEC Higher Nationals / Foundation Degrees

Direct entry to any of these levels is dependent generally upon prior qualifications. For example, entry to a National Diploma in Engineering typically requires a minimum of 4 GCSEs at grade C or above including mathematics, english, and one science-based subject, plus one technology based subject. However, entrants into FE will include staff from the existing workforce who may wish to upskill and also adults who may have been inactive for a period of time.

In the previous sections, we have compared entries here with those of the UK, normalized against the respective populations. However, valid comparison of further education statistics across the UK is difficult as each region defines the sector differently. For example, in England sixth form colleges are included.

There are a number of standardized comparisons published[69] which, although at a higher level, do permit a degree of comparison of STEM uptake. These comparisons are shown in Figure 5.9, the data having been averaged over the years 2004 to 2007, due to the degree of fluctuation in the figures annually.



Source: DELNI

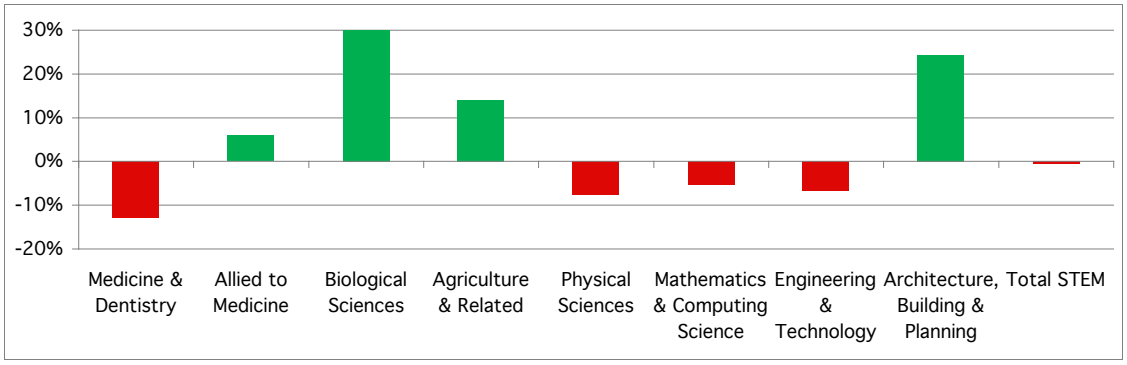
Figure 5.9 NI – UK Comparison of STEM Students in Further Education, 2004 - 2007

69 DCSF, 2008, Education & Training Statistics for the United Kingdom: 2008

We may see that, relative to the UK, there are a considerably higher proportion of STEM students in further education here. The high proportion of science and mathematics students here may be due to the increased uptake of the biological sciences and physical sciences in recent years.

With reference to Table A8.1, there were 55,197 enrolments in STEM subjects in 2006/07, across all levels. This represented an increase of 6% in STEM enrolments from 2001/02 but a fall of around 7% from the peak of 59,056 in 2004/05. The 55,197 enrolments also include two further levels, Entry Level/Level 1 and Degree Level & Higher, the enrolments in this latter category being very small. These levels have been omitted in Table A8.1 for clarity to allow a focus on Levels 2, 3 and Sub-degree, this latter term referring to Levels 4 and 5 on the NQF.

While overall STEM enrolments appear relatively strong, there are distinct differences in the annual trends amongst individual subject areas and levels of study. Figures 5.10 to 5.12 present the annual trends[70] by subject area for Levels 2 to 4 respectively, and it may be observed that there has been significant decline/growth in certain STEM areas from 2001/02 to 2006/07.



Source: Analysis based upon DELNI data

Figure 5.10 Annual Trends in STEM Level 2 FE Enrolments, 2002 – 2007

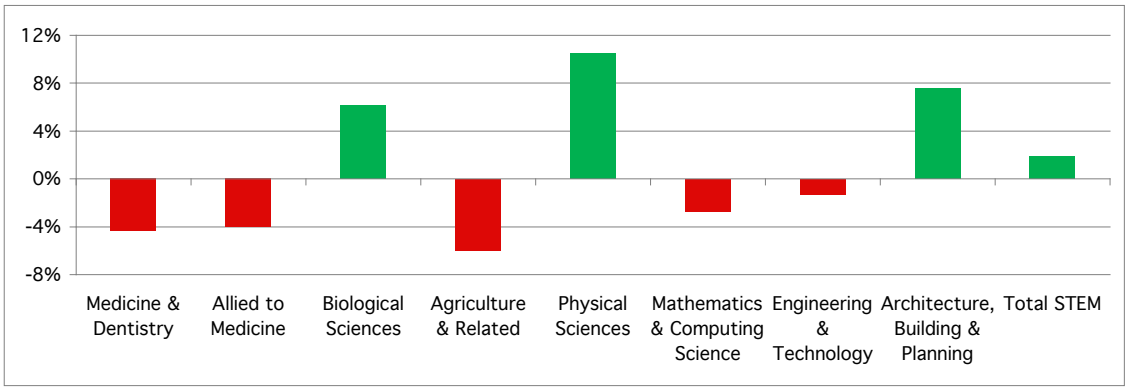
With reference to Figure 5.10 (and Table A8.1), although biological sciences displays the largest percentage increase, the largest growth at Level 2 between 2002 and 2007, in terms of actual numbers, was in architecture, building and planning (2,652), subjects allied to medicine (484) and agriculture & related subjects (461).

Against this, Level 2 engineering & technology enrolments have reduced by 1,646 during the same period, representing an annual decline of ~7%. Level 2 mathematics

70 Annual trends calculated on basis of least squares fit for all years between 2002 and 2007

& computing enrolments have declined at 5% per annum, representing a reduction of 3,374 enrolments between 2002 and 2007.

With regard to Level 3 (Figure 5.11), physical sciences exhibited the largest growth during the period, with an increase in enrolments of 1,185. architecture, building and planning has again shown significant growth with an increase of 1,053 enrolments during the period, representing an annual increase of ~8%.

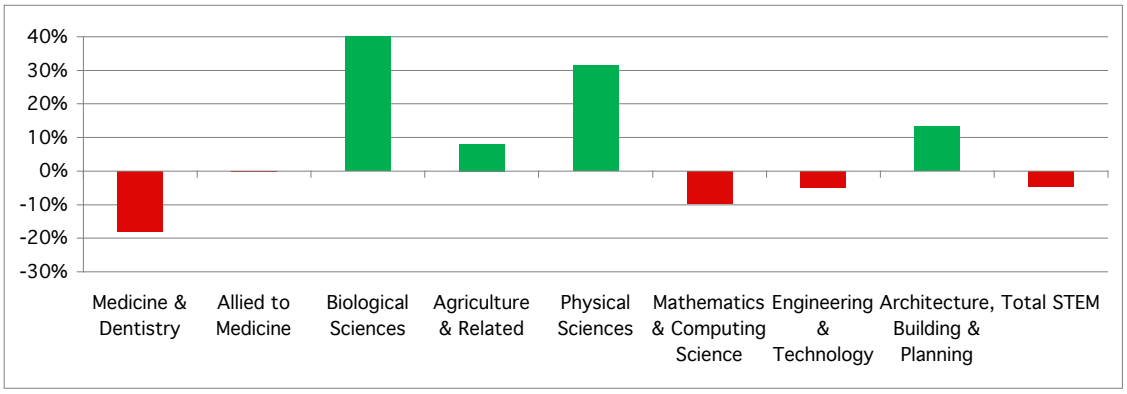


Source: Analysis based upon DELNI data

Figure 5.11 Annual Trends in STEM Level 3 FE Enrolments, 2002 - 2007

However, the above increases at Level 3 are again offset by declines in both engineering & technology and, in particular, mathematics & computing sciences. Engineering & technology declined by 110 enrolments (Level 3) and by 293 enrolments (Level 4) during the period. Mathematics & computing science enrolments declined by 216 at Level 3 and by 986 at Level 4, the latter representing an annual decline of 10%.

With reference to Table A8.1, it may be observed that within the various engineering disciplines, there are significant declines in general engineering and mechanical engineering, at both Levels 3 and 4, and in production engineering at Level 2. Traditionally, these have been important core engineering subjects for the economy.



Source: Analysis based upon DELNI data

Figure 5.12 Annual Trends in STEM Level 4 FE Enrolments, 2002 – 2007

The growth in the biological (by 789 enrolments) and physical sciences (by 1,248 enrolments) at both Levels 3 and 4 is particularly encouraging. Being relatively new subject areas, the enrolments during the past two years would indicate that these enrolments are now stabilising, particularly at Levels 2 and 3.

It has perhaps been the significant growth in architecture, building and planning within recent years at all levels which has balanced the decline in other STEM subject areas. It remains to be seen what the impact of the current recession will be on these enrolments given the particular downturn in the construction industry and whether or not those considering building related courses may instead enrol on other STEM courses.

Total enrolments in medical-related STEM subjects increased slightly between 2001/02 and 2006/07 but again there was considerable variation between individual subjects.

A contributory factor in the declining enrolments in certain FE STEM areas may be the increasing tension between schools and FE colleges as a result of the competition to attract students, post-16. As noted in Section 5.4.1, there has been an increase in the number of pupils remaining at school to take A-levels which is impacting adversely on FE enrolments.

Conclusion 19 – Significant growth and decline in certain STEM areas within further education.

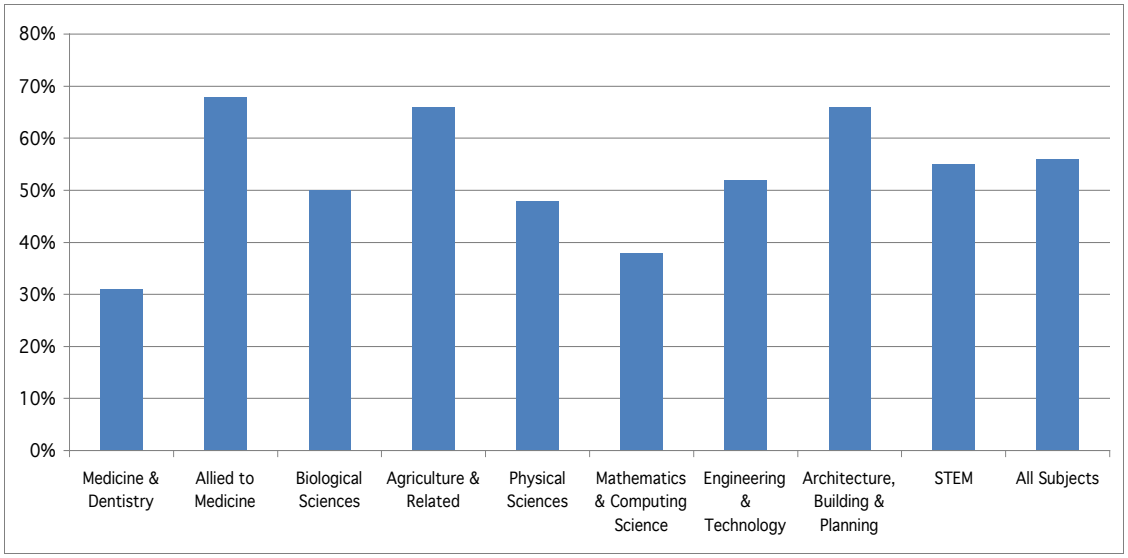
Substantial increase recorded in architecture, building and planning as well as in the physical and biological sciences.

Enrolments in engineering & technology and mathematics & computing science are showing significant decline at Levels 2 through 4.

Success rates (comprising retention and achievement data and relating to the proportion of students who obtain a qualification as a percentage of those who start the course) are difficult to accurately measure as some courses are staggered over a number of academic years. Official DEL statistics would suggest that the overall success rate for STEM courses in FE is 55%, in line with FE as a whole. This figure does not take account of students who may have transferred onto different courses and achieved a qualification.

Figure 5.13 presents success rates for various STEM courses; it is apparent that there is great variation across the different STEM subjects. For example, medicine &

dentistry and mathematics & computing sciences recorded success rates between 30% - 40% whilst subjects allied to medicine and architecture, building & planning showed success rates of almost 70%. The latter cohort of courses compares favourably with most post compulsory education success rates across the UK while the success rates of the former group are low.



Source: DELNI

Figure 5.13 Success Rates by STEM Subject Area, 2005/06

As to contributory factors, discussions with STEM lecturers in colleges suggest that post-primary school pupils, and their parents, need to be more aware of the study demands of National Diplomas and Higher Nationals in colleges. There is often a misconception amongst new students that FE courses are relatively easy.

While level 3 qualifications are equivalent to A-level, the high level of coursework associated with them may often be a surprise to the student transferring from school. Lecturers have also indicated that GCSE mathematics may not be an adequate preparation for some subjects. This issue is discussed in Section 5.3.

The level of practical content is highlighted by lecturers as a major factor in retaining the interest of the students. However, there appears to be an increasing pressure upon lecturers to deliver courses in a reduced number of teaching hours, an issue which has been raised particularly in regard to engineering. Workshop and laboratory time is being reduced with the consequence that students no longer have a good balance of knowledge and practical skills.

Conclusion 20 – Whereas certain STEM courses in FE show high rates of success, significant numbers are being lost from mathematics, computing science ,engineering & technology courses. Lack of awareness of the demands of FE courses and the high level of coursework are believed to be contributory factors in the lower success rates in certain STEM subjects. The reducing amount of practical work is also believed to be a contributory factor.

Professional development remains an issue for FE lecturers given the pressures on the timetable. This is considered further in Section 6.7. Where lecturing staff have successfully engaged with business, the experience gained has helped to enrich the curriculum and has better prepared staff to advise students on career options.

Conclusion 21 – Business links have enhanced STEM education

Where successful links have been forged between colleges and business, the experience gained has both enriched the curriculum and assisted staff in advising students on career options.

Gender imbalance is evident in STEM within further education as can be seen in the analysis of enrolments shown in Table 5.4. Females are in the majority in science and mathematics courses and the male/female ratio here, at 1:1.8, is slightly higher than in the UK. Engineering, technology and manufacturing remain strongly male dominated here with a male/female ratio of around 11:1 compared with the UK figure of 8:1.

Subject Area	(000's)			
	NI		UK	
	Males	Females	Males	Females
Engineering, Technology & Manufacturing	8.0	0.7	146.4	18.3
Science & Mathematics	4.4	7.8	43.5	65.7

Source: DELNI

Table 5.4 NI - UK Enrolments in STEM within FE, 2006/07

Conclusion 22 – STEM Gender imbalance in FE

There is a major gender imbalance in the general area of engineering, technology and manufacturing which has resulted in very small numbers of female entrants into these fields

5.4.3 Apprenticeships

In the future, we will look increasingly to apprenticeships to supply the technicians needed to sustain economic growth within STEM-based industry. Traditionally, the National Diploma would have fulfilled this role but as it has evolved into a route for university entry, it is the apprenticeship which now provides the necessary balance of academic and practical skills.

Furthermore, it is generally considered that apprentices will require Level 3 skills if they are to contribute effectively to economic growth. It has been predicted that 80% of all new jobs to 2010 will be at entry Level 3 or higher[71].

DEL is responsible for funding apprenticeships and in September 2007 replaced the former Jobskills provision with Training for Success. This includes apprenticeship training as well as training for young people who have not yet found employment. In September 2008, in order to market apprenticeships as a flagship provision, DEL branded apprenticeship as a separate provision, entitled ApprenticeshipsNI. The annual projected budget of approximately £54m (which includes training for young people not yet in employment provided under Training for Success) is based on the previous annual out turn of Jobskills.

Those undertaking apprenticeships are required to be in employment from day one. ApprenticeshipsNI consists of two distinct strands:

1. Level 2 Apprenticeships; and
2. Level 3 Apprenticeships

Although a number of sectors have indicated the need to have apprentices trained to Level 3, initial uptake suggests that many apprentices are currently undertaking Level 2 training, en route to achieving a Level 3 qualification.

71 DCSF, 2001, Skills in England 2001: The Research Report, Nov 2001, http://www.dcsf.gov.uk/rsgateway/DB/RRP/u012883/index.shtml

Table 5.5 shows the number of apprentices registered under ApprenticeshipsNI as of February 2009, the Level 2/3 heading shows those apprentices enrolled at Level 2 who are en route to Level 3.

Table 5.5 also shows that the Level 3 uptake in STEM sectors, particularly in the economic areas of agriculture, engineering, construction and ICT is very low; the total for these four areas is only 147. The equivalent number of Level 2 apprenticeships in these four areas is 2,811. Even if a significant proportion of these translate into Level 3 a significant imbalance in the uptake between the two levels will remain.

Sector	Level 2/3 Apprenticeships	Level 3 Apprenticeships
Health, Public Services and Care	1271	326
Agriculture, Horticulture and Animal Care	30	7
Engineering and Manufacturing Technologies	1647	67
Construction, Planning & the Built Environment	1088	56
Information and Communication Technologies	46	17
STEM sub-total	**4082**	**473**
Retail and Commercial Enterprise	1939	47
Leisure, Travel and Tourism	2	2
Arts, Media and Publishing	10	0
Preparation for Life & Work	0	14
Business Administration and Law	706	35
Total	**6739**	**571**

Source: DELNI

Table 5.5 Occupancy of ApprenticeshipNI as of February 2009

We can get an indication of the rate of uptake of apprenticeships by looking at the occupancy quoted for 10 April 2008. At that time, the numbers registered under Level 2 and Level 3 were 2,899 and 222 respectively.

A continued review of the growth of apprenticeships at both Levels 2 and 3 is required, but it is likely that uptake will be reduced in the short term by the current economic downturn which will see a fall in the number of new employees. DEL has identified, through its own research and consultation with key stakeholders, a number of barriers that may be preventing people from undertaking an apprenticeship. These are:

- The significant gender bias in certain sectors with females often perceiving apprenticeships as a male-dominated pathway, particularly in areas such as engineering and manufacturing;
- The significant numbers of young people who prefer to stay in education, with a view to eventually progressing to higher education, rather than entering professional and technical training; and
- The employer-led nature of apprenticeships, which requires employer buy-in; however, employers are not adequately committed to the programmes.

Conclusion 23 – Low STEM Apprenticeship uptake at Level 3

Ensuring the availability of apprentices with level 3 skills will be critical to the growth of our companies and our economy. However, while we recognize that we are still in a period of transition between programmes, the current uptake of Level 3 apprenticeships in STEM sectors is very low.

5.5 Higher Education – First Degree

STEM in first degree university education here is in a relatively strong position. We are well served by two good universities, the University of Ulster (UU) and Queen's University, Belfast (QUB), with the latter a member of the prestigious Russell Group of universities. In addition, we have two university colleges of education, St Mary's and Stranmillis. Students may also follow a distance learning route by enrolling on one of the many courses available through the Open University[72]. For the purposes of this present analysis, however, Open University contributions have been omitted.

Higher education is characterised by a much greater degree of student mobility than the other education and training sectors explored in this report and, as we shall see, NI-domiciled students migrate for a broad variety of reasons. However, we differ from most other UK regions in that we do not attract significant inward migration of HE students from other parts of the UK, and beyond, to compensate for the outward

72 The Open University, www.open.ac.uk/

flow of students. The various migration scenarios and resulting flows are examined in Section 5.7.

With reference to Table A9.1, the nett loss of HE students contributes to some 20% fewer first degree enrolments here, compared to the UK as a whole. However, it is encouraging to note the parity in the proportions of STEM enrolments here compared to the UK, reflecting the fact that our local universities have a higher proportion of their enrolments in STEM subjects than the UK average. With reference to Table A9.1, 50% of first degree enrolments here were in STEM areas compared to just over 40% in the UK, in 2007/08.

With regard to the individual subject areas, our local universities have a much higher proportion of first year, first degree enrolments in architecture, building and planning, subjects allied to medicine and agriculture & related subjects than the UK.

Conversely, entries in the core sciences (biology, physics and chemistry) are each less than 50% of the UK figures. These courses are important feeders into postdoctoral courses and it is critical that the numbers are increased. Enrolments in mathematical sciences are similarly low ~50% of the UK figures.

An examination of the constituent subjects shows that enrolments in the biological sciences are dominated by sports science and psychology which together constitute over 80% of the enrolments in this area compared to less than 70% across UK institutions as a whole. Physical sciences enrolments are dominated by physical and geographical sciences which, according to the JACS[73] (Joint Academic Coding System), cover largely geography-related subjects. Depending on whether it is taught with a physical rather than a social science, geography may be classified as a physical science.

Engineering and technology enrolments are relatively low, at 80% of the UK average. A more detailed analysis of the engineering disciplines reveals that we have higher concentrations of civil engineering enrolments than the UK average. By comparison, electronic and electrical engineering enrolments are very low in relative terms, although there are indications that these numbers may have improved somewhat for 2008/09.

Subjects allied to medicine is the largest group of subject areas, with 1,587 first year first degree enrolments. Nursing is the largest individual subject in this group, with 913 first year first degree enrolments which, on a per-capita basis, is significantly higher than the UK average. Collectively, the group of subjects comprising medicine,

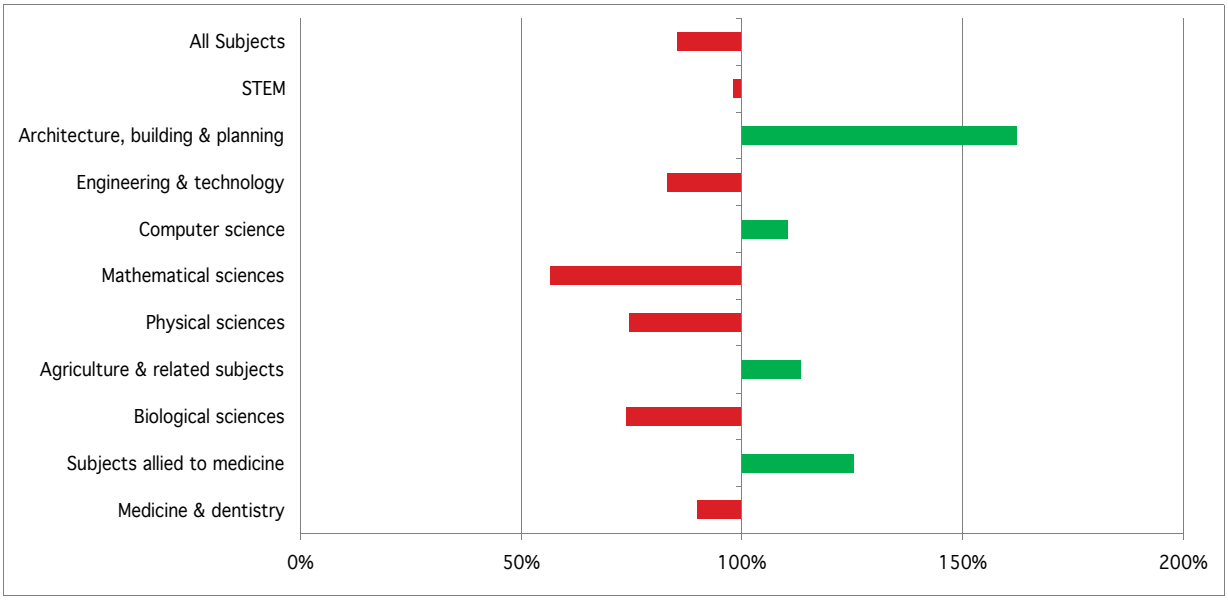
73 JACS Subject Coding System, 1999, *http://www.ucas.ac.uk/website/documents/JACS_coding/jacsclass1.pdf*

subjects allied to medicine and biological sciences accounts for roughly half of all STEM first year first degree enrolments here and in the UK as a whole.

Conclusion 24 – STEM shortages in Key Subjects

Although the overall enrolments in STEM degrees at our local universities are good there are key shortage in the core sciences, mathematics and certain engineering subjects.

Similar patterns emerge when we examine graduate numbers. Figure 5.14 compares the numbers of local graduates with the overall UK figures, again normalizing the figures as a percentage of the respective populations.



Source: HESA and ONS

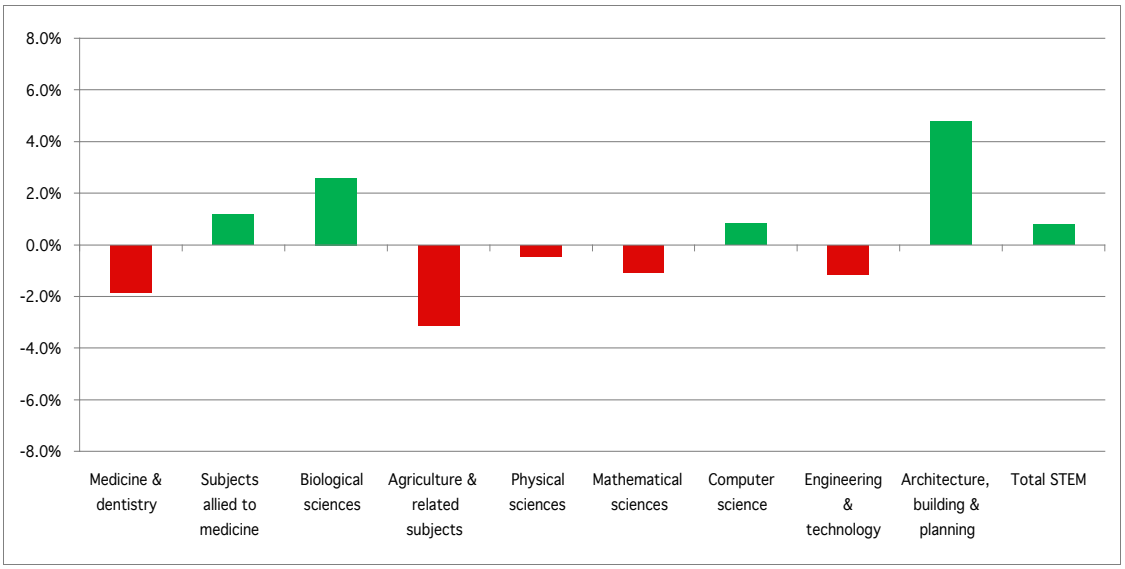
Figure 5.14 NI – UK Comparison of First Degree Graduations in STEM Subjects, 2007/08

We can see from Figure 5.14 that our first degree graduations in STEM exhibit parity with the UK as a whole. However, with reference to Figure 5.14, while the proportions of graduates in STEM are well aligned to the overall UK figures, there are significant variances in individual subjects.

Graduation numbers from our local universities in physical sciences, biological sciences, mathematical sciences and engineering & technology are low compared to the UK.

By comparison, graduations in subjects allied to medicine and in architecture, building and planning are higher, at 125% and 162% respectively. Regarding subjects allied to medicine, it was identified in Section 3.6.2 that we have a significantly higher proportion (126%) of people with degree qualifications than the national average, which is compounded by the graduation figures given above. In the subject group of architecture, building and planning, it is difficult to see how such a high proportion of graduates can be sustained, given the present downturn in the economy.

There is cause for concern in some of the trends in graduation numbers. Although total first degree graduations rose by 19% during the period 2002 to 2008, with architecture, building & planning and biological sciences experiencing particularly strong growth, Figure 5.15 shows that in relative terms, graduation[74] in certain STEM areas has been in decline during this period.



Source: Analysis based upon HESA data

Figure 5.15 Annual Trends in First Degree Graduations in STEM Subjects, 2002 - 2008

74 First degree graduations in any given year have been normalized against total graduations in that year, the annual change then calculated based upon a "least squares" approach

With reference to Figure 5.15, although the largest decline is in agriculture and related subjects, the numbers graduating each year are relatively small at between 70 and 80 students.

While the annual declines in both mathematical sciences and engineering & technology appear relatively small, graduation in these subject areas is already proportionately low compared to the UK average.

The numbers in medicine & dentistry have remained relatively constant at around 215 graduates per annum during the period, but are in decline at ~2%, as a proportion of total graduation.

Both QUB and UU have introduced scholarships, many of which are targeted directly at STEM undergraduates. QUB, for example, has introduced STEM awards of £1,000 for students who attain a minimum of three 'A' grades at A-level and who enrol in a STEM subject. UU has introduced Opportunity Scholarships which reward both enrolment and progression in a variety of courses including STEM.

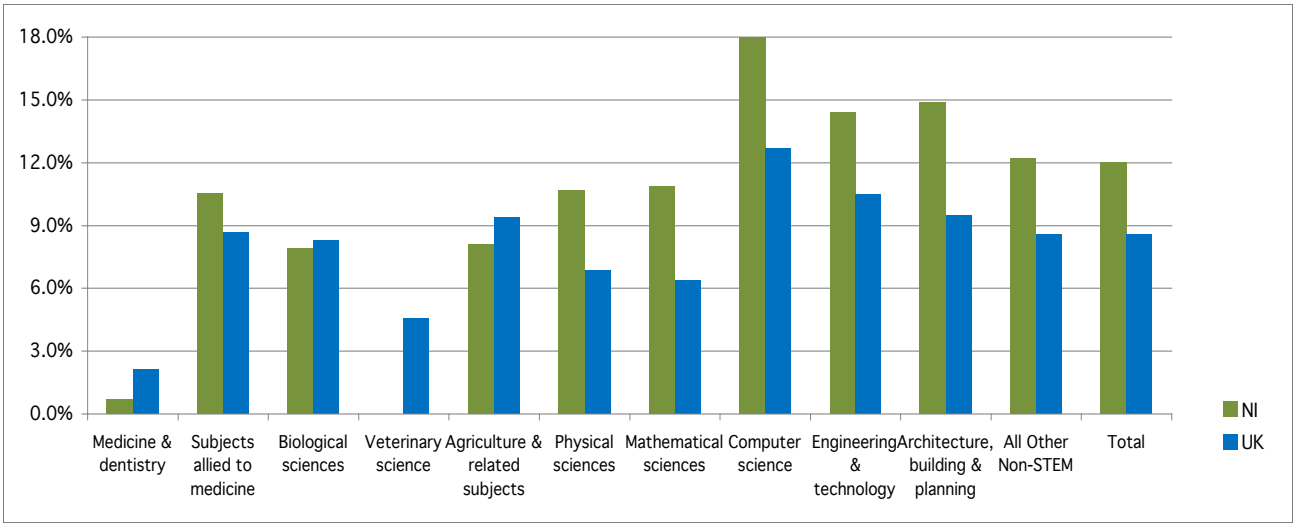
As a general measure of the performance of the local universities, we compared the percentage of first class honours and 2.1 Honours degrees here with the UK as a whole. Table 5.6 shows that our local universities perform significantly better in all subject areas except physical sciences, engineering and technology.

Subject Area	NI Results % 1st & 2.1	UK Results % 1st & 2.1
Medicine & dentistry	N/A	N/A
Subjects allied to medicine	77%	52%
Biological sciences	70%	60%
Agriculture & related subjects	71%	51%
Physical sciences	48%	59%
Mathematical sciences	64%	62%
Computer science	56%	47%
Engineering & technology	55%	56%
Architecture, building & planning	57%	49%
STEM	61%	52%
All Subjects	62%	55%

Source: HESA

Table 5.6 Comparison of First Degree Results, 2006/07

Another major area of concern for the local universities is the level of dropout in STEM subjects which occurs primarily during the first year of study. Figure 5.16 shows the first year dropout for first degrees in the academic year 2006/07, comparing also the local universities with the UK average. As can be seen, certain STEM subjects suffer higher than average losses and it is of particular concern that the level of dropout here is higher than that in the UK overall. After nurturing students in the STEM education artery for so many years, to lose over 600 students (see Table A9.2) annually in STEM subjects from our universities is a major blow to the artery.



Source: HESA

Figure 5.16 First Year Dropout Rates in First Degree, NI versus UK

The highest levels of dropout occur within computer science (18%) and architecture, building and planning (14.9%). In other words, one in every 6 students is lost from the course during the first year.

The subject areas with the next highest dropout is engineering & technology at 14.4%, after which the remaining STEM subjects have dropout rates equal to or less than the local university average. If we compare this with the equivalent UK figures, we suffer between a 3% and 6% higher dropout rate.

QUB and UU are taking particular steps to address this problem, with a range of measures both academic and pastoral. Examples include additional mathematical tutorials, as gaps in mathematics knowledge have been identified as a contributory factor in dropout from STEM subjects. From a pastoral standpoint, a greater emphasis on personal tutorials for first year students and additional monitoring of attendance and submission of work are helping to identify problems earlier.

Pre-entry initiatives, which include master classes and targeted study support, have been set up to ensure that students entering through the widening access pathway have the best chance to succeed. Retention policies have become more formalized and action plans are regularly reviewed to assess their effect. Engaging students more with the university, including the award of credits for sports, charitable work, etc. which leads to the award of a certificate upon graduation, are some of the initiatives being piloted.

Conclusion 25 – Poor STEM retention rates in first degree

We suffer a high level of first year dropouts in STEM and our local universities suffer a higher degree of dropout than the UK overall. Almost 1 in 6 students are lost in key areas such as engineering and computing. Reasons for dropout are complex but lower tariff point entry and gaps in mathematics knowledge have been identified as contributing factors. Universities are implementing measures to address dropout including additional mathematics tutorials and an increased pastoral approach.

The local universities also have a relatively low proportion of foreign students as shown in Table 5.7.

Country	Total international students	% of student population who are international
England	290,880	15%
Scotland	37,125	17%
Wales	18,110	14%
Northern Ireland	5,350	11%
UK	351,465	15%

Table 5.7 Number of international students in the UK by region 2007[75]

Foreign students are particularly important to sustaining the postgraduate education course yet Table 5.7 indicates that we have the lowest percentage of foreign students of any region in the UK

75 UK Council for International Student Affairs, http://www.ukcisa.org.uk/about/statistics_he.php

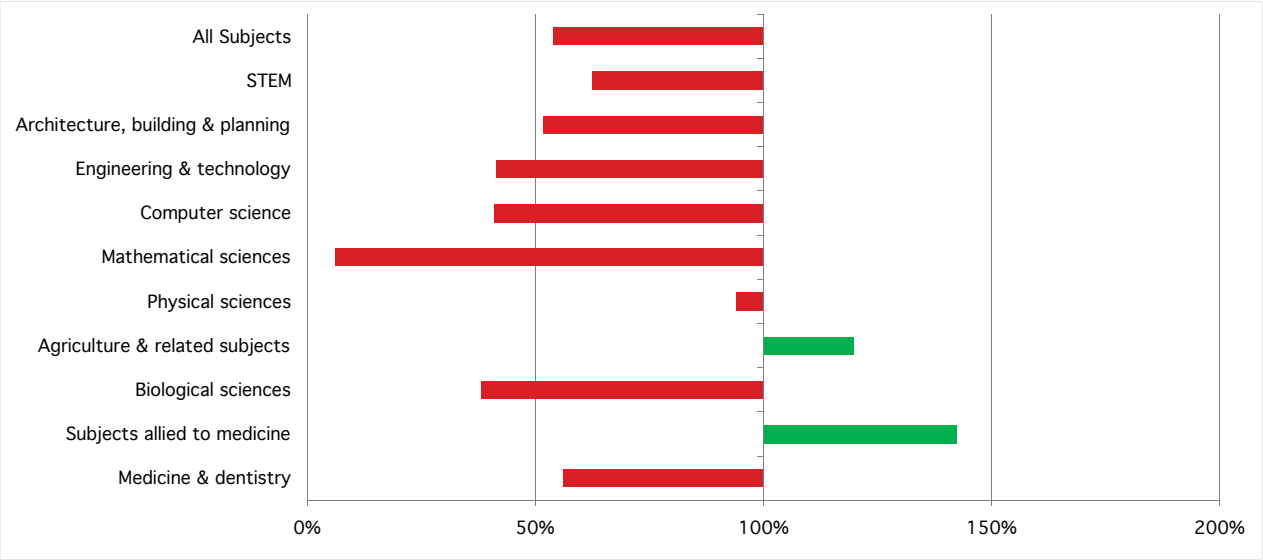
Conclusion 26 – Need to attract more Foreign STEM students to our region

The best STEM students will be important to developing our economy; we need to do more to remove barriers and market our good universities to students from overseas.

5.6 HE Postgraduate

If we are to achieve our aims of a higher value added economy in an increasingly competitive world, our universities must equip more students to hold their own against the best in their knowledge, skills and aptitudes. This requires students to be educated to postgraduate level.

When we normalize the figures for the respective populations and compare, we can see from Figure 5.17 that the numbers of students graduating with higher degrees here does not correlate with the earlier strength of the STEM education artery.



Source: HESA and ONS

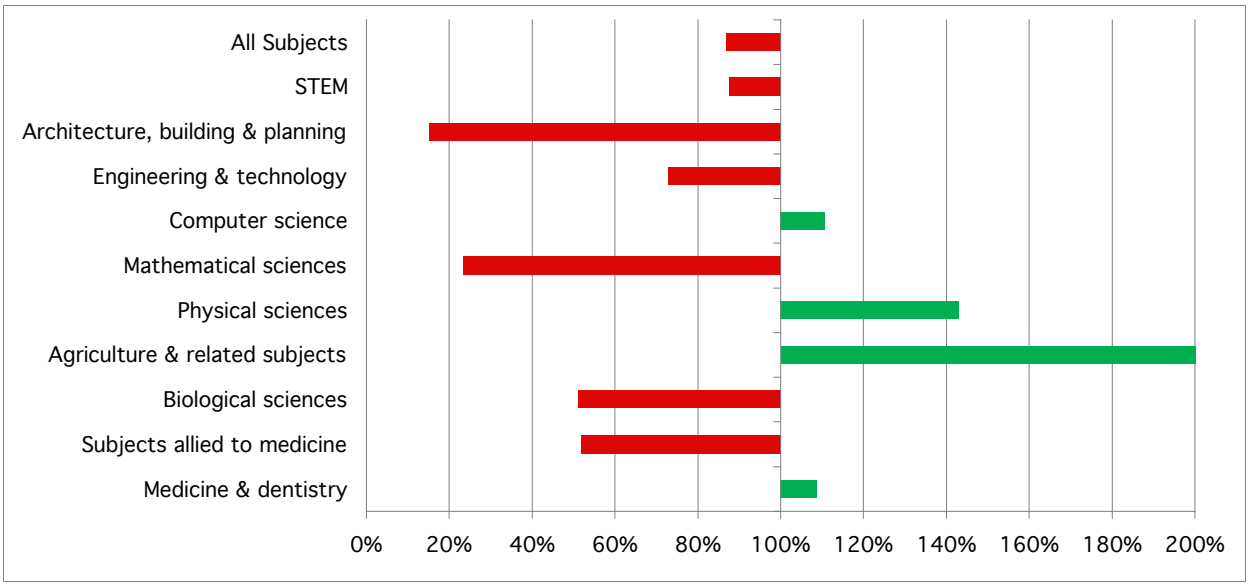
Figure 5.17 NI – UK Comparison of Higher Degrees awarded in STEM Subjects, 2007/08

Thus far, we have observed the general strength of our education system in outperforming the UK average. However, when it comes to higher degrees, we lag significantly behind.

Looking at the progressive decline in uptake, we have 37% more STEM A-level entries than the UK average but at higher degree level, just under 40% fewer are awarded degrees. If we exclude medicine and subjects allied to medicine, this deficit increases to 50%.

An element of this can be explained by the fact that 27% of NI domiciled students study for higher degrees at UK institutions outside NI, reflecting the national and international nature of enrolment decisions at HE level. However, we do not experience sufficient inward migration of students at higher degree level from the UK and beyond to counterbalance this outward flow, an issue we examine further in Section 5.7.

With regard to doctorate level graduation (Figure 5.18), the total STEM numbers here are ~90% of the UK average. Care must be exercised though in drawing conclusions, due to the relatively low numbers engaged in doctorate level study and the consequent annual variations. For example, Figure 5.18 shows that architectural, building and planning doctorates were low in 2007/08, yet in the previous year the proportions were above the UK average. Conversely, computer science graduations were less than 50% of the UK average in 2006/07 but are ~10% higher in 2007/08.



Source: HESA and ONS

Figure 5.18 NI – UK Comparison of Doctorates awarded in STEM Subjects, 2007/08

The lower numbers of doctorates in engineering & technology, mathematical sciences and biological sciences are of greater concern, particularly as we observe the trends in previous years. At 23% of the UK average, doctorates in mathematical sciences are particularly low.

While it may be difficult to discern trends because of the relatively lower numbers involved, we appear to be following the wider UK trend of declining numbers in core STEM subjects; a trend which the Royal Society has highlighted and has urged government intervention to reverse[76]. In response, DEL has committed to increase by 300 the number of PhD places by 2010. Equating to 100 new awards annually over a three year period, these PhDs will be confined to areas of economic relevance.

The eligible areas include the Horizon sectors identified by MATRIX and are agri-food, life & health sciences, advanced materials, engineering, ICT, electronics, software engineering, construction, creative media and financial services. The addition of these new places should largely restore the parity in the proportions of STEM doctorates as compared with the UK.

An analysis of postgraduate students shows, relative to the rest of the UK and RoI, we have the lowest proportion of foreign students studying here. In the UK, students from outside the UK and Europe represent nearly a third of the postgraduate student population. In our local universities, it is less than a sixth. This issue is receiving active consideration within DEL's current postgraduate review, which is due to conclude shortly. In the USA, it has been noted that foreign postgraduate students are very likely to remain in the country where they obtained their postgraduate qualification, with nearly 75% opting to stay[77]. This rate increases in the physical sciences and engineering subjects, which are in greater demand. The USA is seeking to increase its uptake of the best postgraduate students from around the world; a trend other countries are likely to follow.

Historically, postgraduate education, especially to doctorate level, was seen as a preparation for a career in university teaching, but now, with less than a third of USA doctorates or a seventh of German doctorates following an academic path[78], the focus is increasingly on the value these awards add to the economy. However, discussions with business throughout this Review have highlighted that the traditional postgraduate education is not providing the necessary training or skills needed by postgraduates to succeed in industry. As well as the research specialism, employers require postgraduate students to have commercial and managerial skills.

---

76 The Royal Society, January 2008, A higher degree of Concern, Policy Document 02/08, *http://royalsociety.org/displaypagedoc.asp?id=28851*

77 National science Foundation, The Summary Report, *www.nsf.gov/statistics/srs00410/sectc.htm*

78 OECD, 2007, Labour Market characteristics and international Mobility of Doctorate Holders: Results for seven countries, STI Working Paper 2007, *http://www.oecd.org/dataoecd/17/57/38055153.pdf*

Conclusion 27 – Greater Postgraduate Business Links Needed

There is more scope for the postgraduate education provision in Northern Ireland to support the aims of developing a higher value added economy. Engineering & technology, mathematical sciences and biological sciences are particularly under-represented. We also need to attract more of the world's best students here and postgraduate students need to be better equipped with the skills and training to support innovation in our economy.

5.7 STEM Migration Loss

We have previously highlighted that higher education is characterised by a much greater degree of student mobility than the other education and training sectors explored in this report.

We are not unique in this regard with most other regions of the UK also experiencing significant outward migration of their student populations to take up university courses. Recent research[79] indicates that NI-domiciled students migrate for a wide range of reasons including the desire to gain fresh experiences by studying outside their home region. The same research indicates that very few of our students migrate because of a perceived lack of university places at our local universities (the number of full-time undergraduate places at our local universities is subject to a cap, known as the Maximum Student Number).

However, we differ from most other UK regions by the fact that we do not attract significant inward migration of HE students from other parts of the UK and beyond to compensate for the outward flow. As we indicated in Section 5.5, the nett loss of HE students is a contributory factor in the 20% fewer first degree enrolments here compared to the UK as a whole.

The vast majority of NI-domiciled students transferring to higher education will attend university either here or in GB. DEL estimates that the number of our students attending universities in the RoI is a relatively low percentage and may therefore be disregarded in this analysis.

79 R. Osborne et al, June 2008, After School: Attitudes & perceptions of Northern Ireland school leavers towards higher & further education, training & employment

Data[80] on student movement considers four migration scenarios in respect of NI-domiciled students.

1. NI-domiciled students gaining STEM qualifications at NI universities and remaining in NI.
2. NI-domiciled students gaining STEM qualifications at NI universities and leaving NI.
3. NI-domiciled students gaining STEM qualifications at GB universities and returning to NI.
4. NI-domiciled students gaining STEM qualifications at GB universities and remaining outside NI.

Table 5.8 presents migration data for each scenario, based around first degree. The table distinguishes between medicine-related graduates and all other STEM graduates as there were noticeable differences in the patterns of these groups at postgraduate level.

The values presented in Table 5.8 are the percentages of the total cohort of NI-domiciled students gaining qualifications in 2006/07 in the UK, and whose destination was known. So for example, 66% of NI-domiciled students gaining STEM qualifications in the UK, other than in medicine, will have graduated at a local university and then chosen to remain here.

80 HESA Leavers' Survey 2006/07

Subject Area - First Degree	Qualifying at NI university and remaining in NI	Qualifying at NI university and leaving NI	Qualifying at GB university and returning to NI	Qualifying at GB university and remaining outside NI
Medicine & dentistry	67%	7%	7%	19%
Subjects allied to medicine				
Veterinary science	66%	9%	9%	16%
Architecture, building & planning				
Agriculture & related subjects				
Biological sciences				
Physical sciences				
Mathematical sciences				
Computer science				
Engineering and technology				
All Other Non-STEM Subjects	68%	6%	11%	15%
Total - All Subjects	67%	7%	10%	16%

Source: HESA

Table 5.8 Migration of NI-Domiciled Students

There are some important conclusions which may be drawn from the above figures:

- 23% of all NI-domiciled students who graduate within the UK each year choose to live and work outside NI following graduation;
- This figure rises to 26% when considering STEM graduates other than medicine;
- Approximately 11% of NI-domiciled students gaining a STEM subject qualification at a local university will leave NI following graduation;
- The flow of STEM graduates away from NI following graduation is broadly balanced by the number of STEM graduates returning.

The figures for postgraduate migration show a much greater variation between medicine related subjects and all other STEM subjects. 81% of NI-domiciled students graduating in medicine in the UK choose to remain and work here following graduation but this figure drops to 52% for all other STEM subjects.

In an attempt to address this issue, DEL has recently introduced the 'C'mon Over' campaign to help attract graduates back here. The Department, together with a number of employers here, has, to date, attended a recruitment fair in Glasgow and has also established a 'Northern Ireland' page on Facebook.

Conclusion 28 – STEM Migration loss is significant

These figures raise concerns about the loss of STEM talent, particularly when viewed in the context of a global market and the possible drain of STEM talent by countries such as the USA as their economies recover and grow following this current period of recession. We must find ways of attracting our best STEM talent to remain here.

5.8 Careers Education, Information, Advice and Guidance in Post-Primary Schools

Article 3 of the Employment and Training Order, 1988, places statutory responsibility for careers guidance upon the Department for Employment and Learning. Prior to 2004, this responsibility was addressed through the Employment Service (JobCentre Network) but this was restructured to form the present Careers Service.

The Careers Service currently has 175 staff, including 96 Careers Advisers based in 27 locations. The Advisers work with young people and adults in schools, colleges, careers offices, Job Centres, Jobs and Benefits Offices and in the community. In practice, the main focus has been on the delivery of service to young people in schools and in particular to those in year 12.

The services provided include:

- Class talks;
- Group sessions;
- Interviews;
- Psychometric assessment;
- Labour market information; and
- Attendance at parents evenings and careers events.

In 2006, the Education and Training Inspectorate carried out a review[81] of careers education, information, advice and guidance (CEIAG) in post-primary schools. The report stated that, while there have been many developments in CEIAG during the past decade, aspects of which have enhanced provision, there remain significant weaknesses in provision across those schools visited. In the majority of these schools,

1. There is inadequate time allocated to careers education while overall planning of CEIAG is weak
2. Work-related learning often consists of disjointed events offered in isolation by various teachers
3. There is insufficient use of current and accurate labour market information
4. Placement of students is becoming increasingly difficult because of employer insurance costs and a bigger demand on employers for places
5. In a significant minority of schools, teachers providing CEIAG lack appropriate training and as a consequence their knowledge and understanding of CEIAG is limited; they are heavily reliant on materials and briefing packs prepared by career co-ordinators

As highlighted in the recently published Careers Strategy[82], employer visits and job studies play a valuable part in developing an understanding of the modern work place. The opportunity for careers staff to obtain industry experience is also identified as being of particular value, yet the links between business and post-primary schools are largely fragmented and there does not appear to be a clear strategy for business to support CEIAG within schools.

Conclusion 29 – Insufficient STEM CEIAG

There is insufficient time allocated to careers education, information, advice and guidance (CEIAG), both in the provision to pupils and also in the time devoted to planning, within the majority of schools. CEIAG in post-primary schools would benefit greatly from a more integrated support by business but this will require coordination to ensure a consistent approach across the sector.

81 Education and Training Inspectorate, 2006, Report of a Survey on Careers Education, Information, Advice and Guidance in Post-Primary Schools

82 Department for Employment and Learning, January 2009, Preparing for Success, http://www.delni.gov.uk/ceiag_pfs.pdf

5.9 Specialist Schools and Further Education Centres of Excellence

5.9.1 Specialist Schools

Under the Department of Education's Specialist Schools' pilot initiative, 45 schools have been recognized across the following specialist areas. The number of schools in each category is shown in brackets.

- Arts – Performing and Visual (6)
- Business and Enterprise (6)
- ICT (4)
- Languages (3)
- Mathematics & Computing (2)
- Mathematics (3)
- Music (2)
- Science (11)
- Technology (1)
- Sport (2)
- Humanities (5)

The first cohort (12 schools) has operated from September 2006, the second cohort (13 schools) from September 2007 and a third (9 schools) from September 2008. A fourth cohort commences in September 2009, including six STEM specialist schools. The Specialist Schools initiative was established with the following aims:

1. To identify and build on particular curricular strengths;
2. To share good practice and secure whole-school development;
3. To contribute to the development of good leadership in schools; and
4. To take forward a community dimension by working with other schools, FE colleges and business.

The Specialist Award comprises recurrent funding of £100 per pupil annually, originally over a 4 year period and a one off support grant of £75,000. Schools are required to raise unconditional sponsorship of £25,000 to demonstrate commitment.

Evidence[83] would indicate that schools have made a good start to the initiative. Across the 31 emergent area learning communities, well over a quarter have a Specialist School with a specialism in a STEM subject or Business Education.

5.9.2 Further Education Centres of Excellence

In 2000, the then Department of Higher and Further Education, Training and Employment (DHFETE) invited bids from FE colleges for recognition as Centres of Excellence in one or more of the six vocational areas identified as important to the economy. These were construction, electronics, hospitality and tourism, information and communications technology, manufacturing engineering and software engineering.

A total allocation of £1,707,500 was provided to approved centres with a further £888,500 awarded to colleges demonstrating a high standard under certain criteria. Colleges were approved under the previous 16 college structure; these existing centres have now been absorbed within the new six college structure. The approved centres are shown in Table 5.9, the first cohort having been approved in 2000 and the second in 2002 as shown.

College	Manufacturing Engineering	Electronics	Software Engineering	Construction & Built Env	Hospitality & Tourism	ICT & Computing
South Eastern Regional College	O	O	O	O		O
Northern Regional College	O			O		
North West Regional College			O	O		
South West College						
Southern Regional College					O	O
Belfast Metropolitan College		O	O			

Source: DELNI *O - 2000* *O - 2002*

Table 5.9 Approved Centres of Excellence

83 Education and Training Inspectorate, April 2008, Survey Report on the Specialist Schools' Initiative

A number of the centres have been particularly successful in developing industry links. The support provided to business and the relationships thus developed have benefitted the colleges through, for example, equipment donations from companies or the opportunity for college staff to avail of professional development in the company. The knowledge acquired by college staff has helped to enrich the curriculum in related areas.

5.10 Step-Up Programme

We have already made reference to those government initiatives which are currently supporting STEM as presented in Annex 4. One particular programme which has enjoyed a considerable degree of success is the Step-Up programme funded by DEL.

The Step-Up programme is intended to provide an opportunity for disadvantaged pupils, who have low attainment levels and relatively low expectations, to improve their academic performance, self-esteem and motivation. Through Step-Up it is hoped that they will enter, and complete, programmes of study in higher education. The scheme targets pupils who are studying for GCE applied science (formerly Advanced Vocational Certificate in Education).

Step-Up comprises four stages; tutoring; summer school; university induction and mentoring. The programme has operated since 2000 in the University of Ulster's Magee Campus with the first cohort completing their qualifications in 2002. Six cohorts of participants have successfully completed the programme, with 99.8% obtaining the applied science qualification. The first destinations of these students are shown in Table 5.10.

University		Further Education	Employment	Other	Total
UU	Other				
231 (65%)	94 (27%)	9 (2%)	11 (3%)	10 (3%)	355 (100%)

Source: DELNI

Table 5.10 Summary of First Destinations of Step-Up Students (2002 – 2007)

Universities UK, the representative body for Universities, described Step-Up as an "outstanding example of best practice in the provision of educational opportunities for students from socially and economically disadvantaged backgrounds". The success of the programme is further emphasized by comparing GCE grade predictions and actual grades obtained; an analysis reveals that all pupils, without exception, achieved at least

one grade higher than predicted, with over 70% achieving two grades higher than predicted.

Of those students progressing directly to university:

- 92% enter STEM related programmes of study;
- The retention/ completion rate of Step-Up students is 95%; and
- 68% of Step-Up students achieve First or Second Class degree classifications.

The project is being expanded into Belfast, consistent with the Department's strategy to widen participation in higher education by disadvantaged students. The programme in Belfast has been allocated funding of £1.59 million over the period 2006/07 – 2012/13.

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

Thus far we have examined the STEM artery primarily in terms of the student flows within the system. Much data is available, allowing us to examine specific losses which will directly affect the ability of the artery to deliver the needs of the workforce and society.

There are however broader issues which, although they will have a significant influence on the STEM artery, are not so easy to quantify in terms of the problem or the impact of change. These wider issues act as constraints on the ability of the STEM artery to deliver on its potential and therefore need to be addressed.

6.1 Society's viewpoint

Despite a history of being the birthplace of many STEM innovators (see Annex 11), STEM and science are not terms synonymous with our population which remains largely indifferent to STEM. In a 2005 DTI survey of attitudes to science in the UK[84], we were shown to be the region least involved in STEM and with the lowest levels of science qualifications in the UK.

Within this survey, it was noted that a section of the population had been deterred from taking or developing an interest in science because of the way that their school had approached science. Indeed 29% of respondents here indicated this was the case, compared with 20% for Great Britain.

One bright spot in the DTI report was the widely visited and well received W5 science centre in Belfast. In the Skills and Science Programme between 2006 and 2008, W5 ran a wide range of events, workshops and activities which succeeded in engaging over 36,000 young people in STEM related activities.

In a Public Attitudes to Science 2008 survey[85], we were rated third lowest of the four UK regions, with a rating less than average. This survey gives a valuable insight into the attitudes within different sections of our society. it indicates, for example, that emphasis needs to be greatest on those groups least engaged in science, namely, the over 60's, younger women, those from poorer backgrounds, and parents with children under 16.

However, the media interest in STEM here is disappointing, with little reporting or broadcast programmes related to STEM locally. For example, in 2007 Coleraine Academical Institution won the F1 Schools World Championship and the students were presented with the trophy by Bernie Ecclestone at the Melbourne F1 Grand Prix. Yet this event went largely unnoticed in the media here.

84 DTI, 2005, Science in Society Survey

85 Research Councils UK, March 2008, Public Attitudes to Science 2008, *http://www.rcuk.ac.uk/sis/pas.htm*

We need to promote STEM awareness amongst the population. As we have already noted, a STEM educated society will be key to growing our economy but we must also understand that many parents do not recognise a vibrant private sector which offers exciting career opportunities for young people.

Currently within Great Britain, the 'Beacons for Public Engagement' project[86] is seeking to build linkages between the public and higher education institutions. Seven Beacons have been set up; science is one of the many areas being promoted to the public. There may be opportunities to either link with, or learn from, the experiences of those Beacons.

Conclusion 30 – Lack of STEM Awareness in this region

Creating a greater awareness and appreciation of STEM in society is fundamental to improving STEM provision in schools and colleges. As parents we need to understand the role of STEM in our economy and the many rewarding careers available to our children. However, recent surveys indicate that we are the region least involved in STEM and with the lowest levels of science qualifications in the UK.

6.2 Business viewpoint

The business community is arguably the key stakeholder in the STEM review process since economic growth will depend on an adequate supply of STEM talent. However the engagement in STEM by businesses, with some notable exceptions, has traditionally not been strong.

The level of business related R&D expenditure as a percentage of Regional Gross Value Added shows that we are the third lowest of the twelve UK regions[87]. The trend is improving with expenditure by business showing a 6% rise in 2006 and R&D employment growing 10%. For the first time in 4 years, business R&D expenditure exceeded expenditure by the higher education sector but we will have to increase expenditure by a further £164m to reach the national average.

86 Beacons for Public Engagement, http://www.publicengagement.ac.uk/project/default.htm

87 DETI, 2007, Research & Development Report November 2007

More so now than at any time in the recent past, the business community recognizes the problems related to STEM here and the need to take a leading role in addressing the challenges, if it is to ensure the supply of STEM talent needed for future growth. However, while there are many good examples of links between businesses and schools or FE colleges, this tends to be patchy and uncoordinated at best.

There is a need for a business-led framework of stakeholders which will engage directly with schools, FE colleges and universities to focus on growing the STEM artery across the education service and the promotion of STEM across our society. This is the view shared by the various companies, representative bodies and Sector Skills Councils involved in the STEM Review; it is critical that we engage the business community in a lasting way.

The potential exists to have business involved in all aspects of a STEM strategy, from partnering with primary schools, supporting careers guidance in post-primary schools, facilitating teacher and lecturer professional development, developing skills with FE colleges and engaging with the universities in joint research programmes.

We will face a particular challenge in this regard given the proportion not only of small and medium enterprises (SMEs) but also of micro-businesses which collectively make a much greater contribution to our economy, relative to that of small firms in the UK. 97% of firms here employ less than 50 staff yet they account for 61% of all the employment (against 45% in the UK). Coordination will be key and we will therefore rely heavily on the various business representative bodies and the Sector Skills Councils if we are to engage business effectively in moving forward the STEM agenda.

Conclusion 31 – Relatively smaller size of regional based STEM Businesses here

The relatively small size of businesses here will make engaging with the business community on STEM difficult.

6.3 Coordination of STEM within Government

The PfG puts growing a dynamic and innovative economy at the heart of its plans and there are some key goals which directly relate to the STEM agenda, namely:

- Increasing the number of PhD research students by 300; and
- Increasing the number of students studying STEM subjects by 25% by 2015.

STEM is implicit within many of the targets set and we need to continually identify its contribution to economic growth within the PfG. This will be part of the communication process with the Executive as we seek to develop a strategy for STEM and as we develop an action plan for the recommendations within this report.

As we may see from Annex 4, there is considerable evidence of STEM-related funding across government departments. What is needed, however, is a much greater level of coordination to ensure that the monies currently being made available for STEM are being focussed where they will achieve the greatest impact.

While other regions of the UK have the importance of science or STEM reflected in their structures and Chief Scientific Advisors within their government, this is not the case here. Although the use of industrial science panels for consultation has been an effective tool in other regions, it is not a substitute for having a strong STEM focus within government itself.

Conclusion 32 – Inadequate STEM structures in Government

The Programme for Government does include STEM targets but we need to distil and continually promote the role of STEM in achieving the economic targets set out by the Executive. Considerable funding already exists for STEM but it needs to be better coordinated.

6.3.1 The STEM Review and MATRIX, the NI Science Industry Panel

MATRIX was set up by DETI in 2007 to advise government on the commercial exploitation of R&D and science and technology. As a business-led expert panel, its remit has been to identify key areas of science, technology and innovation in which we have a lead over our competitors and advise on the policy required to exploit these strengths to the benefit of the economy. The MATRIX report[88] was formally presented to the Minister for Enterprise, Trade and Investment on 8 November 2008.

The STEM Review has actively engaged with MATRIX throughout and has assisted in shaping the recommendations of the MATRIX review. There has been crossover

88 MATRIX, http://www.matrix-ni.org/

of membership and the relationship between the two reviews has ensured that the recommendations arising from each are well aligned to the needs of our future economy. The two Reviews are mutually dependent; the vision of the economy will not be achieved without the supply of STEM skills and knowledge while the attraction of young people into STEM education will require an effectively communicated vision of future career opportunities within a growing economy.

6.4 The Relative Attraction of the Public and Private Sectors

Our principal focus within the STEM Review is the growth of our economy and specifically the supply of people well educated in STEM subjects in our workforce to sustain such growth. This implies a strong private sector and it is important that business attracts the most capable people at all qualification levels to ensure that we achieve our vision for growth.

But we must also recognize that the public sector, through its many different organisations and size, will absorb a large number of those people leaving our education system. Many of these people will be qualified in STEM subjects and it is important that, in seeking to grow the private sector, we better understand the relative attraction and supply needs of the two sectors.

The DETI Labour Market Bulletin published 2 December 2005[89], identified 139,000 graduates and 567,000 non-graduates in employment as of Spring 2005. The relative proportions of these groups within the public and private sectors is shown in Table 6.1; just over half our graduates work in the public sector (53%) while the majority of non-graduates (75%) work in the private sector. We can also see that more females work in the public sector while the private sector has a higher proportion of males.

Gender	Graduates Public Sector	Graduates Private Sector	Non-Graduates Public Sector	Non-Graduates Private Sector
Male	48%	52%	15%	85%
Female	59%	41%	38%	62%
All	53%	47%	25%	75%

Source: DETI Labour Market Bulletin 2005

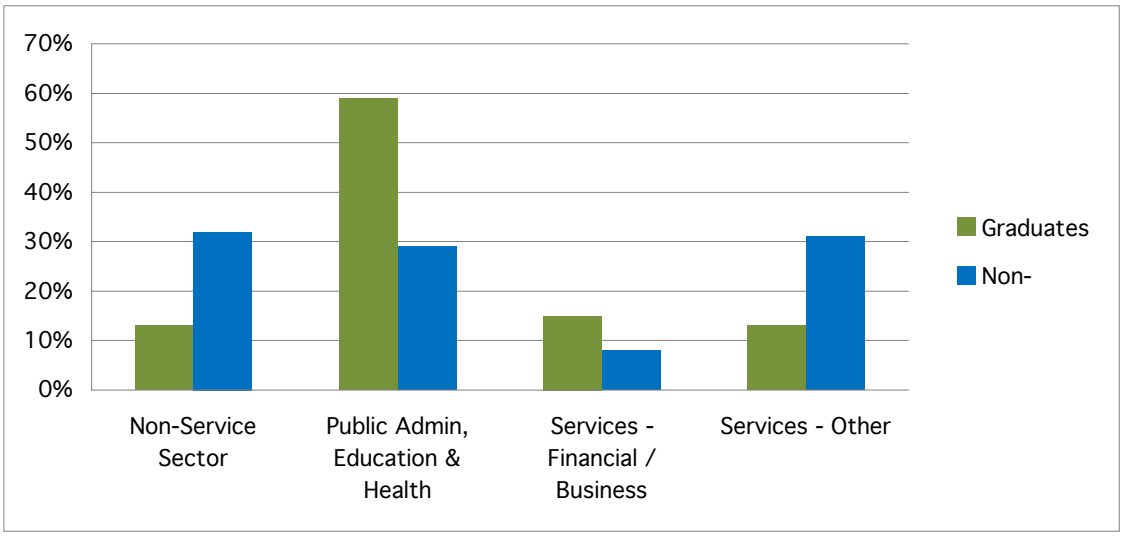
Table 6.1 Employment Comparison, Public and Private Sectors

89 DETI, December 2005, Graduates in the Labour Market in Northern Ireland 2005, http://www.detini.gov.uk/cgi-bin/downdoc?id=1785

Figure 6.1 shows the employment proportions across a number of sectors and we can now see the dominance of public administration, education and health which attracts around 59% of the total graduate number. If we apply the actual numbers quoted above, we find that the ratio of graduates to non-graduates in the public sector is around 1:2.

By comparison, the non-service sector, which includes manufacturing, construction, energy, water, agriculture and fishing, accounts for 13% of graduates. A similar comparison of graduates to non-graduates shows that the ratio in the private sector is around 1:10.

We have already discussed the need to raise the skills and knowledge level of those in the workforce at sub-degree level through increased apprenticeships, but we must also find a way to increase the numbers of graduates choosing to move into the private sector. According to the DETI figures, the ratio of graduates choosing public sector over private (non-service) sector is just under 5. While we cannot split these into STEM / non-STEM, we may reasonably assume that a significant number of STEM graduates are attracted to the public sector for reasons which we will now consider.



Source: DETI Labour Market Bulletin 2005

Figure 6.1 Percentages of Graduates and Non-Graduates by Broad Sectoral Area

6.4.1 Comparing Benefits and Opportunities

The public sector comprises many different organisations and opportunities to the extent that almost any qualification can be used when applying for a job. Working conditions are perceived to be good and there are many routes for career progression.

Flexible working is attractive particularly to those with families, although the private sector has increasingly been addressing this issue. Training and personal development is encouraged by public sector organisations within their staff, perhaps more so than the private sector where training budgets are often vulnerable to business fluctuations. Public sector pensions are also a strong attraction.

It is in the area of salaries that the private sector needs to review its current remuneration if it is to compete with the public sector for new staff. If the private sector here does not take steps to improve remuneration for STEM employment, it will be difficult to present a credible promotion of the benefits of a STEM career within the private sector, to parents and pupils alike.

Table 6.2 shows the gross weekly pay for full-time employees here, based upon the Annual Survey of Hours and Earnings[90] by the Office of National Statistics. We can see that in 2005 the mean of public sector earnings was 30% higher here than the private sector. By comparison, the differential in 2005 in England was 2% while in Scotland and Wales it was 13% and 19% respectively.

Year	Public Sector		Private Sector	
	Median	Mean	Median	Mean
1997	359	379	246	294
1998	380	395	259	304
1999	387	406	270	318
2000	408	420	283	334
2001	408	431	298	353
2002	427	455	314	364
2003	440	474	317	377
2004	470	498	330	394
2005	489	522	340	402

Source: ONS

Table 6.2 Gross Weekly Pay Comparison, Public – Private Sector

90 They Work for You, http://www.theyworkforyou.com/wrans/?id=2006-01-10b.39793.h

6.5 STEM Market Failure

There is a dichotomy around remuneration of STEM which appears to be unique to the private sector here.

Nationally and globally, the pay of STEM graduates is increasing yet despite the reported shortages of STEM graduates for certain subjects over the past two years, the pay level of graduates has not shown any increase locally.

Throughout this Review, we will identify various steps which must be taken on the supply side to grow the flow of people with STEM qualifications into the workforce. But it will be difficult to articulate the need for more students to support the local economy if there is not a benefit seen to accrue for this line of study.

Furthermore, graduates are becoming increasingly mobile and will be attracted by the offer of substantially higher salaries in economies such as that of the USA.

Conclusion 33 – STEM Market Failure Regionally

Despite reported shortages of STEM personnel, the pay level of graduates has not shown any increase locally. It will be difficult to promote the importance of STEM if remuneration does not reflect this.

6.6 STEM Teacher Supply

The quality of STEM teaching is fundamental to pupils' attainment. For example, it has been shown[91] that the qualification of physics teachers was the second most powerful predictor of pupil achievement in GCSE and A-level physics after pupil ability (measured by prior attainment).

In the following section, we will examine the issues of Initial Teacher Education and teacher supply, however the data on teacher vacancies is complex and it is difficult to obtain a precise picture. In addition, there is no data available on the extent to which STEM teaching is delivered by teachers whose qualification is not in the subject being taught (for example a biology teacher covering for a chemistry teacher during absence).

91 A. Smithers and P. Robinson, 2005, Physics in Schools and Colleges, Teacher Deployment and Student Outcomes, http://www.buckingham.ac.uk/education/research/ceer/pdfs/physicsprint.pdf

This review of Initial Teacher Education will be followed by an examination of teacher vacancies and the distribution of STEM teachers by subject area.

6.6.1 Initial Teacher Education

There are five initial teacher education providers here who provide courses as follows:

1. Primary Sector

   - The principal qualification is the Bachelor of Education (BEd) (Honours) degree provided by Stranmillis University College and St Mary's University College. The 2009/2010 approved intake for this provision is 190.

   - The University of Ulster (UU) offers a one-year course directed at primary level teaching leading to the award of a Postgraduate Certificate of Education (PGCE). St Mary's also offers a one-year PGCE course directed at primary level teaching in Irish Medium Schools, whilst Stranmillis offers a one-year PGCE course for early years teachers. The 2009/2010 approved intake for these provisions is 75.

2. Post-Primary Sector

   - The main qualification here is the PGCE which is delivered by Queen's University Belfast (QUB), UU and the Open University. The 2009/2010 approved intake for this provision is 278.

   - Stranmillis University College and St Mary's University College both offer BEd (Hons) at this level. The 2009/2010 approved intake for this provision is 100.

Within the approved intake numbers set annually by DE, the various institutions determine the targets or 'internal quota' for each subject. Since 2004/2005, the Higher Education Institutions (HEIs) have sought to increase intakes to mathematics and science courses. In 2006/2007, DE also approved two new post-primary pathways, mathematics and science, in the post-primary options offered on the BEd courses at Stranmillis and St Mary's Universtity Colleges.

In recent years, biology has been over-subscribed, chemistry has been slightly over-subscribed or on target and physics has been on or below target. Table A10.1 in Annex 10 provides data on applications and intake to initial teacher education between 2002 and 2007. Compared with previous years, PGCE mathematics applications have dropped substantially in 2007/08.

If we look at the applications in the sciences, we can see that the figures for biology are significantly greater than either chemistry or physics in each of the years. We may reasonably expect that in those subjects where competition for places is greatest, the institutions are able to recruit the largest proportion of students exhibiting the potential to become teachers of the highest quality.

Graduate figures for 2002 to 2006 are presented in Table A10.2 and we may see that there were only 8 physics teachers graduating in both 2005 and 2006, which is around one third the number of biology teachers.

In PGCE courses, students undertake main methods studies in the college or school of education for only 10 weeks, with the balance spent in schools on teaching experience. Given the time necessary for covering the increasingly complex and demanding STEM curricula, there would be merit in reconsidering this balance.

Conclusion 34 – Low Physical sciences applications to PGCE

Applications for the Physical sciences in PGCE courses continue to be low compared with biology and this is reflected in the relatively low numbers graduating in these subject areas each year. Mathematics applications have also dropped significantly in 2007/08.

6.6.2 Teacher Shortage

The issue of teacher shortage is less clear and difficult to determine, as highlighted in a recent Department of Education report[92]. Despite reports in the UK of difficult-to-fill vacancies[93], the data on vacancies here does not at first appear to support this. Indeed, a substantial number of science students emerging from the PGCE course fail to secure full-time, permanent positions on entry into the profession.

Table A10.3 presents the figures for vacancies which have been filled and those still existing in 2007/08. We can see that the numbers of existing vacancies in the sciences are very low, yet teachers and principals involved in the Review have highlighted problems in recruiting science teachers. Design and technology is the area where there seems to be the most problem filling vacancies although again

92 P. Eaton et al, 2006, The Recruitment and Retention of teachers in Post-Primary Schools in Northern Ireland, The Department of Education for Northern Ireland, Research Report No 43 (ISBN 1 897592 92 2)

93 http://news.bbc.co.uk/1/hi/education/7478302.stm accessed October 2008

the numbers are relatively low. However most schools report difficulties in finding substitute STEM teachers to cover for absence and training.

Research has shown that teaching outside of subject specialisms remains a problem. This was the conclusion of Eaton et al[94] who found that in mathematics and physics, approximately 10% of permanent full time teachers here were teaching outside of their particular subject specialism. While the breadth of the data was limited, the findings did indicate that, in the case of physics, this was an even bigger issue in non-selective schools where 15% of physics teachers were not qualified in that particular specialism.

In general, the trend was to use non-specialists at Key Stage 3 rather than more advanced levels. However, we have already identified Key Stage 3 as a critical time in developing a young person's attitudes to STEM when pupils are making crucial decisions about whether or not to study STEM subjects to a higher level. Pupils may be denied the expertise and enthusiasm of a subject specialist when they would particularly benefit from it.

Teacher recruitment and the usage of non-specialist teachers remain key issues but further examination is beyond the scope of this present review.

Conclusion 35 – Teacher shortage

Despite reported difficulties in recruiting science teachers, the available data on vacancies does not reflect this. However, research on teachers teaching outside of subject specialisms does indicate a problem particularly in the areas of mathematics and physics.

6.6.3 Distribution of STEM Teachers

Figure 6.2 shows the distribution of permanent or temporary, contracted registered STEM teachers by subject area and gender. As we may see, there are considerably more female STEM teachers than male, the ratio being almost 2:1.

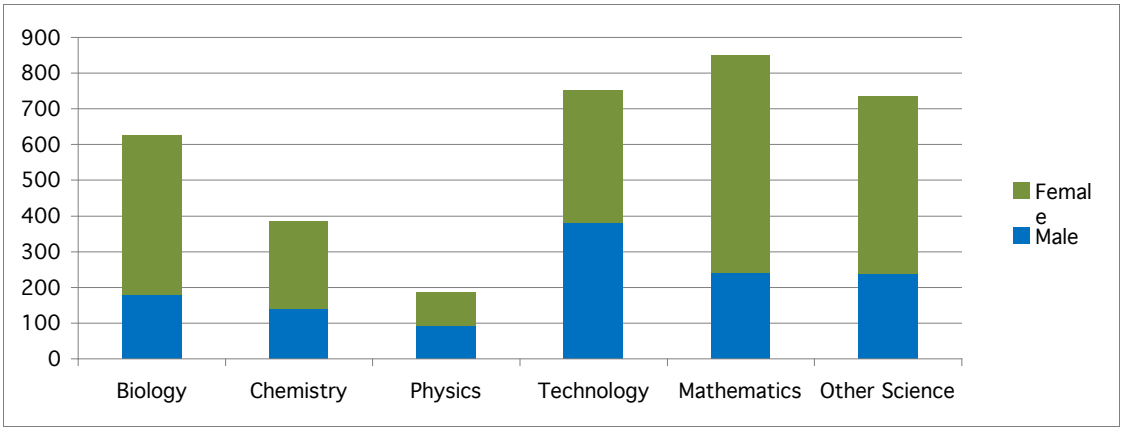
Most striking is the low number of physics teachers compared with other subject areas; there are fewer than 200 physics teachers currently registered and teaching

94 P. Eaton, Who is Teaching your Child? The Issue of Unqualified Subject Specialists in Northern Ireland, Cambridge Journal of Education, Vol 36, No 4

here. It is difficult to see how this correlates with the provision of physics in schools, at least through GCSE where physics should be on a par with other subject areas.

In the NI Substitute Teacher Register in Table A10.4, physics represents a low proportion of STEM teachers. Of particular concern is the fact that over 50% of these physics teachers are 55 years of age or older which will have consequences in coming years as a result of retirement.

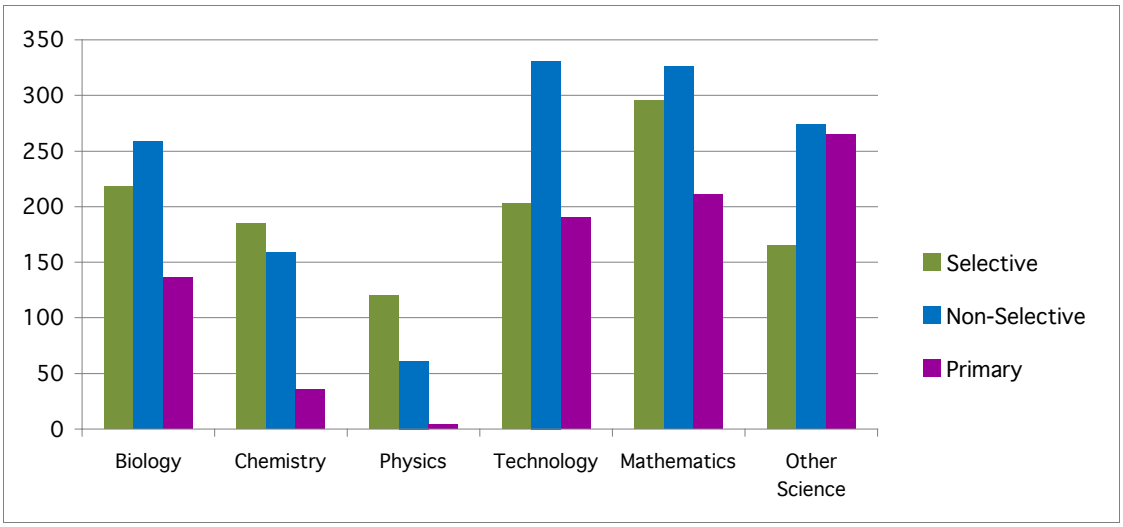
This issue of age profile does not appear to extend to the broader area of STEM teachers currently in employment. We can see in Table A10.5 that the age distribution for all STEM subject areas is also very similar for females and males.



Source: GTCNI

Figure 6.2 Numbers of Permanent/Temporary Contracted STEM Teachers by Subject Area and Gender

Considering the numbers of STEM teachers by subject area in primary and post-primary, we may note from Figure 6.3 that the majority of physics teachers are employed in selective schools. This is also reflected in chemistry while biology, like the other STEM subject areas, has a majority of teachers in the non-selective sector.



Source: GTCNI

Figure 6.3 Analysis of STEM Teachers by Subject Area and School Type

Conclusion 36 – Distribution of STEM Teachers

There are no obvious variations in age profile of employed teachers across the various STEM subject areas although overall numbers of physics teachers are very low. In terms of gender bias, female STEM teachers outnumber their male counterparts by around 2:1. Physics and chemistry teachers are predominant in selective schools. In general, there are insufficient substitute STEM teachers available to cover for teachers who are involved in continuing professional development.

6.7 Continuous Professional Development

Continuing professional development (CPD) is necessary for developing knowledge in the specialism taught including, in particular, an understanding of current developments and its relevance to the world of work.

The CPD of teaching staff within our schools is, in principle, addressed through the Curriculum Advisory and Support Service (CASS) although this responsibility will pass to the new Education & Skills Authority (ESA) when it is established on 1 January 2010. CASS was formally created in the five Education and Library Boards (ELBs) as

a result of the Northern Ireland Education Order 1989 (1989 Order) and in addition to CPD, also provides teacher and curriculum support, leadership and management development, post-inspection support, Board of Governor training and support to special programmes.

In light of other educational priorities, the ELBs have in recent years reduced the overall funding for CASS. Discussions with those ELB science representatives involved in the STEM Review has highlighted that training in the primary sector has concentrated on the revised curriculum with science and technology subject training limited to one in-service education and training (INSET) day for coordinators and beginning teachers. At the post-primary level, there have been two subject support INSET days in the past two years focussing on embedding ICT, literacy, numeracy and personal capabilities in the science curriculum.

This low level of CPD in schools has been reported elsewhere and is recognized as a key contributing factor to the decline in uptake of STEM amongst students[95]. Teachers and lecturers are the primary interface with students and can make STEM exciting and relevant, but only if they are equipped with the knowledge to help them contextualize the subject and make it relevant to young people.

Further Education is served through the support provided by the Learning and Skills Development Agency (LSDA). The Lecturers into Industry scheme has proven successful in areas such as engineering and there may be potential to extend this in an appropriate form to schools' staff.

An audit of the professional development needs of teachers in STEM areas is presently being undertaken by DE.

Conclusion 37 – Greater need for STEM CPD

Continuous Professional Development (CPD) is fundamental for STEM teachers to keep abreast of current developments in their subjects. However, CPD for teaching staff has been limited in recent years and this is seen as a key contributing factor to the decline in STEM uptake amongst students. There are good examples of CPD in further education which may find application in schools.

95 NI Science Education Forum, May 2005, A Scientific Future for Northern Ireland, Report from the Science Futures Conference

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

An overview of the model for the STEM supply is depicted in Figure 7.1. A typical progression for a student would be to follow a path from Key Stages 1 – 4 and then on to A-levels or further education. Some students leave after A-Level to take up employment while others continue to an undergraduate course at university. After graduation some students take up employment while others remain in education to pursue a postgraduate qualification. Many students may choose to continue their education through FE colleges and move to either take up employment or continue along the education path. During this time there are also gains and losses of students due to migration to and from other regions.

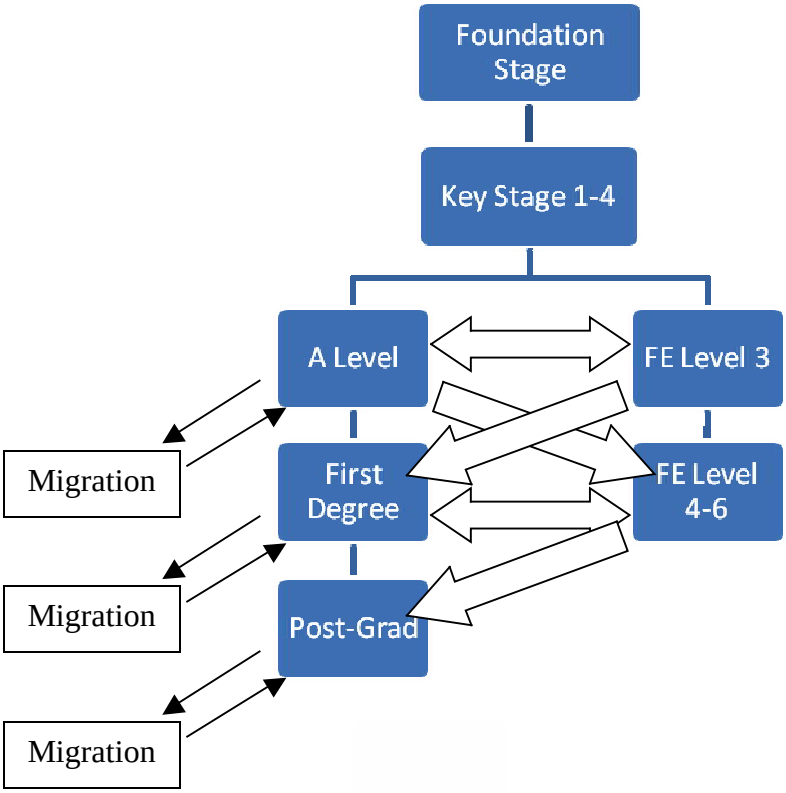


Figure 7.1 STEM Supply Model

The current tracking systems and the complicated interactions of the STEM supply and demand make it extremely difficult to interrogate the true nature of the STEM supply and demand and hence forecast its future direction. This is particularly true for the lower qualification levels. Consequently, this present analysis has limited itself to people qualified at sub-degree, degree and postgraduate levels (i.e. NQF 4-8), in an attempt to examine the balance between predicted supply and demand.

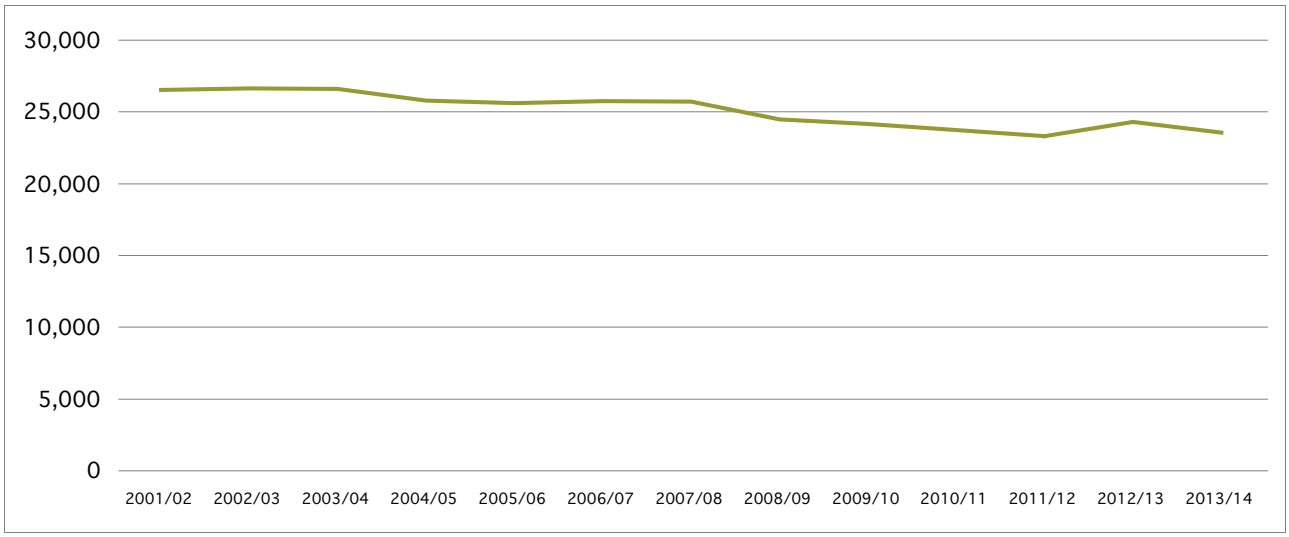
The projected demand is derived from the Oxford Economics[96] forecast and we have restricted ourselves to the view from 2011 onwards when the effect of the current economic downturn is expected to have eased. We have compared the projected demand for both the 'Baseline' and 'Aspirational' scenarios outlined in section 3.6.2 and we have made the following assumptions.

- STEM demand is calculated as a proportion of overall demand based upon past trends in the proportions of STEM subjects within overall qualifications obtained. A caveat is required in that these past trends show the historical supply to employers as opposed to what they may have actually required. This may not be representative of the future demand.
- The change in qualifications between 2007 and 2020 is assumed to be linear.

In preparing the projected supply we have assumed the following.

- The number of students choosing to study first degrees has been projected to remain a constant percentage of the total student population.
- The growth in total student population is projected to be a balance between the ongoing increase in student numbers (just over 2% annually) and the demographics of year 12 students which will see an ongoing annual decline of ~1% in total student numbers (Figure 7.2). A nett annual growth of 1.0% has therefore been applied to overall student numbers.

96 Oxford Economics, February 2009, Forecasting Future Skills Needs in Northern Ireland

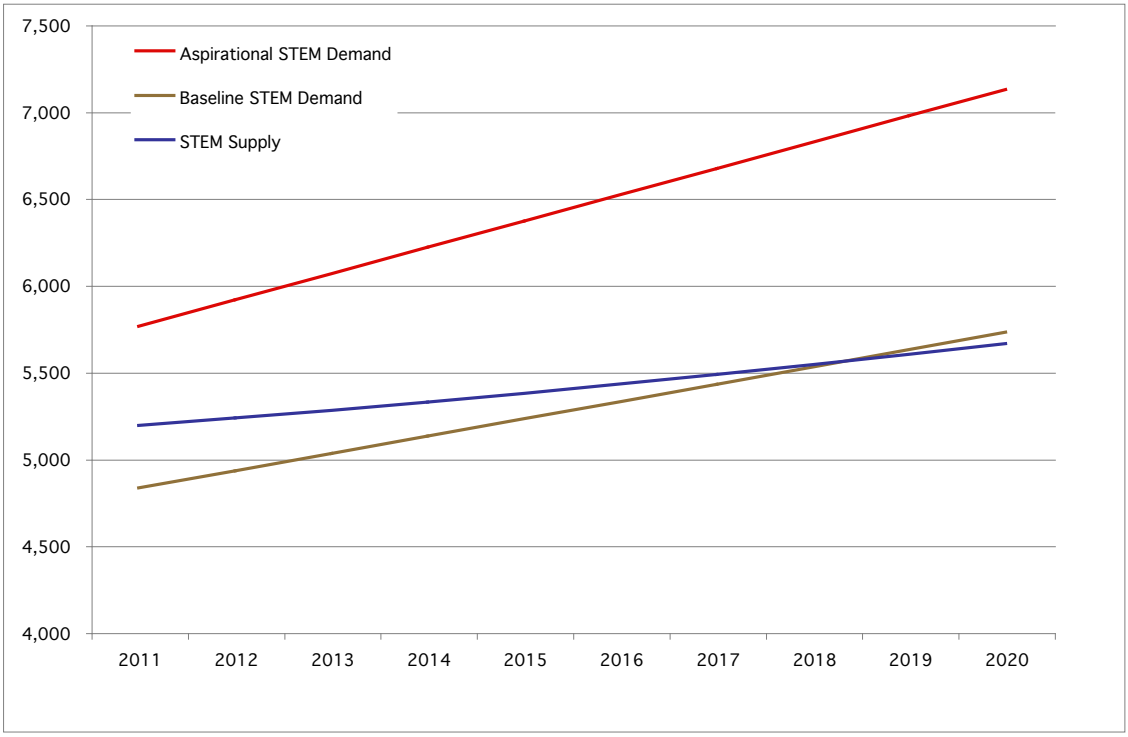


Source: DENI

Figure 7.2 Year 12 Pupil Projections

- We have examined the changing trends in student choices for graduate and postgraduate subjects over the last 5 years and have projected these forward to 2020.
- The effect of migration can be ignored as we have previously shown that the migration loss due to students studying locally and then moving away is largely balanced by students moving abroad to study their first degree and then returning to live and work here.
- The numbers of students choosing to study postgraduate degrees going forward remains the same as the average of the past 5 years.
- Since STEM demand relates to new entries to the workplace to satisfy expansion and replacement demand, sub-degree and first degree supply is based upon full-time graduates. Postgraduate numbers include both full-time and part-time students.

The projected STEM supply and demand through 2020 is shown in Figure 7.3 below.



Source: Oxford Economics & HESA

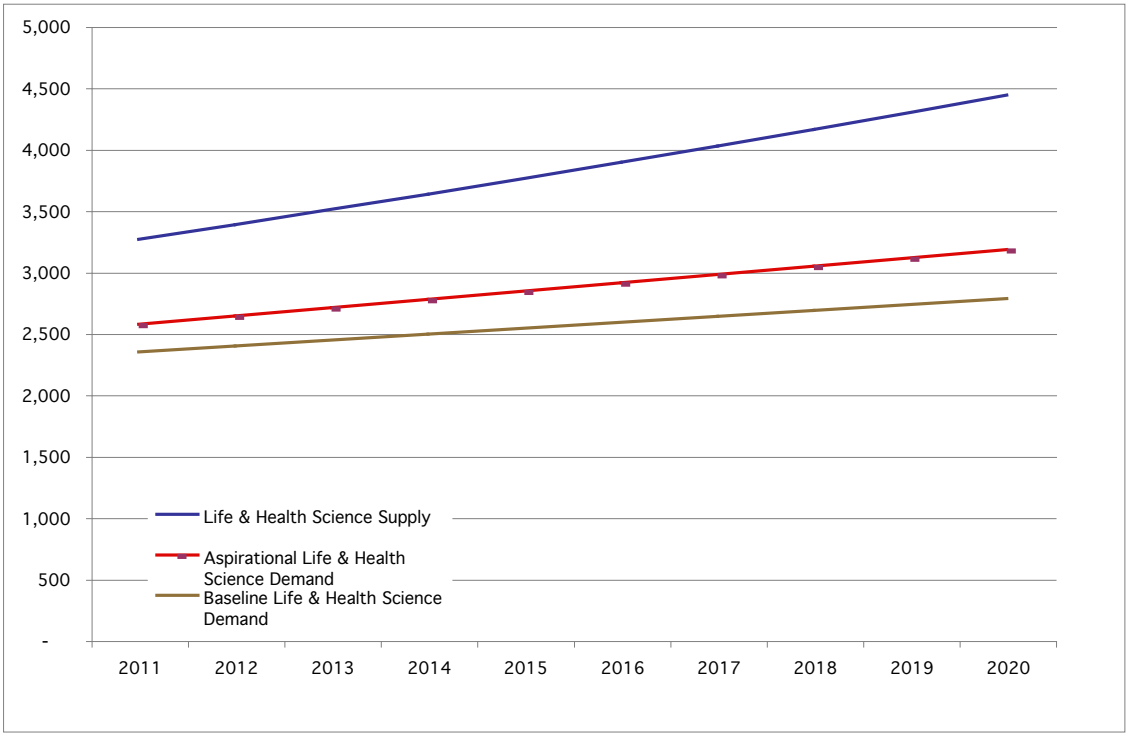
Figure 7.3 Projected STEM Supply and Demand

STEM demand is expected to grow in line with the anticipated demand for higher level qualifications in the coming years. The projected STEM supply, although just about able to meet the baseline demand requirements in 2011, starts to fall behind the needs of the Aspirational scenario rather quickly.

To better understand the components of this imbalance, we need to examine the trends in the underlying subjects. While we may combine the STEM subjects in various ways, we have observed some distinct trends between the groups of subjects which we may define as life & health sciences related and those which we may define as physical sciences related.

We will examine first the life & health sciences group which, with reference to Intute[97], embraces medicine & dentistry, subjects allied to medicine, biological sciences, veterinary sciences and agriculture and related subjects. Figure 7.4 compares the projected supply with both the Baseline and Aspirational demand scenarios and as we see, supply appears to be well in excess of the projected demand.

97 Intute, www.intute.ac.uk/

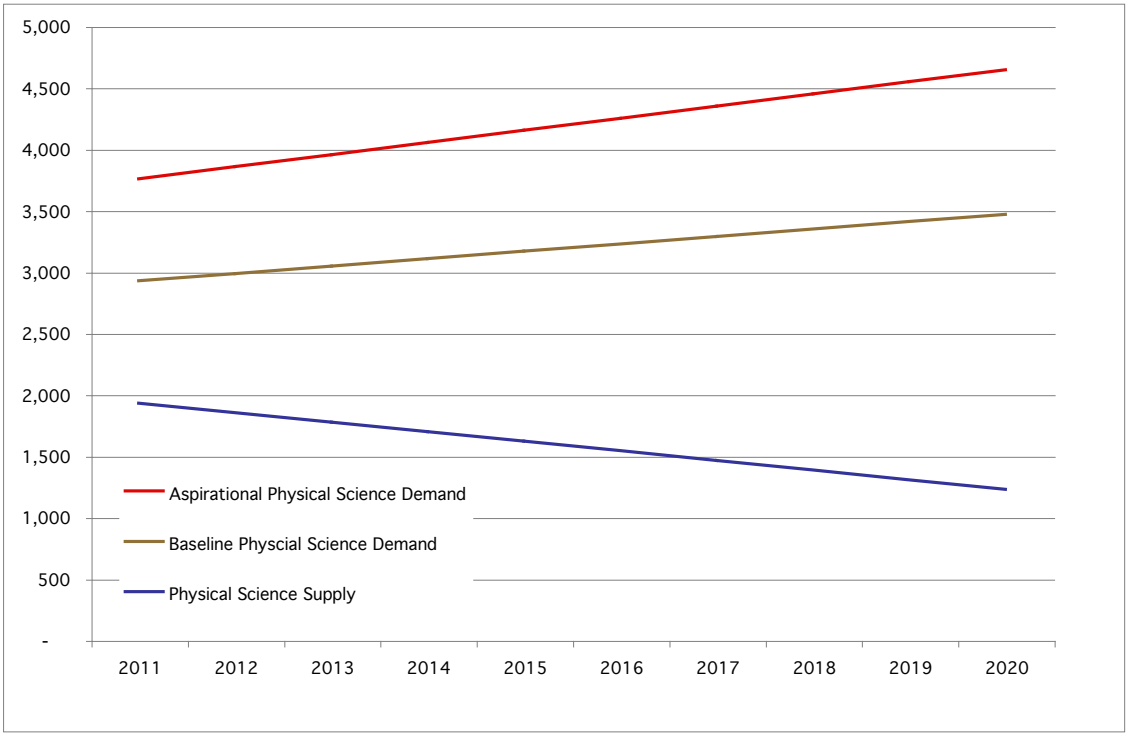


Source: Oxford Economics & HESA

Figure 7.4 Projected Life Science STEM Supply and Demand

Although forecasts of supply and demand can have significant errors, the numbers do point to a serious issue which needs to be addressed.

If we examine the supply and demand for the corresponding physical science related subjects i.e. physical science, mathematical sciences, computer science, engineering & technology, and architecture, building & planning, the results are as displayed in Figure 7.5.



Source: Oxford Economics & HESA

Figure 7.5 Projected Physical Science STEM Supply and Demand

The supply of physical science students is considerably below the demand from either scenario and is heading in the wrong direction. Unless there is a correction this could have a serious impact on achieving either forecast scenario.

Conclusion 38 – Forecast shortfall in STEM Graduates

Despite the current recession and lower forecast growth within the economy, there will be a shortfall in the supply of STEM graduates at the higher qualification levels, NQF4 – 8 to meet the targets set in the Programme for Government. An analysis of the key STEM groups indicates an oversupply in life & health sciences and a major shortfall in the physical science related qualifications. Shortfalls may also exist at other levels, but accurate analysis becomes increasingly difficult at lower qualification levels.

MATRIX has identified the market opportunities open to us through its Horizon Scanning programme and success in each of these will demand an availability of STEM skills at these higher qualification levels. Given the multi-dimensional nature of the skills needed within the various business sectors, it is critical that we provide a broad base of STEM skills to enable growth within our private sector.

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

In the report thus far we have identified the issues, considered the evidence and presented key conclusions around those areas which directly impact upon STEM. We shall now draw upon those conclusions as we develop our recommendations.

Though presented individually, the recommendations have an interdependence which derives from the original Terms of Reference. Implemented individually, each will achieve a level of success but if we are to progress towards our vision for STEM and achieve the dynamic and innovative economy to which we aspire, we must address the recommendations as a concerted series of actions coordinated within an overall STEM programme.

The recommendations are aligned into 4 major imperatives:

1. Business must take the lead in promoting STEM;
2. We must alleviate key constraints in the STEM artery;
3. There needs to be increased flexibility in the provision of STEM education; and
4. Government must better coordinate its support of STEM.

8.1 Business must take the primary role in promoting STEM

Business must take the leadership role in firmly establishing STEM as the centre of a global innovative economy. Government, universities, FE colleges and schools need to support the initiatives but only business can provide the credible and effective leadership to achieve the goals.

There is a shortage of enthusiasm among students for STEM subjects, particularly the physical sciences as seen in Conclusion 6, Conclusion 15 and Conclusion 16. A key factor in this lack of enthusiasm is a failure to see the value in the STEM subjects, both in their applicability and the career opportunities which they offer. In Conclusion 21, we saw how business links have enhanced the curriculum within FE and assisted the staff in advising on career options. The business community must increasingly recognize its pivotal role in making STEM more attractive to students.

In addition, we saw in Conclusion 30 that the importance of STEM is less appreciated in this region than any other in the British Isles. Business, by making a strong commitment, can help change that better than anyone.

Although there are some businesses which have shown leadership and engaged with local schools, colleges and universities to help encourage STEM, the results have been patchy and uncoordinated. A factor in this (as seen in Conclusion 3) is the lack of

suitable organization or mechanisms to coordinate the activities. This brings us to our first recommendation.

Recommendation 1 – Establish a business-led STEM framework

Business should develop and lead a framework of stakeholders which will engage directly with schools, FE colleges, universities and government to focus on growing the STEM artery across the education service and the promotion of STEM within our society.

If business is to help grow and sustain our economy, it needs a good supply of STEM staff. However, in Conclusion 28 we see that we lose significant numbers of STEM students to migration, a fact not helped by the relatively lower level of remuneration of STEM staff as seen in Conclusion 33. To date business has also been slow to partake in STEM apprenticeships (Conclusion 23).

In addition, many STEM students set their sights on a career in the health professions (see Conclusion 38) and the public sector and there are clear monetary and societal rewards for such a course of action. Business is increasingly losing out and therefore needs to articulate the rewards and advantages of pursuing a career in the private sector whilst also addressing the remuneration issue. Such promotion of STEM career path should factor in progression through to postgraduate level which is critical to future business development and of need of greater business involvement (Conclusion 27). This brings us to our next recommendation.

Recommendation 2 – Develop a clear STEM careers path

Business, in conjunction with the Sector Skills Councils, professional bodies, DEL and DE need to develop and promote clear career paths for STEM students. Linking formally with the Careers Advisory Service, the pathway should identify the benefits of taking up apprenticeships, graduate and postgraduate education and the career opportunities available within the private sector.

For the local economy to succeed we need to retain the brightest and best students to help sustain and increase innovation. As we have already seen we are losing significant numbers of students to migration (Conclusion 28). In addition, we are failing to attract the numbers and quality of students from the rest of the world that other regions do (Conclusion 26).

We need to increase the incentives to attract our best STEM students to study here if we are to help reverse the fall off in certain STEM subjects at FE level (Conclusion 19), undergraduate level (Conclusion 24) and postgraduate level (Conclusion 27). This brings us to our third recommendation.

Recommendation 3 – Introduce prestigious STEM scholarships

Business, professional bodies and DEL should introduce prestigious scholarships in STEM subjects for students entering FE and HE, targeted at retaining our most able STEM students following graduation.

Gender bias is a major STEM issue. Not only are women increasingly under represented in the STEM artery as a whole (Conclusion 7) but the gender bias is particularly strong in the physical sciences and engineering and then especially in employment. This is a major loss of talent to the STEM artery and business once again is best placed to help address this gender imbalance with the promotion of role models in industry. This brings us to our fourth recommendation.

Recommendation 4 – Address gender bias

Business, in conjunction with Sector Skills Councils, and in partnership with schools, colleges and universities, must address the issue of gender bias, particularly the disparity between the physical sciences and engineering on the one hand and the life sciences on the other.

For the framework in the first recommendation to be successful, it needs to have sufficient size and critical mass to effect change. However, the relatively small to micro-sized businesses locally (Conclusion 31) will make this difficult to achieve. To increase its effectiveness, the organization should seek partnerships in neighbouring regions and especially on the island of Ireland in order to develop a critical mass of businesses capable of promoting STEM. The government in Ireland has already been active in promoting STEM and many of the stakeholders already have all-island links. This brings us to our fifth recommendation.

Recommendation 5 – Develop regional STEM links

The framework to engage business should include mechanisms to join with STEM businesses in neighbouring regions and especially on the island of Ireland, to create a critical mass of larger businesses to enhance STEM promotion. In support links should also be developed with DETI.

8.2 We must alleviate key constraints in the STEM artery

It is clear we are in a fortunate position in that the quality of our education is generally strong; however, there are number of constraints which need to be addressed;

While many schools are achieving very good STEM results, significant variation exists in STEM performance across the remainder of post-primary schools. We have seen the PISA results which show that there is an abnormally large spread in the science results of our 15 years olds (Conclusion 12). Thus, while our science performance is generally strong, we have the longest tail of lower performing pupils of any other country.

There may be some clues from PISA as to the origins of this disparity. It was noted that the relationship between the performance of students and the school principal's perceptions of the quality of the school's educational resources (and the activities to promote the learning of science[98]) was statistically significant.

There is also evidence that a relatively small proportion of schools (~20%) account for over 70% of the entries in STEM subjects at A Level (Conclusion 18). We have also raised questions around the opportunities for pupils in the non-selective sector to progress in the STEM artery (Conclusion 17). Care should be exercised in drawing conclusions from these high-level patterns as the factors impacting on attainment are complex and interactive. However it is clear that there is an issue around disadvantaged pupils that needs to be addressed.

As we have seen in Conclusion 5, the balance of the qualification levels is expected to move upwards in the future and it will be the students with the lowest level of attainment in STEM who will find it increasingly difficult to find employment. It is imperative then that we focus resources on raising attainment of these pupils. This brings us to our sixth recommendation.

98 PISA, 2006, Executive Summary, *http://www.oecd.org/dataoecd/15/13/39725224.pdf*

Recommendation 6 – Address the disparity in STEM performance amongst schools

There needs to be action focused on raising the achievement of poorer performing pupils in STEM, particularly in science and mathematics. Improving pupils' mathematical knowledge and the application of their mathematical skills will be a prerequisite to support such action.

Conclusion 8 highlights the concerns and apparent lack of confidence amongst primary school teachers to teach the 'World Around Us' area of learning and in particular, the science element of the curriculum. It is critical that we provide children with a rich experience of science at this age. This brings us to our seventh recommendation.

Recommendation 7 – Support primary school teachers in teaching the World Around Us area of learning

As a matter of urgency, there needs to be a programme of support for primary school teachers to ensure they develop the confidence and enthusiasm to teach science in ways which motivate and engage pupils.

As we have seen in Conclusion 13, the performance in mathematics is a major contributor to the decline in physical sciences and needs to be addressed. It is recognised that there is a debate nationally on this subject and currently there is the roll out of the revised numeracy strategy here. Our eighth recommendation therefore addresses the adequacy of current mathematics initiatives to support the STEM artery.

Recommendation 8 – Review ongoing developments in mathematics in relation to STEM provision

There is a need to review whether or not current initiatives are adequately addressing the development of mathematical knowledge and the difficulties experienced by many young people in applying their mathematical skills, which hinder their progress in science, engineering and technology. In particular, DE, DEL and CCEA should review how ongoing developments in GCSE mathematics will impinge on the provision being offered by schools, FE colleges and training organisations.

Despite the overall high performance of STEM locally, we are also the region in the PISA report which reports the least enjoyment of science of the local regions. A key factor in enjoying STEM is to increase the level of investigation and experimentation in the classroom. Perhaps the single most recurring theme around curriculum has been the importance of experimentation and practical work in retaining a young person's interest in STEM.

In Conclusion 10 we identify that the teaching of mathematics is made more effective by making it interactive. In FE we see how, as work became less practical, it had a negative effect on STEM enjoyment – Conclusion 20.

Reasons for the omission of practical work vary from lack of confidence of teachers, teaching which is dependent on revising past examination papers, limited space within the timetable or health and safety concerns, but the research clearly shows that practical content is a major factor in retaining young people within the STEM artery. And so to our ninth recommendation.

Recommendation 9 – Make STEM learning more enquiry based

Young people's STEM learning in schools, FE colleges and training organisations needs to be much more investigative and enquiry-based than it is now. The relevance of STEM in everyday life should be emphasized by all the key interests.

It could be argued that Key Stage 3 is the most critical stage in forming a child's interest in STEM yet, as we identified in Conclusion 9, there is a marked fall off in enjoyment during this period. Previous research would suggest that repetition of work carried out in Key Stage 2 is a major contributing factor to the decline in enjoyment of STEM at Key Stage 3.

Recommendation 10 – Improve planning at the Key Stage 2/ Key Stage 3 interface

Post-primary schools and their feeder primary schools need to plan jointly to ensure that there is improved continuity and progression from KS2 to KS3, so that the teaching of STEM builds effectively upon the children's earlier learning.

8.3 There needs to be increased flexibility in the provision of STEM education

The provision of STEM education more than any area needs to be flexible to meet the changing demands of technology in society and the workplace.

Students are facing increasing numbers of specialist STEM subjects from GCSE up and are increasingly moving away from the traditional combinations (Conclusion 16). This has implications for courses later in the STEM artery; students following different subject combinations may no longer have the requisite knowledge to progress successfully in certain subjects.

Business on the other hand is becoming more multi-disciplinary and the preference of most businesses is for students to study general STEM subjects rather than specialist subjects.

As reported earlier, there are already shortages in key STEM subjects (Conclusion 24) which will have implications for the opportunity to develop the postgraduate resources required for a thriving economy. It is clear that, as a small region with limited resources, it would be preferable to have more students studying the core STEM subjects to allow the greatest flexibility in the STEM artery to respond to technological and market changes.

Medicine has a major influence upon a student's subject choice. If the medical profession were to consider recruiting significant numbers of students through a graduate programme as in the USA, and increasingly in the UK and Ireland, it would help increase flexibility. Students, uncertain as to a career in medicine, could study STEM subjects and delay their decision until after graduating in their first degree choice. Students who then decided to follow a career in medicine would be equipped with a deeper understanding of areas which might relate to future specialisms in Radiology, Oncology etc.

Recommendation 11 – Increase the focus on the core sciences and mathematics subjects

STEM teaching resources, scholarships and grant assistance should be focused on the core STEM courses, viz physics, chemistry, biology, and mathematics to provide maximum flexibility and efficiency later in the STEM artery, to meet the changing demands of the economy. In addition postgraduate subjects such as medicine should consider the implementation of a graduate stream to allow easier transfer from core science courses.

The current trend in STEM education is to follow the more academic route, a consequence being that students often find themselves in educational styles for which they are not well equipped. This is one factor in the worsening retention rates in universities (Conclusion 25).

Students who drop out may have difficulty rejoining the STEM education artery and there should be proactive mechanisms to offer alternative STEM course options to students to avoid such losses from the STEM artery.

Recommendation 12 – Facilitate easier two-way transfer between FE & HE

Our local universities and FE colleges should introduce mechanisms to permit easier two way transfer, thereby allowing students additional time and space to choose between academic, technician, or apprenticeship style courses and providing alternative choices in the event of non-continuation; courses must sit within the qualifications and credit frameworks.

DEL has already started to review barriers which may exist to apprenticeships and which prevent STEM students from receiving support from government. This review should be extended to all areas of STEM support if we are to attract the best students to our local universities, no matter where they come from (Conclusion 26).

Recommendation 13 – Reduce barriers to obtaining support in STEM

Government, in conjunction with FE and HE, should review the financial support for students both full-time and part-time on all STEM courses.

In Conclusion 37, the importance of continuing professional development was highlighted in assisting a teacher or lecturer in contextualizing the subject, relating it to current developments in the field and linking it to everyday life in such a way as to create a more vibrant learning experience for the student. FE colleges, through the "Lecturers into Industry" programme run by LSDA, have recognized the benefit. It is critical that we provide a wider range of teachers and lecturers with the benefit of this type of CPD so that children can have a richer experience of STEM.

Recommendation 14 – Develop a STEM CPD framework

There needs to be a clear CPD framework related specifically to STEM, which continues to update teachers, lecturers and support staff on STEM development and issues globally and to promote best practice in respect of curriculum, pedagogy and assessment.

Insufficient time is devoted to Careers Education, Information, Advice and Guidance (CEIAG) as we saw in Conclusion 29 and this is contributing to the decline in STEM. As there is now a greater range of subjects being offered to pupils, and an increasing range of career opportunities, it is clear that more resources need to be allocated to STEM CEIAG. As stated in Recommendation 2, there needs to be a formal linkage between the proposed business framework and the Careers Advisory Service in this regard.

Recommendation 15 – Increase the emphasis on STEM CEIAG

There needs to be more resources allocated by business and government to Careers Education, Information, Advice and Guidance (CEIAG) for STEM. In support, formal links should be created between the business framework and the Careers Advisory Service.

8.4 Government must better coordinate its support for STEM

Although government has recognised the importance of STEM, its approach has lacked coordination. In order to compete effectively in a dynamic global economy, the Executive must have a clear strategy which incorporates STEM as stated in Conclusion 2.

We would recommend that the Executive takes the following actions:

Recommendation 16 – DE and DEL, supported by other relevant Government departments, should develop a clear STEM strategy & vision

Building on the Executive's Programme for Government to create a dynamic, innovative economy, DE and DEL, supported by other relevant departments, should develop a clear strategy for STEM recognizing the critical role of STEM and the skills required for sustained economic growth.

To put this strategy into action will require coordination across a number of government departments. In Conclusion 32 it was stated that current structures are not sufficient. We therefore propose:

Recommendation 17 – DE and DEL, supported by other relevant Government departments, should introduce cross-departmental structures to help develop appropriate STEM strategies and policies.

The structures should include a Chief STEM advisor who would carry the educational responsibilities of a Government Chief Scientist and a National STEM Director.

The principal driver of the demand for skills should be the private sector, but while government is the primary destination for STEM graduates it must be more proactive in managing the skills artery, especially in health and education (Conclusion 38)

As was highlighted in Conclusion 4, current systems do not readily permit an assessment of the numbers flowing into the workplace at the various qualification levels nor is there a readily available economic forecast against which to compare this. Yet as we have shown in this Review, such data is necessary if we are to better understand the dynamics of supply and demand within the economy.

Recommendation 18 – Develop a more proactive approach to managing STEM supply and demand

Government needs to be more proactive in managing the supply and demand of skills in relation to economic needs. To assist in this, DEL supported by other relevant departments should develop appropriate systems to better assess the flow of skills into the workforce at the various qualification levels, including the application of ongoing foresight.

The overall number of physics teachers here is very low (Conclusion 36), as are the applications to physical sciences in PGCE courses (Conclusion 34). Mathematics applications to initial teacher education have also dropped significantly in 2007/08 (Conclusion 34) and there is a need for further research into the issue of teachers teaching outside of subject specialisms (Conclusion 35). Our penultimate recommendation is therefore,

Recommendation 19 – Increase the number of applications for physical sciences and mathematics places in Initial Teacher Education courses

DE, in partnership with Initial Teacher Education institutions, should continue to seek to increase the number of students entering Initial Teacher Education courses in the physical sciences and mathematics. Further research is required into the issue of STEM subjects which are taught by teachers without appropriate specialist qualifications

In Conclusion 5 we saw that the future economy will be increasingly 'skills-hungry', demanding higher level STEM skills within the workforce.

While we need to increase the supply of STEM skills generally, there will also be a need to develop resources which can react quickly to acute shortages created by shifts in the economy or by major inward investment projects. DEL, together with the Sector Skills Councils, should have contingency plans to cope, not only with the longer term needs, but also any rapid fluctuations in business sectors.

This brings us to our final recommendation.

Recommendation 20 – Expand the capacity to respond to critical skills shortages as they arise

DEL, in conjunction with business, should continue to develop and build upon its current initiatives to tackle skills shortages. This should include the application of foresight and knowledge of important emerging market opportunities.

PHOTO REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

Annex 1

Terms of Reference for the STEM Review

The Terms of Reference established by DE and DEL for the STEM Review were as follows.

1. Vision

- establishing the Government's vision of STEM
- identifying the current issues and concerns in respect of STEM
- establishing the data, quantitative and qualitative, for the provision of and the outcomes for STEM in Northern Ireland and benchmarking against the UK and Ireland

2. Curriculum

- recommending the way forward for schools and FE in respect of:
- curriculum
- pedagogy
- coherence across the various subject areas

3. Attitudes

- establishing how to promote an understanding and acceptance of STEM, and the importance of investing in STEM education to society in NI

4. Resources

- analysing and make recommendations in respect of teacher demand and supply in these areas

5. Demand side

- analysing and recommending better linkages between business, schools and FE colleges

6. Government

- promoting coherence of current government policy in respect of promoting STEM in society;
- defining the links between STEM in schools and FE and the Government's Skills and Innovation Strategies

Annex 2

STEM Subjects within Schools, Further Education and Higher Education

Schools (GCSE and A-level)

21st century science
Additional mathematics
Applied mathematics
Applied science
Biology
Chemistry
Computer studies
Computing
Construction
Engineering
Further mathematics
Geology
Information and communications technology
Information technology
Manufacturing
Mathematics
Physics
Psychology
Science double award
Science single award
Statistics
Technology and design

Further Education (All levels)

Medicine & Dentistry	Clinical Dentistry
	Clinical Medicine
Allied to Medicine	Anatomy & Physiology
	Pharmacy
	Nutrition
	Opthalmics
	Audiology
	Nursing
	Medical Technology
	Other Medical Subjects
	Pharmacology
Biological Sciences	Biology
	Biochemistry
	Microbiology
	Other Biological Sciences
Agriculture & Related	Veterinary Science
	Agriculture
	Food Science
	Other Agricultural Services
Physical Sciences	Chemistry
	Physics
	Geography Studies as a Science
	Environmental Science & other Physical Science
Mathematics & Computing Science	Mathematics
	Computing
	Other Mathematical Sciences
	Statistics

Engineering & Technology	General Engineering
	Civil Engineering
	Mechanical Engineering
	Aeronautical Engineering
	Electrical Engineering
	Electronic Engineering
	Production Engineering
	Chemical Engineering & Fuel Technology
	Other Engineering
	Metallurgy
	Minerals Technology
	Polymers & Textiles
	Others Material Technology
	Other Technologies
	Marine Technology
Architecture, Building & Planning	Architecture
	Building
	Town & Country Planning
	Other Architectural Studies
	Environmental Technologies
	Urban & Regional Planning

Higher Education

Medicine & dentistry	Pre-clinical medicine
	Pre-clinical dentistry
	Clinical medicine
	Clinical dentistry
	Others in medicine & dentistry
Subjects allied to medicine	Broadly-based programmes within subjects allied to medicine
	Anatomy, physiology & pathology
	Pharmacology, toxicology & pharmacy
	Complementary medicine
	Nutrition
	Ophthalmics
	Aural & oral sciences
	Audiology
	Nursing
	Medical technology
	Others in subjects allied to medicine
Veterinary science	Pre-clinical veterinary medicine
	Clinical veterinary medicine & dentistry
Architecture, building & planning	Architecture
	Building
	Environmental Technologies
	Landscape design
	Planning (urban, rural & regional)
	Others in architecture, building & planning
Agriculture & related subjects	Animal science
	Agriculture
	Forestry
	Food & beverage studies
	Agricultural sciences

Biological sciences	Broadly-based programmes within biological sciences
	Biology
	Botany
	Zoology
	Genetics
	Microbiology
	Sports science
	Molecular biology, biophysics & biochemistry
	Biochemistry
	Psychology
Mathematical sciences	Broadly-based programmes within mathematical sciences
	Mathematics
	Operational research
	Statistics
Computer science	Computer science
	Information systems
	Software engineering
	Artificial intelligence
Physical sciences	Chemistry
	Materials science
	Physics
	Forensic & archaeological science
	Archaeology as a Physical Science
	Astronomy
	Geology
	Ocean sciences
	Physical & terrestrial geographical & environmental sciences
	Environmental Science and others in physical sciences

Engineering & technology	General engineering
	Civil engineering
	Mechanical engineering
	Aerospace engineering
	Naval architecture
	Electronic & electrical engineering
	Production & manufacturing engineering
	Chemical, process & energy engineering
	Minerals technology
	Metallurgy
	Polymers & textiles
	Materials technology not otherwise specified
	Maritime technology
	Biotechnology

Annex 3

Membership of the STEM Review

The following lists the membership of the Steering Group and the three Working Groups

Steering Group

Dr Hugh Cormican	Chair of the Review and Director, Bioptics Inc
Dr Alan Blair	Programme Manager
Prof Richard Millar	Dean, Faculty of Engineering, UU
Prof Tom Millar	Dean, Faculty of Engineering & Physical Sciences, QUB
John D'Arcy	Chief Executive, ANIC
Dr Claire Passmore	Matrix
Peter McAlister	Science Advisor, SEELB
Dr Patricia Eaton	Programme Leader – TEPP, Stranmillis UC
John Lockett	Former Headmaster, Grosvenor GS
Greg McDaid	Managing Director, Fujitsu Services NI
Stanley Goudie	Assistant Chief Inspector, ETI
Dr Tim Harrison	Vice President – R&D, ALMAC
John Anderson	Managing Inspector, ETI
Fiona Hepper	Head of Strategic Policy Division, DETI

Business-Led Working Group

Dr Tim Harrison	Chair of Working Group and Vice President – R&D, ALMAC
Dr Alan Blair	Programme Manager
Noel Jones	Personnel Director, FG Wilson
Brian McCann	Managing Director, Clarehill Plastics Ltd
Mike Mullan	HR Director, United Dairy Farmers
Dr Peter Donnelly	CEO, BioBusinessNI
Prof Eileen Harkin-Jones	School of Mechanical & Aerospace Engineering, QUB
Martine Mulhern	Science Co-ordinator, St Mary's College, Creggan, Londonderry
Ann Morrison	Science Coordinator, BIFHE
William McKeown	Science & Technology Advisor, NEELB
Geoff Lamb	Business Development Manager, Food & Drink Training Council
David Seffen	NI Partnership Manager, Lantra
Ronnie Moore	Skills Director – National

ETI-Led Working Group

John Anderson	Chair of Working Group and Managing Inspector, ETI
Dr Alan Blair	Programme Manager
Dr Ruth Jarman	Lecturer in Science Education, QUB
Dr Mike Malone	Director of Technology & Innovation, NDAI
David Farrell	IT Director, Dunbia, Granville Industrial Estate, Dungannon, Co Tyrone, BT70 1NJ
David Hatton	Chief Executive, Engineering Training Council NI
Maureen Walkingshaw	HR Director, BT Ireland
Gerry Garvey	Project Manager – Exams Modernisation, CCEA
Harold Brownlow	Principal, Ballymena PS
Simon Harper	Principal, Rathfriland HS
Dr Catherine Donnelly	Head of Physics, Ballymena Academy
Dr Sally Montgomery	Chief Executive, W5
Irvine Richardson	Principal Inspector of Science, ETI
Prof Valerie McKelvey-Martin	Head of School of Biomedical Sciences, UU
Dr Nick Todd	Principal Inspector of Mathematics
John Murray	Specialist Inspector, Technology & Design
Deirdre Gillespie	Inspector (Careers Education) ETI

Government-Led Working Group

Fiona Hepper	Chair of Working Group and Head of Strategic Policy Division, DETI
Dr Alan Blair	Programme Manager
Michael Gould	Skills & Industry Division, DEL
Dave Tovey	Environment & Risk Prevention Manager, Michelin
Brian Turtle	Former Principal and Chief Executive, Belfast Metropolitan College
Damian McGivern	Head of Careers Development Centre, UU
Dr Caroline Greer	Head of Science, RBAI
Sean Maguire	General Advisor – Science & Technology, NEELB
Jim Clarke	Deputy Chief Executive, CCMS
Irvine Richardson	Principal Inspector of Science, ETI
Teresa Mullan	Chemistry Teacher, St Louis Grammar School
Trevor Carson	Director, LSDA
Dr Norman Apsley	CEO – Northern Ireland Science Park
Dr Martin Brown	NISEF
Tracy Meharg	Managing Director – Innovation & Capability, InvestNI

Annex 4

Audit of Existing STEM Initiatives in Government

Lead Department	Lead Organisation	Policy/ Programme name and period covered	Objective	Who is the target population for your policy/ programme	How does the policy/ programme address the STEM agenda?	Resources allocated (£m)	Positive outcomes to date
DHSSPS	R+D Office	R+D Office Bursary Scheme Annual since: 1998	Funding fees and other misc expenses for Masters level courses	HSC/voluntary sector employees involved in the delivery of Health & Social Care	Provide support to undertake research modules and/or dissertation	£0.23m	131
DHSSPS	R+D Office	R+D Office Learning Sets Annual since: 2006	Support/facilitate potential applicants for post-graduate fellowships or post-doctoral research awards	HSC/voluntary sector employees involved in the delivery of Health & Social Care	Develop initial research question into full research proposal	No cost as University staff give time for free	25 participants 6 applications 1 fellowship awarded
DHSSPS	R+D Office	Doctoral Fellowships Annual since: 1998 Duration: 2-6 years FT/PT	Provide funding for salary, tuition fees, training and research expenses and conference travel to support completion of Doctoral level postgraduate research qualification e.g. PHD, MD	HSC/voluntary sector employees involved in the delivery of Health & Social Care	Build research capacity in clinical academic arena	£10.8m	98 Av. 96% completion rate

DHSSPS	R+D Office HRB	Cochrane Short Courses Annual since: 2001	Training in Systematic Review	HSC employees, voluntary sector and HEIs	Raising awareness of Cochrane Library and systematic review and preparation to carry out systematic reviews	£0.02m	450 attendees at courses
DHSSPS	R+D Office HRB	Cochrane Fellowships Annual since: 2002	Provide funding for protected time to conduct systematic reviews	HSC employees, voluntary sector and HEIs	Increasing knowledge base in health and social care interventions and participation of Irish researchers on systematic review	£0.5m	15 reviews completed by NI researchers

DHSSPS	Joint schemes R&D Office with the National Cancer Institute (NCI) Washington	NCI – Ireland – Northern Ireland Cancer Consortium:					
		(a) Cancer Prevention Fellowship Programme	Post-doctoral – research experience	Cancer researchers with PhD, MD	Provides means to undertake MPH and research experience at the NCI – a world leader in this field	£0.17m	2
		(b) Joint Research Projects in Cancer	US-NI partnership post-doctoral fellow employed	Cancer researchers – the post-doc – can have MD or PHD	Offers experience of joint research with the NCI and their expertise	£0.64m	3
		(c) NCI Summer Cancer Courses	Education Programmes	Cancer researchers	Offers access to world leaders in cancer prevention	£0.11m	7
		(d) Clinical Trials Nursing Training	Education Programme and experience of NCI clinical trials unit	Nurses involved in cancer clinical trials	Offers opportunity to train in US, NIH and NCI, work closely with nurse – preceptors, learn about trial management	£0.01	2

DHSSPS	R+D Office	Health & Social Care Services Studentships (HSCSR) 2004-2006	To give training in an important, under developed area of research	Degree level qualified individuals with potential and interest in HSCSR	Offers MSc level training in year one and a 3 year PHD training programme	£0.74m	11
DHSSPS	R+D Office	M Phil Fellowships 2004-2005	Full salary, tuition fees, research and training support to acquire M.Phil degree	HSC/Voluntary sector employees involved in the delivery of health and social care	Build research capacity in clinical academic arena	£0.48m	7
DHSSPS	R&D Office / NIHR (England)	NIHR Fellowship Scheme* Annual since: 2000 *Formerly DH National Personal Awards Scheme	Provide funding support for Doctoral Level postgraduate research qualification eg PhD	HSC/voluntary sector and HEIs	Build research capacity in clinical academic arena	£0.4m	2 @ PhD/MD level
DCAL	DCAL	Creative Learning Centres	To deliver educational provision in a range of digital technologies.	Primary and post-primary school children, Teachers and Youth Workers.	The programmes will develop digital technology skills in young people and the teaching profession	£500k per annum for three years from 2008/09	Delivery of 130 programmes to 3,996 children and young people and participation of 1,794 teachers in courses and programmes during 08/09

DCAL	W5	Skills and Science Appliance of Science Events Programme	Make Science relevant and engaging to pupils in schools and Further Education Colleges	Pupils 11-19 years	The programme aims to inspire and engage young people with the challenges and opportunities presented by science, technology, engineering and maths, and develop the practical skills associated with these subjects.	£800k 2006/07 £1m 2007/08 Funding ceases in March 2008. A late bid under the Innovation Fund was unsuccessful	Forecast to the end of March 2008 of over 22,000 participants over the 2 year programme
DCAL	AOP	Skills and Science Appliance of Science Events Programme	Make Science relevant and engaging to pupils in schools	Pupils 14-19 years	The programme provides an Outreach Programme, taking the Planetarium's aim of providing space astronomy and related science education outside the Planetarium in Armagh and around the country.	£300k in 2006/07 £300k in 2007/08 Funding ceases in March 2008.	Forecasts show that the Planetarium is on track to meet target of 20,000 young people visited through the 2 year Outreach Programme

DARD	DARD – Service Delivery Group	Annual postgraduate student awards for study in agriculture, food production and food processing disciplines.	To ensure an appropriate skills base for Northern Ireland's agri-food and rural sectors. This will ultimately assist DARD in the achievement of its Strategic Plan 2006 -2011 goals.	Funding is provided for full-time study only. Postgraduate Studentships are provided for a period of research normally leading to a PhD or MSc.	It provides the incentive for increased participation so ensuring PG level expertise in STEM subjects is available to the agri-food and rural sectors.	For the financial year 2007/08 approximately £400k was allocated to postgraduate awards.	In the financial year 07/08 a total of 34 PhDs/MScs were supported.
DARD	DARD - Central Policy Group	Funding for tertiary level agri-food research and education at the Institute of Agriculture, Food and Land Use (IAFLU), QUB. Responsibility for this will transfer to DEL in September 2008.	As above	School leavers for undergraduate courses and graduates for research posts. Admission is not restricted to Northern Ireland, but the bulk of students are drawn from local population.	An expert base in STEM subjects is available for capitalisation by the agri-food and rural sectors	In the academic year 2007/08 £1.43M approximately. This includes a Research Grant of £1.38K	In 2007/08 the programme supports 166 undergrads, 5 taught postgrads and 21 postgrad researchers. First cohort will graduate 2008.
DARD	DARD – College of Agriculture, Food and Rural Enterprise (CAFRE)	DARD education programmes for new entrants to the agri food sector	To develop the basic skills of those wishing to pursue a career in the agri food sector	Level 2 students who do not have GCSE Maths at Grade C or above	Essential skill of Numeracy		Raising the numeracy standard of most students completing the programme by one level

DE	Sentinus/ Department of Education	STEM - Promotion of impact on careers education	To ensure that all school pupils in Northern Ireland within the age range 4 19 have access to Science, Technology, Engineering and Maths (STEM) programmes in school.	All pupils in Northern Ireland, but mainly pre-primary pupils	Sentinus offers a wide range of activities in STEM designed to enhance understanding of the subjects and make young people aware of the exciting career opportunities in these areas. By engaging young people in exciting and challenging work based activities and giving them access to role models, Sentinus and DE hope to raise awareness, enhance understanding and increase enthusiasm for STEM.	£400k in the 2007/08 year. Approximately $^{2}/_{3}$rds STEM; $^{1}/_{3}$rd Employability	This year Sentinus had 35,000 pupils from schools throughout Northern Ireland participate in their STEM programmes.

DE	Department of Education	Specialist Schools Programme	To support the implementation of the Entitlement Framework by increasing learning opportunities for young people and the wider community through schools and FE Colleges sharing best practice, resources and expertise in specific curricular area.	All post-primary schools with KS4 pupils.	The Specialisms include Science, Technology and Maths. There are 25 Specialist Schools in total.	Currently investing over £3m.	There are 9 Science specialist schools and 2 maths schools to date. A fourth cohort has been launched and is expected to be announced in Spring 2009. DE has encouraged applications in the STEM area.
DE	Department of Education	Development of Careers Education, Information and Advice and Guidance for STEM areas	To improve young people's knowledge and understanding of the opportunities for entering well paid and challenging careers which require a background in STEM subjects.	All pupils in Northern Ireland.	This programme will raise young people's awareness of STEM and inform them of the benefits of seeking employment in these areas.	2008/09 £0.6m 2009/10 £0.8m 2010/11 £0.8m This funding is from the Innovation Fund.	

DE	Department of Education	Development of curriculum resources to support growth of STEM take-up in schools.	To develop web-based and other links with national bodies for the promotion of STEM-based subjects in GB and the ROI. To promote STEM curriculum development in the primary sector within the revised NI curriculum through materials and equipment, and focus on the professional development of primary science & technology teachers and post-primary science, technology and maths teachers.	All pupils in Northern Ireland. Teachers of STEM subjects.	By promoting STEM-based subjects and improving resources in the primary sector to encourage the uptake of STEM subjects. By encouraging the professional development of teachers in STEM areas.	2008/09 £0.5m 2009/10 £0.7m 2010/11 £0.7m This programme is funded through the Innovation Fund.	

DE	Department of Education	Promotion of STEM work in primary and post primary schools through competitions and exhibitions.	To promote STEM work in primary and post-primary schools through competitions and exhibitions such as sub-regional Primary Science Fairs, a regional Key Stage 3 Post-Primary Science Exhibition and a specialist science week involving the colleges and universities.	All pupils in Northern Ireland from primary through to university level.	By raising awareness of STEM work.	2008/09 £0.2m 2009/10 £0.2m 2010/11 £0.2m This project is funded through the Innovation Fund.	
DEL	DEL	Critical Sector Initiatives	To increase the number of university level applications for STEM subjects. This will include support for sector specific pre-employment training for key economically important industries.	Pupils in Northern Ireland	By setting up training interventions in the critical sectors and raising awareness of STEM subjects.	2m per annum over 2008 – 2011 from the Innovation Fund.	-

DEL	DEL's Higher Education Research Policy Branch (in collaboration with the Engineering and Physical Sciences Research Council)	Science and Innovation Awards – Plasma Physics Centre at Queen's University. (FY 2006/07 to 2011/12).	To build expertise in plasma theory to match the experimental capability already present in the International Research Centre for Experimental Physics established under Round 1 of DEL's Support Programme for University Research (SPUR 1).	Industry, school students, physics undergraduates.	Increases both the local and national expertise in plasma physics research (identified by the UK Government as a strategically important area).	£710k (DEL).	Establishment of an MSc stream and strategic international linkages.
DEL	DEL's Higher Education Research Policy Branch	North-South Research Programme to include US-Ireland R&D Partnership. (FY 2008/09 to 2010/11).	To strengthen the all-island research base through strategic partnerships and to lever additional investment.	Universities on the island of Ireland.	The collaborations are limited to areas of economic relevance, including STEM.	£17.2m (including £10.5m from "Funding for Innovation").	12 cross-border projects approved for funding. Activities commenced November 2008.
DEL	DEL's Student Finance Branch in collaboration with Higher Education Research Policy Branch	New cohort of 100 PhD entrants (AY 2008/09 onwards) for 3 years.	To increase the number of qualified PhD available to local companies and to potential FDI companies.	Key sectors of Northern Ireland industry.	The PhDs will be limited to areas of economic relevance as agreed between DEL and DETI.	£5.1m (Budget 2007) £7.1m ("Funding for Innovation") 2008 -2011	First cohort successfully recruited.

DEL	Invest NI/ DEL/ e-skills/ Momentum	ICT Action Plan.	Action plan to address short term skills shortages in the ICT sector in Northern Ireland 2008-2010.	Year 10 school pupils; Year 12 school pupils; university entrants; parents of above. Industry and education and training providers for ICT.	Co-ordinates actions from key stakeholder organisations – industry; industry associations and government to address short term skills shortages in software engineering/ development from 2008/2010. Includes career attractiveness marketing campaign.	Tbd but likely to be less than £1 million. Action Plan drafted and agreed within INI/ DEL/e-skills UK and Momentum. Action Plan to be agreed with ICT sector in March.	Review of all current interventions in ICT undertaken. Action Plan drafted and agreed within INI/ DEL/e-skills UK and Momentum.
DEL	DEL	Software Professional Course	To provide non-IT graduates with the skills needed to work in the IT industry.	Unemployed non-IT graduates (degree or HND).	Increases the numbers of potential employees in the IT industry.	Demand Led-Projects Spend of £1.5 million by 2009/10.	First cohort provided 32 graduates and 80% have since gained employment. Further 47 people currently in training.

DEL	DEL with UU	Step-UP (2000 – present)	Aims to provide new learning opportunities in science for talented young people from areas of social and economic disadvantage	Key Stage 4 in social and economically disadvantaged areas	Targets students studying for GCE Applied Science Examination	£1.59m allocated over period 2006 – 2012.	92% of university entrants from the scheme commence STEM related programmes of study.
-	Women in Technology and Science / InterTrade-Ireland	Re-Enter Programme (2008-2009)	Re-skill and re-train 20 experienced women scientists, engineers and technologists who want to return to work after a career break of a year or more.	Women STEM/ SET graduates	The programme will raise awareness of female STEM graduates by making employers aware of their untapped skills	These figures await final determination.	Programme launched in February 2008 by DETE minister, Micheal Martin
DFP	DID (DFP) working with Queens University, DETI and Science Park in Belfast	Innovation Hotspot Programme in early planning stages	To set up a location for exploring the business potential of emerging ICT .	Tertiary Students	Programme will involve students from science, technology and engineering backgrounds.	No resources allocated yet as still in the early stages of planning.	Too early to comment

DFP	ICT HR section of DID	NICS ICT Student Placement Scheme 2008 onwards	To give ICT students in their sandwich year the opportunity to work in the ICT field within NICS	ICT students who meet the necessary criteria	Programme will employ up to 25 ICT students yearly. This will give the student hands on work experience, thus allowing them to put into practice the skills learned pre sandwich year.	Students will be paid the equivalent to a casual AA – which on the 1st August 2008 will be £13,130. Total spend - £328,250.00	Direct work experience for up to 50 ICT students in each of recent years. Numbers curtailed for current intake.
DFP	DID with Belfast Metropolitan Colleges	**C4NI** 2007 onwards **WIMPS** (Where Is My Public Servant) 2006 onwards	Aims to encourage the engagement of young people in the democratic process via ICT. Third level students have had a direct involvement in building technology platforms.	Tertiary Students	Engages with students and young people and allows them access to Government in ways and means that they have developed themselves.	C4NI - £100,000 WIMPS - £50,000	

DFP	OSNI with DID	Geo mash up competition Late 2007 – ongoing. Due to complete 27th March 2008.	Aim is to introduce awareness of data mash ups with view to stimulating new and further uses of data mashing.	Tertiary students.	Aims to introduce and increase awareness of data mash ups amongst students. Initiate creative thought and innovation.	£10,000	3 finalists have been shortlisted with the winner being notified on the 27th March 2008. Prize distribution to take place at a later date. It is hoped to continue to investigate this area but maybe not in the current competition format. Project still to be evaluated

Annex 5

The Development of the NI Curriculum, 1989 - 2007

A5.1 Background

Prior to 1989 there were no statutory requirements specifying which subjects should be taught in schools (apart from Religious Education). Schools were free to offer whatever range of subjects they felt appropriate for their pupils.

A5.2 Introduction of the NI Common Curriculum

The NI Common Curriculum was established in 1989 and followed on from the introduction of the National Curriculum in England and Wales in 1988. Both established a statutory curriculum for all pupils for the first time. The curriculum was defined in terms of subjects and groups of subject experts were convened to define the content of the subjects and the progression through the Key Stages.

While the structure of the curriculum here was similar to that in England and Wales, the details within each subject differed from that in England and Wales.

Science was made compulsory at all key stages. At Key Stage 4 (14-16) pupils had to follow a course in balanced science. Students following a GCSE course could take double award science which included elements of physics, chemistry and biology and provided a basis for further study in science or all three individual sciences (so-called "triple science"). At a later stage single award science was added as an option for those who did not wish to pursue science post 16. There was a new emphasis in science on investigative work at all key stages.

Technology and design also became compulsory at all key stages. While science was well established in schools as a subject, technology had no strong base within schools and required the re-training of teachers from other subject backgrounds.

From 1990, as the curriculum was rolled out, there was a huge investment in support for schools. New technology suites were built, science laboratories were re-furbished and large numbers of teachers were seconded to support the introduction of the curriculum in schools.

Criticisms of the Common Curriculum

In the early 1990s there were a number of criticisms made of the Common Curriculum.

There was a concern that the curriculum was overcrowded by the statutory elements leaving no time for anything that was not prescribed and that one size curriculum did not fit all. Teachers in primary schools felt ill-equipped to deal with science and technology and were unhappy with the division of their teaching into discrete subjects. The assessment of subjects generally was considered to be over-burdensome. The assessment of investigative work in science led to recipe type teaching

During the 1990s there were a number of reviews which sought to address some of these issues. For example, the level of detailed prescription was reduced, science and technology were amalgamated in primary schools, compulsory external assessment was limited to English, science and mathematics, publication of league tables ceased and provision was made to exempt students from aspects of the statutory curriculum.

A5.3 Review of the NI Common Curriculum

Phase 1

While there had been a number of minor revisions, the first major review of the Common Curriculum was instigated by the Minister in 1999. The aim was to devise a curriculum 'to meet the needs of young people, society, the economy and environment in the 21st Century'. Feeding into that review were the outcomes of curriculum monitoring, results of consultation with teachers and other stakeholders and the findings of a longitudinal study of pupils perceptions (The NI Cohort Study). Phase 1 was to produce a framework for working groups to develop further in Phase 2.

Consultation on a proposed framework took place in 2000. This included the proposal to combine elements of geography, history, science and technology at Key Stages 1 and 2. At Key Stage 3 there were proposals for 18 subjects[99], including new offerings such as citizenship and employability, with defined percentages of curriculum time. At Key Stage 4 the statutory subject requirements were relaxed but there was still a proposal that all students should study science or technology.

In the consultation responses the proposals for 'The World Around Us' at Key Stages 1 and 2 were welcomed. The proposals for Key Stage 3 were criticised for being too

99 Proposals for Changes to the NI Curriculum Framework, CCEA, June 2000
http://www.nicurriculum.org.uk/docs/background/curriculum_review/currevp1.pdf

rigid and at Key Stage 4 ' a substantial number of people felt it wrong to single out science and technology as the only subject area for inclusion in the core'1.

Further consultation on Key Stage 4 was inconclusive with a majority opposing the exclusion of all academic subjects from the legal requirements. Eventually after informal discussion with principals and curriculum managers, CCEA recommended to the Minister in 2003 that there should not be any compulsory subjects at Key Stage 4 although it was 'expected that the great majority of young people will continue to follow a balanced science course'2.

Phase 2

Groups of subject specialists were convened to work on the subject content at Key Stages 1 to 3 and produced a set of proposals with much reduced content compared to the previous provision. An overview sub group within CCEA was charged with vetting the final proposals. The proposals for Key Stages 1 and 2 were well accepted but the Key Stage 3 proposals were considered to be unmanageable and overcrowded, with still too much statutory content within the subjects. Subsequently a small development group was established to work on the Key Stage 3 proposals across all subject strands.

Phase 3

The final Revised Curriculum was accepted by the Minister in June 2004 and is now in the process of implementation.

At Key Stages 1 and 2, science & technology is a contributory element within 'The World around us' and the minimum content is similar to the statutory content in the previous curriculum.

At Key Stage 3, the revised curriculum places emphasis on the totality of pupils' experiences across the curriculum. Subjects no longer have their own discretely defined areas of knowledge and skills set out in detailed form and teachers are encouraged to make links across traditional subject boundaries. Science & technology and design are both contributory elements within the science & technology area of learning but, consistent with the revised curriculum areas of learning, the content framework is skeletal. The responsibility for designing appropriate learning experiences now rests with the school. CCEA and the Partnership Management Board (PMB), as well as some commercial publishers, are providing support materials to help teachers.

At Key Stage 4, in a parallel development, GCSE courses have been redesigned. In science subjects there is a new emphasis on science needed to equip young people to play a full part in a technological society and this has been included in all specifications.

Annex 6

GCSE and A-Level, STEM Entries and Results in Selective and Non-Selective Schools

STEM Subject	Selective		Non-Selective	
	Entries	%Results A* - C	Entries	%Results A* - C
Biology	3,129	95%	432	70%
Chemistry	2,606	94%	147	76%
Physics	2,367	92%	144	79%
Science/Single Award	121	96%	7,440	47%
Double Science Award	5,374	94%	4,810	73%
Mathematics	8,679	97%	14,086	44%
Additional Mathematics	2,749	93%	304	78%
Information Technology	2,988	95%	4,031	77%
Design and Technology	1,948	93%	3,834	58%
All STEM Subjects	29,961	95%	35,228	55%
All Subjects	85,471	93%	95,959	59%

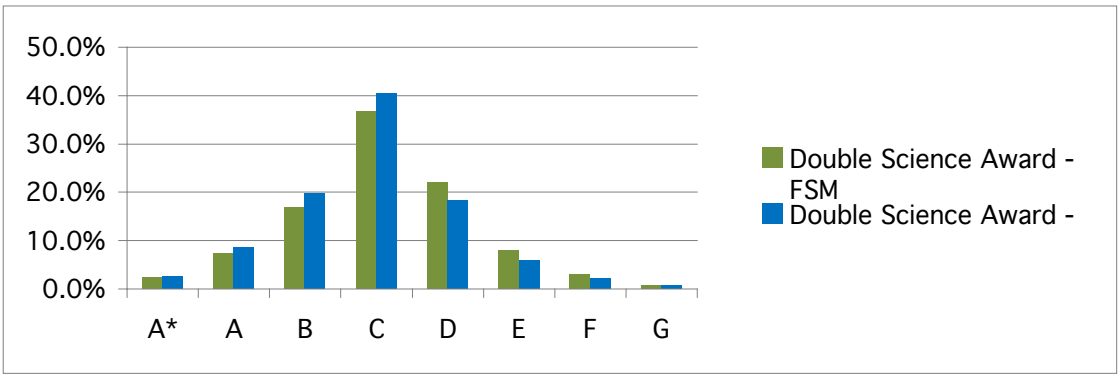
Source: DENI

Table A6.1 GCSE Entries and Results for STEM subjects in Selective and Non-Selective Schools, 2007/08

STEM Subject	Selective		Non-Selective	
	Entries	%Results A* - C	Entries	%Results A* - C
Biology	2,696	84%	461	65%
Chemistry	1,648	85%	175	67%
Physics	1,134	79%	107	62%
Psychology	175	60%	74	57%
Mathematics	2,209	92%	292	70%
Further Maths	147	93%	6	83%
Computer Studies	115	62%	4	100%
Information Technology	903	84%	98	74%
Design and Technology	525	85%	195	53%
All STEM Subjects	9,552	85%	1,412	65%
All Subjects	23,235	88%	5,458	72%

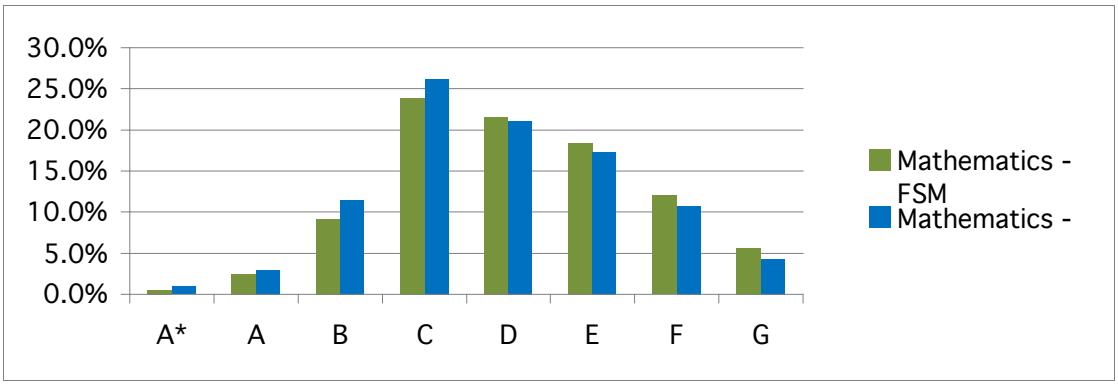
Source: DENI

Table A6.2 A-Level Entries and Results for STEM subjects in Selective and Non-Selective Schools, 2007/08



Source: DENI

Figure A6.1 Comparison of GCSE Grade Attainment – Double Award Science



Source: DENI

Figure A6.2 Comparison of GCSE Grade Attainment – Mathematics

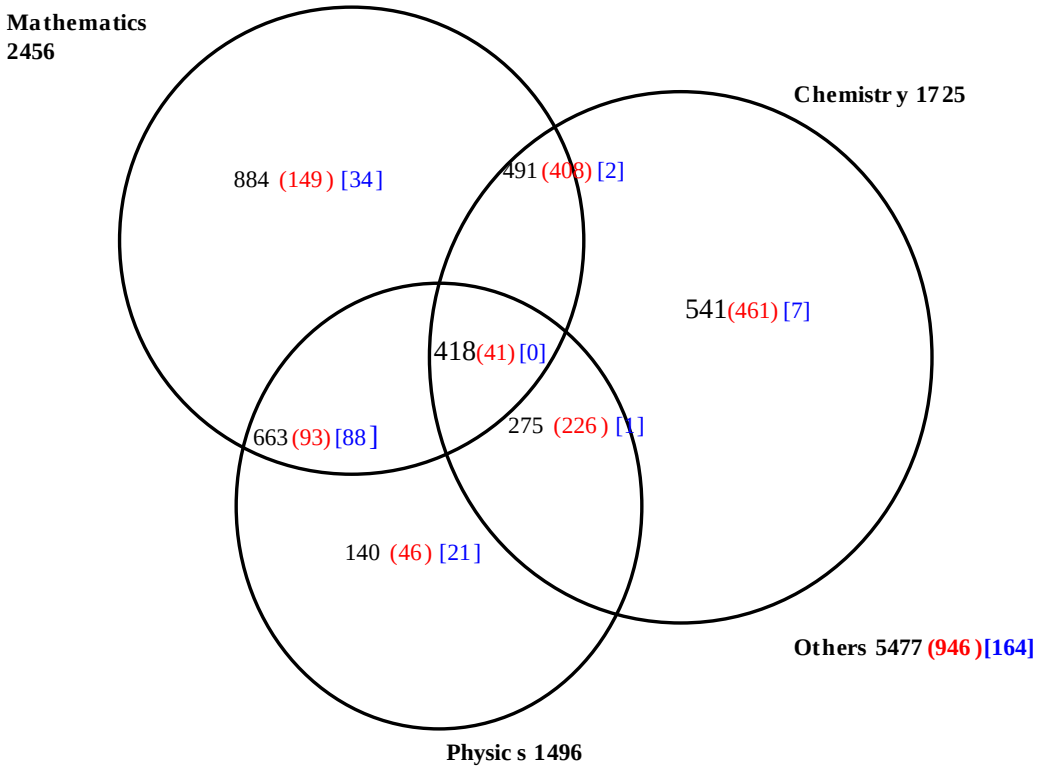
Annex 7

Subject Combinations Chosen at A Level, 1995 - 2005

Distribution of subjects studied

(Biology figures in round brackets) [Technology in square]

All 8889(2370)[317]



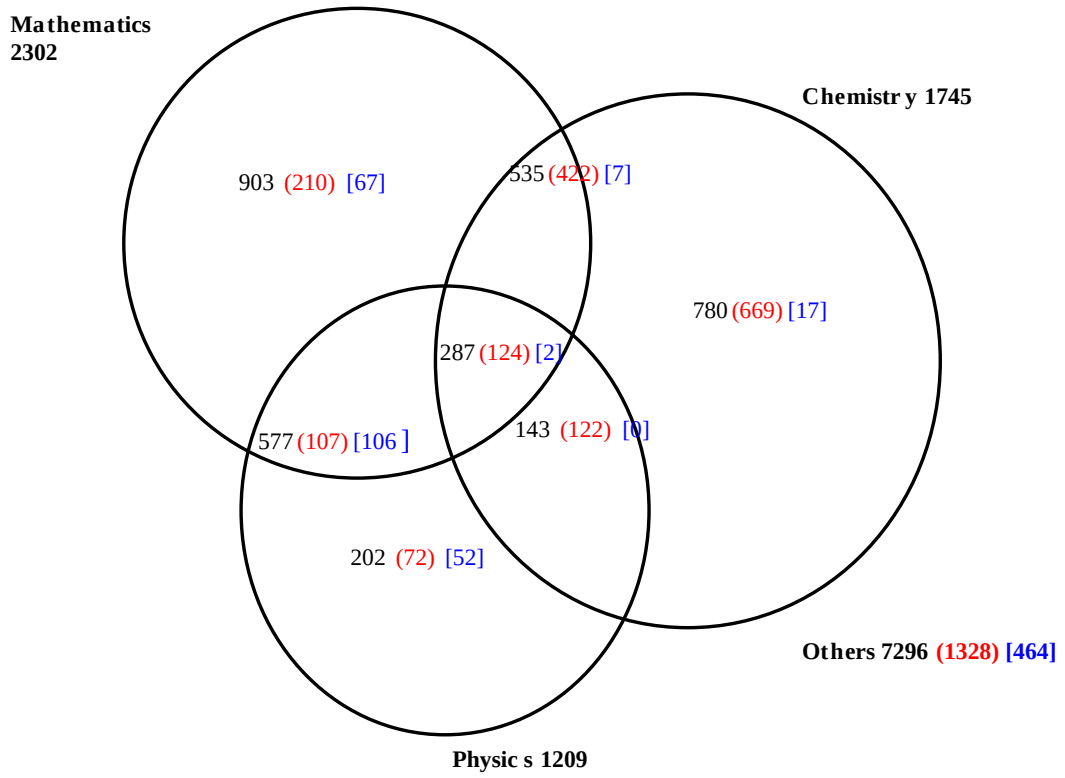
Source: DENI

Figure A7.1 Combinations of A Level Subjects, 1995/96 (all schools)

Distribution of subjects studied

(Biology figures in round brackets) [Technology in square]

All 10723(3054)[715]



Source: DENI

Figure A7.2 Combinations of A Level Subjects, 2005/06 (all schools)

Annex 8

STEM Enrolments and Qualifications in Further Education, 2001/02 & 2006/07

		2001/02				2006/07			
Subject Area	Sub Group	Level 2	Level 3	Sub degree	Total	Level 2	Level 3	Sub degree	Total
Medicine & Dentistry	Clinical Dentistry	9	36	11	56	-	10	-	10
	Clinical Medicine	-	-	-	-	-	23	-	23
Allied to Medicine	Anatomy & Physiology	-	21	-	21	65	77	-	142
	Pharmacy	-	67	-	67	35	56	-	91
	Nutrition	-	-	-	-	-	33	-	33
	Opthalmics	-	-	-	-	-	-	-	-
	Audiology	223	115	-	502	104	9	-	186
	Nursing	182	974	153	1,443	441	756	149	1,445
	Medical Technology	-	-	-	-	3	40	-	43
	Other Medical Subjects	634	1,446	128	2,844	875	969	164	3,081
	Pharmacology	-	-	-	-	-	-	-	-
Biological Sciences	Biology	-	23	13	36	124	786	39	949
	Biochemistry	-	-	-	-	-	-	-	-
	Microbiology	-	-	-	-	-	-	-	-
	Other Biological Sciences	-	-	-	-	-	-	-	-
Agriculture & Related	Veterinary Science	26	49	-	105	82	130	20	232
	Agriculture	81	101	-	198	129	130	18	646
	Food Science	283	405	31	2,107	657	204	1	3,034
	Other Agricultural Services	17	-	-	17	-	-	-	30
Physical Sciences	Chemistry	-	240	-	240	17	860	2	879
	Physics	-	-	-	-	21	190	-	211
	Geography Studies as a Science	-	-	-	-	-	184	-	184
	Environmental Science & other Physical Science	5	-	53	58	81	191	114	386
Mathematics & Computing Science	Mathematics	-	410	-	525	3,257	362	-	3,623
	Computing	11,104	4,160	1,964	25,938	4,458	3,997	978	17,183
	Other Mathematical Sciences	-	43	-	43	15	38	-	75
	Statistics	-	-	-	-	-	-	-	-
Engineering & Technology	General Engineering	1,436	775	239	2,515	592	319	39	1,110
	Civil Engineering	41	78	81	200	-	71	169	240
	Mechanical Engineering	1,050	1,043	190	2,558	944	850	112	2,736
	Aeronautical Engineering	-	115	22	137	-	75	18	93
	Electrical Engineering	241	623	254	1,166	507	1,032	213	1,907
	Electronic Engineering	194	397	57	720	252	308	48	631
	Production Engineering	1,334	211	201	1,794	486	418	179	1,406
	Chemical Engineering & Fuel Technology	-	-	25	25	6	-	14	20
	Other Engineering	73	130	-	217	31	161	15	385
	Metallurgy	-	-	-	-	-	-	-	-
	Minerals Technology	-	14	-	14	-	58	-	58
	Ceramics & Glasses					-	-	-	11
	Polymers & Textiles	19	-	-	77	28	11	-	56
	Others Material Technology	26	7	-	33	-	-	-	-
	Other Technologies	69	5	31	105	-	-	-	-
	Marine Technology	9	15	-	35	-	-	-	-
Architecture, Building & Planning	Architecture	-	-	36	36	-	20	42	62
	Building	3,423	2,775	495	8,090	6,088	3,908	770	13,956
	Town & Country Planning	-	13	17	30	-	-	34	34
	Other Arcitectural Studies	13	-	-	13	-	-	6	6
	Environmental Technologies	-	87	-	87	-	-	-	-
	Urban & Regional Planning	-	-	-	-	-	-	-	-
Total Science, Technology, Engineering & Mathematics		20,492	14,378	4,001	52,052	19,298	16,276	3,144	55,197

Source: DELNI

Table A8.1 Enrolments in STEM Subjects at FE Colleges, 2001 and 2006

		2001/02				2005/06			
Subject Area	Sub Group	Level 2	Level 3	Sub degree	Total	Level 2	Level 3	Sub degree	Total
Medicine & Dentistry	Clinical Dentistry	1	13	7	21	-	4	-	4
	Clinical Medicine	-	-	-	-	-	15	-	15
Allied to Medicine	Anatomy & Physiology	-	16	-	16	8	66	-	74
	Pharmacy	-	34	-	34	18	14	-	41
	Nutrition	-	-	-	-	-	30	-	30
	Opthalmics	-	-	-	-	-	-	-	-
	Audiology	87	13	-	154	42	-	-	91
	Nursing	136	336	93	612	279	264	43	713
	Medical Technology	-	-	-	-	1	9	-	10
	Other Medical Subjects	384	611	62	1,489	581	589	10	1,940
	Pharmacology	-	-	-	-	-	-	-	-
Biological Sciences	Biology	-	10	5	15	38	278	7	323
	Biochemistry	-	-	-	-	-	-	-	-
	Microbiology	-	-	-	-	4	-	-	4
	Other Biological Sciences	-	-	-	-	-	-	-	-
Agriculture & Related	Veterinary Science	9	17	-	26	11	38	7	75
	Agriculture	30	46	-	83	58	16	5	210
	Food Science	204	343	14	1,847	212	119	-	2,204
	Other Agricultural Services	-	-	-	-	-	6	-	6
Physical Sciences	Chemistry	-	52	-	52	4	340	-	344
	Physics	-	-	-	-	5	54	-	59
	Geography Studies as a Science	-	-	-	-	-	115	-	115
	Environmental Science & other Physical Science	-	-	11	11	35	31	29	120
Mathematics & Computing Science	Mathematics	-	401	-	489	804	113	1	938
	Computing	6,990	1,572	694	13,416	2,938	1,465	436	9,002
	Other Mathematical Sciences	-	10	-	10	13	-	-	32
	Statistics	-	-	-	-	-	-	-	-
Engineering & Technology	General Engineering	703	277	88	1,106	478	192	28	720
	Civil Engineering	8	21	23	52	26	31	71	128
	Mechanical Engineering	317	324	59	760	365	204	51	756
	Aeronautical Engineering	-	34	-	34	-	37	-	37
	Electrical Engineering	91	202	77	381	159	322	40	545
	Electronic Engineering	103	218	18	349	96	152	38	301
	Production Engineering	594	66	7	693	226	55	63	429
	Chemical Engineering & Fuel Technology	-	-	-	-	-	-	4	4
	Other Engineering	51	42	-	93	21	3	-	100
	Metallurgy	-	-	-	-	-	-	-	-
	Minerals Technology	-	14	-	14	-	41	-	73
	Polymers & Textiles	5	-	-	20	3	1	-	26
	Others Material Technology	-	3	-	3	-	-	-	-
	Other Technologies	-	3	5	8	-	-	-	11
	Marine Technology	2	4	-	13	-	-	-	-
Architecture, Building & Planning	Architecture	-	-	8	8	7	-	12	27
	Building	1,211	1,074	180	2,701	3,338	1,320	173	5,254
	Town & Country Planning	-	-	17	17	-	-	7	7
	Other Arcitectural Studies	11	-	-	11	-	-	-	-
	Environmental Technologies	-	34	-	34	-	-	-	-
	Urban & Regional Planning	-	-	-	-	-	-	-	-
Total Science, Technology, Engineering & Mathematics		10,937	5,790	1,368	24,572	9,770	5,924	1,025	24,768

Source: DELNI

Table A8.2 Qualifications Gained in STEM Subjects at FE Colleges, 2002 and 2006

Annex 9

Higher Education Entrants and Retention

STEM Subject Area	Principal Subject	NI Total	UK Total	%NI Students relative to UK
(1) Medicine & dentistry	(A1) Pre-clinical medicine	0	4629	0%
	(A2) Pre-clinical dentistry	0	606	0%
	(A3) Clinical medicine	264	3852	238%
	(A4) Clinical dentistry	47	567	287%
	(A9) Others in medicine & dentistry	0	40	0%
(1) Medicine & dentistry Total		**311**	**9694**	**111%**
(2) Subjects allied to medicine	(B0) Broadly-based programmes	0	196	0%
	(B1) Anatomy, physiology & pathology	166	4182	138%
	(B2) Pharmacology, toxicology & pharmacy	151	3994	131%
	(B3) Complementary medicine	16	1319	42%
	(B4) Nutrition	82	1360	209%
	(B5) Ophthalmics	33	780	147%
	(B6) Aural & oral sciences	26	840	107%
	(B7) Nursing	913	18118	175%
	(B8) Medical technology	73	1785	141%
	(B9) Others in subjects allied to medicine	128	6554	67%
(2) Subjects allied to medicine Total		**1587**	**39128**	**141%**
(3) Biological sciences	(C0) Broadly-based programmes	0	230	0%
	(C1) Biology	100	7467	46%
	(C2) Botany	0	40	0%
	(C3) Zoology	9	1091	29%
	(C4) Genetics	7	443	55%
	(C5) Microbiology	3	608	17%
	(C6) Sports science	219	11120	68%
	(C7) Molecular biology, biophysics & biochemistry	23	2508	32%
	(C8) Psychology	399	19846	70%
	(C9) Others in biological sciences	0	1902	0%
(3) Biological sciences Total		**760**	**45254**	**58%**
(4) Veterinary science Total		**0**	**970**	**0%**
(5) Agriculture & related subjects Total		**108**	**2709**	**138%**
(6) Physical sciences Total		**329**	**19514**	**59%**
(7) Mathematical sciences Total		**136**	**9071**	**52%**
(8) Computer science Total		**715**	**21301**	**116%**
(9) Engineering & technology Total		**692**	**30153**	**80%**
(A) Architecture, building & planning Total		**658**	**12580**	**181%**
STEM Total		**5296**	**190373**	**96%**
All Other Non-STEM		**5269**	**269866**	**68%**
Grand Total		**10565**	**460239**	**80%**

Source: HESA

Table A9.1a NI and UK First Degree University Entrants, 2007/08

STEM Subject Area	Principal Subject	NI Total	UK Total	%NI Students relative to UK
(1) Medicine & dentistry Total		**311**	**9694**	**111%**
(2) Subjects allied to medicine Total		**1587**	**39128**	**141%**
(3) Biological sciences Total		**760**	**45254**	**58%**
(4) Veterinary science	(D1) Pre-clinical veterinary medicine	0	410	0%
	(D2) Clinical veterinary medicine & dentistry	0	560	0%
(4) Veterinary science Total		**0**	**970**	**0%**
(5) Agriculture & related subjects	(D3) Animal science	0	883	0%
	(D4) Agriculture	37	1076	119%
	(D5) Forestry	0	70	0%
	(D6) Food & beverage studies	71	525	469%
	(D7) Agricultural sciences	0	1	0%
	(D9) Others in vet sciences, agriculture & related	0	155	0%
(5) Agriculture & related subjects Total		**108**	**2709**	**138%**
(6) Physical sciences	(F0) Broadly-based programmes	0	307	0%
	(F1) Chemistry	55	4466	43%
	(F2) Materials science	0	79	0%
	(F3) Physics	46	3683	43%
	(F4) Forensic & archaeological science	0	2427	0%
	(F5) Astronomy	9	498	63%
	(F6) Geology	0	2026	0%
	(F7) Science of aquatic and terrestrial environments	50	1435	121%
	(F8) Physical geographical sciences	169	3736	157%
	(F9) Others in physical sciences	0	858	0%
(6) Physical sciences Total		**329**	**19514**	**59%**
(7) Mathematical sciences	(G01) Broadly based programmes	0	50	0%
	(G1) Mathematics	134	8356	56%
	(G2) Operational research	0	127	0%
	(G3) Statistics	2	538	13%
(7) Mathematical sciences Total		**136**	**9071**	**52%**
(8) Computer science	(G02) Broadly based programmes	0	48	0%
	(G4) Computer science	530	15380	120%
	(G5) Information systems	164	4119	138%
	(G6) Software engineering	17	1631	36%
	(G7) Artificial intelligence	4	123	112%
(8) Computer science Total		**715**	**21301**	**116%**
(9) Engineering & technology Total		**692**	**30153**	**80%**
(A) Architecture, building & planning Total		**658**	**12580**	**181%**
STEM Total		**5296**	**190373**	**96%**
All Other Non-STEM		**5269**	**269866**	**68%**
Grand Total		**10565**	**460239**	**80%**

Source: HESA

Table A9.1b NI and UK First Degree University Entrants, 2007/08

STEM Subject Area	Principal Subject	NI Total	UK Total	%NI Students relative to UK
(1) Medicine & dentistry Total		**311**	**9694**	**111%**
(2) Subjects allied to medicine Total		**1587**	**39128**	**141%**
(3) Biological sciences Total		**760**	**45254**	**58%**
(4) Veterinary science Total		**0**	**970**	**0%**
(5) Agriculture & related subjects Total		**108**	**2709**	**138%**
(6) Physical sciences Total		**329**	**19514**	**59%**
(7) Mathematical sciences Total		**136**	**9071**	**52%**
(8) Computer science Total		**715**	**21301**	**116%**
(9) Engineering & technology	(H0) Broadly-based programmes	0	125	0%
	(H1) General engineering	120	4625	90%
	(H2) Civil engineering	245	4929	172%
	(H3) Mechanical engineering	119	5359	77%
	(H4) Aerospace engineering	26	1909	47%
	(H5) Naval architecture	0	135	0%
	(H6) Electronic & electrical engineering	66	6264	37%
	(H7) Production & manufacturing engineering	44	1067	143%
	(H8) Chemical, process & energy engineering	17	1635	36%
	(H9) Others in engineering	0	202	0%
	(J1) Minerals technology	0	45	0%
	(J2) Metallurgy	0	35	0%
	(J3) Ceramics & glasses	0	12	0%
	(J4) Polymers & textiles	0	823	0%
	(J5) Materials technology not otherwise specified	0	498	0%
	(J6) Maritime technology	0	218	0%
	(J7) Biotechnology	4	159	87%
	(J9) Others in technology	50	2114	82%
(9) Engineering & technology Total		**692**	**30153**	**80%**
(A) Architecture, building & planning	(K0) Broadly-based programmes	0	93	0%
	(K1) Architecture	186	4921	131%
	(K2) Building	363	5351	235%
	(K3) Landscape design	0	299	0%
	(K4) Planning (urban, rural & regional)	109	1680	224%
	(K9) Others in architecture, building & planning	0	236	0%
(A) Architecture, building & planning Total		**658**	**12580**	**181%**
STEM Total		**5296**	**190373**	**96%**
All Other Non-STEM		**5269**	**269866**	**68%**
Grand Total		**10565**	**460239**	**80%**

Source: HESA

Table A9.1c NI and UK First Degree University Entrants, 2007/08

Subject Area	Overall NI			Overall UK		
	No longer in HE	Total	%NI drop out	No longer in HE	Total	%UK drop out
Medicine & dentistry	2	285	0.7%	189	8903	2.1%
Subjects allied to medicine	157	1492	10.5%	2600	29952	8.7%
Biological sciences	62	783	7.9%	3433	41323	8.3%
Veterinary Science				45	984	4.6%
Agriculture & related subjects	8	99	8.1%	250	2662	9.4%
Physical sciences	41	384	10.7%	1315	19206	6.8%
Mathematical sciences	14	129	10.9%	525	8225	6.4%
Computer science	150	835	18.0%	2458	19416	12.7%
Engineering & technology	87	604	14.4%	2099	20060	10.5%
Architecture, building & planning	103	692	14.9%	822	8682	9.5%
All Other Non-STEM	752	6150	12.2%	21279	248741	8.6%
All Subjects	**1376**	**11453**	**12.0%**	**35013**	**408154**	**8.6%**

Source: HESA

Table A9.2 NI and UK First Year Retention of First Degree Students, 2006/07

Annex 10

Initial Teacher Education and Supply

Course	Main Subject	2002/03		2003/04		2004/05		2005/06		2006/07		2007/08	
		Appl	Intake	Appl	Intake	Appl	Intake	Appl	Intake	Appl	Intake	Appl	Intake
Stranmillis University College													
B Ed	T and D	32	6	41	13	65	14	59	13	52	10	41	8
B Ed	Maths/Sc	–	–	–	–	–	–	–	–	–	–	30	7
B Ed	All subjects	181	44	232	41	309	49	317	53	263	47	264	51
St Mary's University College													
B Ed	T and D	n/a	n/a	n/a	13	67	9	62	10	49	11	52	10
B Ed	Maths	–	–	–	–	–	–	–	–	42	9	–	–
B Ed	Maths/Sc	–	–	–	–	–	–	–	–	–	–	121	7
B Ed	All subjects	124	57	322	49	434	49	369	48	383	57	455	47
Queen's University Belfast													
PGCE	Maths	91	39	95	39	103	40	100	42	98	44	79	40
PGCE	Biology	75	29	57	23	74	24	62	24	103	30	65	24
PGCE	Chemistry	38	16	33	14	29	13	31	15	68	14	41	13
PGCE	Physics	14	6	25	10	24	10	25	9	35	9	30	16
PGCE	All subjects	599	205	639	205	641	206	605	205	696	205	595	188
University of Ulster													
PGCE	T and D	37	10	54	12	51	8	39	10	36	6	25	11
PGCE	All subjects	511	124	541	129	629	125	621	126	644	127	557	117
Overall Post Primary Figures													
PGCE + BEd	STEM subjects	n/a	n/a	n/a	124	413	118	378	123	483	133	484	136
PGCE + BEd	All subjects	1415	430	1734	424	2013	429	1912	432	1986	436	1871	403

Source: DENI

Table A10.1 Applications and Intake to Initial Teacher Education, 2002 – 2007

Main Module	2002/03	2003/04	2004/05	2005/06	2006/07
Technology and Design (UU + OU)	10	11	9	12	8
Mathematics (QUB + OU)	39	38	40	42	46
Computing/IT (all QUB)	10	16	14	12	10
Biology (all QUB)	27	21	24	24	29
Chemistry (all QUB)	15	13	13	14	13
Physics (all QUB)	6	10	10	8	8
Science (all OU)		5	4	4	5
Total STEM Post-Primary	107	114	114	116	119
Total PGCE Post-Primary	318	325	339	343	334

Source: DENI

Table A10.2 PGCE Graduate Figures, 2002 – 2006

Full-time Vacancies	Vacancies filled				Existing Vacancies			
	Permanent	Temp (1 year or more)	Temp (less than 1 year)	All	Permanent	Temp (1 year or more)	Temp (less than 1 year)	All
Mathematics	31	17	0	48	3	0	0	3
Design and Technology	11	2	2	15	4	0	1	5
Information Technology	17	11	0	28	1	0	2	3
Chemistry	9	4	1	14	0	0	0	0
Physics	12	2	0	14	0	0	0	0
Biology	15	4	1	20	1	0	0	1
Integrated	6	10	0	16	1	0	1	2
Other	2	2	3	7	0	0	1	1
Total Non-STEM	**176**	**79**	**18**	**273**	**24**	**7**	**4**	**35**
Total	**279**	**131**	**25**	**435**	**34**	**7**	**9**	**50**

Source: DENI

Table A10.3 Filled and Existing Vacancies, 2007/08

	Under 25	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60+	Total
Biology	5	44	16	11	7	8	4	9	5	109
Chemistry	1	9	8	4	8	3	3	6	12	54
Design and Technology	4	15	1	2	2		2	6	8	40
ICT	10	43	35	14	11	8	3	11	2	137
Mathematics	17	50	9	14	14	11	14	19	20	168
Physics	2	4	1	3	4	4	2	5	17	42
Science	1	10	1	1	4	3	4	2	1	27
Total	**40**	**175**	**71**	**49**	**50**	**37**	**32**	**58**	**65**	**577**

Source: DENI

Table A10.4 Substitute Teacher Register

Age	Biology		Chemistry		Physics		Technology		Mathematics		Other science	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
24 and under	2		2		2		12	10	14	5	11	1
25 to 29	53	18	17	14	11	5	69	51	110	36	101	33
30 to 34	102	38	52	24	17	11	81	78	143	51	138	62
35 to 39	116	42	52	26	23	19	109	70	151	60	103	58
40 to 44	112	35	75	34	22	24	62	72	110	50	75	38
45 to 49	32	23	31	17	12	23	25	52	40	19	38	20
50 to 54	19	15	5	16	3	2	8	30	24	5	22	12
55 to 59	11	8	9	10	4	6	5	17	15	10	10	11
60 to 64	1	1	1	1	1	3	1	1	4	4		3
65 and over										1		
Totals:	**448**	**180**	**244**	**142**	**95**	**93**	**372**	**381**	**611**	**241**	**498**	**238**

Source: GTCNI

Table A10.5 Distribution of STEM Teachers by Age and Gender

Annex 11

Local STEM Innovators

Lord Kelvin	Physicist & Engineer
Thomas Andrews	Shipbuilder
John Boyd Dunlop	Inventor of pneumatic tyre
Harry Ferguson	Tractor innovator
Eric Mervyn Lindsay	Astronomer
Sir David Bates	Physicist
John Stewart Bell	Quantum Physicist
Jocelyn Bell Brunell	Astrophysicist & discoverer of Pulsars
Sir James Martin	Airplane manufacturer and inventor of the ejector seat
Frank Pantridge	Inventor of the portable defibrillator
David Perry	Computer games innovator
Sir Bernard Crossland	Engineer

Annex 12

Abbreviations

ANIC	Association of Northern Ireland Colleges
BRIC	Brazil, Russian, India, China
BSE	Bovine Spongiform Encephalopathy (commonly known as "mad cow disease")
BTEC	Business & Technology Education Council
BERD	Business Expenditure on Research and Development
CAGR	Compound Annual Growth Rate
CASS	Curriculum Advisory Support Service
CCEA	The Council for the Curriculum, Examinations & Assessment
CEIAG	Career Education, Information, Advice and Guidance
CPD	Continuous Professional Development
CSA	Chief Scientific Adviser
DARD	Department of Agricultural and Rural Development
DE	Department of Education
DEL	Department of Employment and Learning
DETI	Department of Enterprise, Trade and Investment
DFP	Department of Finance and Personnel
DHSSPS	Department of Health, Social Security & Public Services
ELB	Education and Library Boards
ESA	Education & Skills Authority
ETI	Education and Training Inspectorate
FDI	Foreign Direct Investment
FE	Further Education
FMN	Further Mathematics Network
GB	Great Britain
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
GDP	Gross Domestic Product
GVA	Gross Value Added
HDI	Human Development Index

HEIs	Higher Education Institutions
HSC	Health and Social Care
HSCSR	Health and Social Care Services Research
ICT	Information and Communication Technology
IDA	Industrial Development Agency
LSDA	Learning Skills Development Agency
NI	Northern Ireland
NIHR	National Institute for Health Research
NISEF	Northern Ireland Science Education Forum
NQF	National Qualifications Framework
NVQ	National Vocational Qualification
OCED	Organisation for Economic Co-operation and Development
PfG	Programme for Government
PG	Postgraduate
PGCE	Postgraduate Certificate in Education
PISA	Programme for International Student Assessment
PSA	Public Service Agreement
QUB	Queens University Belfast
R&D	Research and Development
RISAP	Regional Innovation Strategic Action Plan
RoI	Republic of Ireland
ROSE	Relevance of Scientific Education
SOC	Standard Occupation Classification
SSDA	Sector Skills Development Agency
STEM	Science, Technology, Engineering and Mathematics
UG	Undergraduate
UK	United Kingdom
UU	University of Ulster

Given the global market challenges facing our economy and in particular its science and technology based industries, the place of STEM within the education system will become increasingly important in the years ahead.

General Enquiries
Department for Employment
and Learning
Adelaide House
39-49 Adelaide Street
Belfast BT2 8FD
Tel: 028 9025 7777 Fax: 028 9025 7778
Email: del@nics.gov.uk

Department of Education
Rathgael House
43 Balloo Road
Bangor BT19 7PR
Tel: 028 9127 9279 Fax: 028 9127 9100
Email: mail@deni.gov.uk