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A critical review of evidence for the claims and perceptions of a shortage of science and engineering graduates in the UK.

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University of Sussex
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Declaration

I hereby declare that this thesis has not been and will not be submitted in whole or in part to another University for the award of any other degree.

Signature:

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UNIVERSITY OF SUSSEX

CAROL WHITE, DOCTOR OF PHILOSOPHY

A critical review of evidence for the claims and perceptions of a shortage of science and engineering graduates in the UK.

Summary

After critically reviewing evidence in historical debates of a persistent claim of a declining interest in the sciences, the thesis draws on contemporary HESA data to calculate first-year STEM intake figures to Higher Education from 2002-03 to 2014-15 to estimate both a level of STEM recruitment and the number of STEM graduates produced after completing a graduate and post graduate programme over the same period. The supply of graduates is then considered against a level of demand estimated through two proxy indicators, the vacancy rate and salary levels for science and technology graduates. An analysis of the recruitment patterns for science and engineering to identify factors affecting recruitment was also conducted. The research study was supplemented with a 'before and after' survey of the London Youth International Science Forum initiative, to assess its impact on recruitment to STEM subjects. Despite the perception of a shortfall in STEM numbers, the findings show graduate recruitment numbers rising over the period under examination, although a regional variation in supply, and shortfalls in some STEM disciplines, may account for claims of a shortfall in graduate numbers. The contribution to knowledge of this research lies in the in-depth analysis of the student recruitment patterns to Science, Technology, Engineering and Mathematics (STEM) in the UK over the period from 2003 to 2015. While the analysis identified several relevant factors: contextual, political and financial acting as constraints to STEM recruitment, nevertheless, the research found no quantitative evidence of a crisis in recruitment.

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Glossary of Acronyms

ABI...... Annual Business Inquiry

BAE....... British Aerospace Systems

BIS......... Department for Business Innovation and Skills

BME....... Black or Minority Ethnic backgrounds

BRIC...... (Countries) Brazil, Russia, India and China

BTEC...... The Business and Technology Education Council

BVA....... The British Veterinary Association

CBI....... .The Confederation of British Industry

CE......... Cambridge Economics

CERN...... The European Organisation for Nuclear Research

CfWI...... The Centre for Workforce Intelligence

CIHE...... Council for Industry and Higher Education

CIPD...... The Chartered Institute of Personnel and Development

CPD....... Continuing professional development

DfEE....... Department for Education and Employment

DfES....... Department for Education and Skills

DEFRA.... Department for Environment Food and Rural Affairs

DH......... Department of Health

DIUS...... Department for Innovation Universities and Skills

D&T....... Design and Technology

DTI......... Department of Trade and Industry

EPSRC.... The Engineering and Physical Sciences Research Council

ESRC...... The Economic and Social Research Council

ERT....... European Round Table

ETB......... Engineering Technology Board

FTE......... Full Time Equivalent

GDE....... Gross Domestic Expenditure

GDP....... Gross Domestic Product

HE......... Higher Education

HEFCE.... The Higher Education Funding Council for England

HEI......... Higher Education Institution

HENSE.... The Health and Education National Strategy Exchange

HESA...... The Higher Education Statistics Agency

HNC....... Higher National Certificate

ICT....... . Information and Communications Technology

IER......... Institute of Employment Research

ILO......... International Labour Organisation

ISCO 08...... International Standard Classification of Occupations

JACS....... Joint Academic Coding of Subjects

LFS......... Labour Force Survey

LIYSF...... The London International Youth Science Forum

LSC......... Learning Skills Council

MBA....... Masters in Business Administration

MDM...... Multisectoral Dynamic Model

NHS....... National Health Service

NQF......... National Qualifications Framework

OBR....... The Office for Budget Responsibility

OECD.... .Organisation for Economic Co-operation and Development

ONS....... Office of National Statistics

PISA....... Programme for International Student Assessment

PPP....... .Purchasing Power Parity

PSSRU.... Personal Social Services Research Unit

QCA....... The Qualifications and Curriculum Authority

QLFS....... Quarterly Labour Force Survey

RAE....... Royal Academy of Engineering

RCUK...... Research Councils UK

RCVS...... Royal College of Veterinary Surgeons

R&D....... Research and Development

RDA....... Regional Development Agencies

S&T....... Science and Technology

SET....... Science Engineering and Technology

SIC....... . Standard Industrialisation Clarification

SOC.........Standard Occupation Classifications

SSC.........Sector Skills Councils

SSDA......Sector Skills Development Agency

STEM......Science, Technology, Engineering and Mathematics

THE....... Times Higher Education

UCAS......The Universities and Colleges Admissions Service

UKCES.... .UK Commission for Employment and Skills

UNESCO...United Nations Educational, Scientific, and Cultural Organization

WTO....... .World Trade Organization

'Social action, no less than physical action is steered by perception'.

Kurt Lewin 1948

Chapter 1

Introduction

The perceptions and claims of a shortage in the supply of scientists and engineers in the economy holding back the UK's prosperity are both persistent and widespread. So too, is the suggestion that a failure to address concerns about downward trends in the numbers of science, technology, engineering and mathematics (STEM) graduates, is likely to be very serious indeed for the UK's productivity and its competitive position in the global market place. While it may well be that highly skilled scientists and engineers are vital to the R&D and productive capabilities of the nation, and therefore of great importance to its economic wellbeing, the issue of a persistent shortfall in the numbers of UK science and engineering graduates with the right skills remains in question. Nevertheless, a number of respected sources and economic correspondents are convinced the quality and quantity of the UK's future science and engineering skills will not be sufficient to take advantage of investment in R&D against an increasingly globalised market place unless remedial action is taken. Not least among them was the physicist Sir Gareth Roberts whose Review, under government commission, of the supply of science graduates and postgraduates *SET for Success* in 2002 provides the starting point of this research.

Also of great influence in the science skills supply and demand debate and still very active is the Confederation of British Industries (CBI) which acts to represent UK business interests. Since 2008 the CBI have conducted an annual *Skills and Education Survey* sponsored by Pearson, the private educational and training specialists. The surveys invite employers to respond to a number of questions about their experiences in recruiting staff in key sectors such as science and engineering, construction and manufacturing. The results are published annually and over the years have repeatedly portrayed the STEM skills situation in expressions of alarm.

The first survey in 2008 for example reported: *'Fierce competition for talent contributes* *to recruitment difficulties'* (CBI, 2008, p. 30). By 2012 there were warnings for the *'... low-skilled'* against *'... a growing hunger for skills in the future'.* The CBI News headlines for 24 July 2015 about the latest Education and Skills Survey, warned *'Lack of skills could starve growth'.* On 24 August, referring to the same 2015 survey it was announced, *'Skills crisis biting across the UK'.* Just one week later a further report claimed *'Two of the greatest challengers facing the UK economy are a worsening skills crisis and persistently low levels of productivity'.* The report continued:

Last year - for the first time in the 17 year history of the CBIs annual employments trends survey concerns over skills emerged as the most significant perceived threat to workforce competitiveness.

The findings of the 2015 Education and Skills Survey the CBI refers to, are based on the responses of 310 companies which together, according to the 24 July 2015 news report, employed over one million employees.

Using the responses of 310 employers appears to offer a convincing source of experiences and opinions about recruitment difficulties. The UK however, in 2015 supports 5.4 million businesses (Rhodes, 2015). Of this number 24 per cent are listed as employers. This gives a target population of 1.3 million employers.

While the CBI surveys are clear and expansive about their approach to weighting survey responses using data from the Office for National Statistics to reflect the sectoral spread across the economy (see page 11 of the 2008 survey, for example), they appear to have overlooked informing their readers about the reliability of their survey findings in terms of the validity of sample base size and the use of standard indicators such as the confidence interval (margin of error) and the confidence level, in their Education and Skills Survey over the years.

The CBI's sample base of 310 in the 2015 Education and Skills survey for example would be considered as being below the lowest recommended figure for a sample base if used with the standard industry indicator levels of a five per cent margin of error and a ninety-five percent confidence level which requires a sample base of 384 to offer a widely acceptable level of reliability in its findings (Krejcie & Morgan, 1970, p. 2). The CBI advise that their survey data informs the Bank of England, the Economic Commission, HM Treasury and the Office for Budget Responsibility, key stakeholders, data vendors, analysts and the media (CBI, 2013, p. 8-14). As such it would be expected that their data would be highly reliable. However not knowing that these fundamental measures are in place leaves a degree of uncertainty about the CBI survey collection processes.

While the CBI approaches the supply of science skills in their surveys through the respondent firm sizes and the economic sectors they represent (CBI, 2008, p. 11), others view the topic through the geographical lens of a regional supply and demand scenario. A report by Bosworth et al. (2013), for the UK Commission for Employment and Skills (UKCES) for example, came to the conclusion that in total there was a balance in the Core STEM occupations in England 'equal to the employed population used on the supply side', although the report issued concerns about STEM skills regional availability. Commuting for example was seen as responsible in 2011 for a net gain to London of 87,000 core STEM workers, while the South East suffered a net loss of 50,000; the East of England lost 20,000 and the East Midlands 22,000 according to Bosworth for UKCES (Bosworth et al., 2013, p. 6). This level of analysis by the UKCES report looked beyond the more straightforward approach adopted by the CBI to the question of STEM skills supply in terms of numbers per se, to examine the same concerns from a wider perspective across the geographical boundaries of the UK. In doing so they arrived at a different conclusion to the CBI, and one that would imply the need for a different policy approach. This suggests that if the problem is to be more precisely addressed, a better understanding of the relationships between the supply of those with STEM skills and the question of demand is called for.

1.1 Purpose and aims of the research

The policy reports of Dainton (1968) and Roberts (2002) were both commissioned by the government of the day to identify and address obstructions to a high quality supply of scientists, engineers and technologists (under Roberts new acronym "SET"), in the academic supply chain. Determining an 'adequate supply', as Roberts saw it, of high quality STEM skilled graduates can only be estimated when supply is considered relative to the level of demand for their services. In this, the argument tends to be polarised. On the one hand there are those who insist there is an adequacy of supply (Bosworth et al., 2013) and those who see nothing but a yawning deficiency (Dyson, 2015; Cable, 2015). Adding to the difficulties in seeking to reconcile the opposing arguments is the practice (particularly in engineering) of using projected figures to foresee the future requirement for STEM skilled workers, which tend to run into the thousands.

The purpose of this chapter therefore is not to attempt to anticipate the level of STEM skills needed to meet future manpower needs, but rather to consider the evidence for the current STEM numbers by analysing the supply data against an estimated demand. The aims of the research are to judge whether concern about a shortfall in the STEM graduate recruitment is justified, to identify and understand constraints to student intake by analysing the recruitment patterns. This allows the appropriateness of some policy initiatives, used to encourage science interest in young people to address the perceived problem, to be considered in greater depth.

1.1.1 Research Question

The aims lead directly to the overall research question:

- Is there a contemporary crisis in recruitment to Science and Technology in the UK?

1.2 Why the topic was chosen

The question of whether there is shortfall in the number of UK science and engineering graduates against the labour market demand is seen in the literature as both long standing and unresolved. The argument about STEM supply is polarised between those who insist that employer difficulties in recruitment indicates the shortage of STEM skills while the opposing view suggests the level of unemployed STEM graduates confirms an overabundance of supply. A third argument is considered. That of a mismatch of graduate skills to employer needs. This raises both a financial and an ethical dilemma; that a shortfall in the STEM workforce will inhibit the country's economic growth and competitiveness, while training workers at length for scarce or nonexistent employment presents a moral issue.

This develops an interesting scenario and one which calls for a fresh examination of the supply evidence and new approach to reconciling the disparate arguments.It provides the motivation of this study.

1.2.1 Background

The science skills debate is seen as active and as challenging today as it appears to have been in past. Three examples are given of claims that science was facing a decline, were made by those of influence in their respective fields. In each case I argue (Chapters 3 and 4) they were not backed with sufficient evidence to conclusively prove the assertions. The debate has developed and continued since as to whether there exists a serious shortage in the supply of UK STEM skills.

Institutions and individuals of influence today make similar calls about the state of science, and the inadequacy of the supply of graduates to meet the UK's needs. A parallel is seen with the historical claims, by suggesting an unquestioning acceptance of the situation by policy makers and others leads to a persistent narrative.

1.3 Scope of the research

A notable absence in this thesis is any account of the supply of science and engineering skills during the Second World War years against national demand. This extraordinary period noted for its scientific and technological advances is outside the remit of this thesis.

Included however are one of the earliest historical accounts of concern about science in England, and two more recent policy reports, which all call attention to the state of science progress in the UK at three specific time periods within the 19th, 20th and the 21st centuries, that is 1830, 1968 and 2002 respectively. The accounts are not only to provide the contextual background of the contemporary debate, but to illustrate the particular persistency that has appeared to accompany a conviction of a decline in science over the years.

Where the longevity and the interest of the subject matter has produced an over-abundance of related literature, a narrow focus had been adopted. The question of decline therefore has been examined by a fresh analysis of the supply data over the period dating from the last policy report by Roberts in 2002, and considered against Labour Market and employer demand.

In considering the pertinence of the policy initiatives to the perceived problem of STEM supply, the results are presented in this study of a 'before and after' survey of a London based science event (LIYSF) along with an in-depth analysis of the recruitment patterns of STEM students. This analysis to the best of my knowledge, is an original approach to understanding the wider contributory factors affecting STEM student recruitment in looking beyond a student-centric approach.

1.3.1 My contribution

The contribution to knowledge of this research lies in the in-depth analysis of the student recruitment patterns to Science, Technology, Engineering and Mathematics (STEM) in the UK over the period from 2003 to 2015. The analysis identified several relevant factors: contextual, political and financial, as well as policy responses to perceived scarcities.

1.4 The Thesis structure

The following gives a brief outline as to how the thesis chapters will proceed.

Chapter 2 Analytical framework and methodological approach

The Introduction to the overall methodological approach to investigating the research problem such as the approach, quantitative and empirical-analytical for example to study the phenomenon. Details and description for the archival documents examined and the location, setting, approach and method of data collection for both the survey and the supply and demand data are given, with an explanation of the methods used to analyse the various elements.

The methodology also includes the statistical examination of the Higher Education Statistical Agency (HESA), undergraduate and postgraduate intake numbers of those choosing to study science and engineering. Establishing a measure for the demand side of the debate however was less straightforward in the absence of tangibility and substance. The use of proxies such as salary and vacancy rates were critically analysed for their fidelity as indicators of demand.

A multi-method methodology within an analytical framework and a quantitative statistical approach was used to understand the gains and losses of STEM student intake numbers over time, and to consider the results of the fieldwork survey, and the analysis of the recruitment data. The strengths, weaknesses and limitations to the methodological approaches used are discussed.

Chapter 3 Historical background to the research

Concerns about the progress of science in the Nineteenth Century triggered by Babbage's claim of a *'Decline of Science in England'* of 1830 and of Dainton's reputed claim of a *'swing away'* from science by the school pupils of the late 1960s, are examined against contemporary science concerns. The two historical accounts were both seen as the subject of some controversy. Babbage for his bitter attack and personal grievances against the Royal Society leadership and the universities (1830), and Dainton for his alleged misinterpretation of the data used to support his claim of a pupil *'swing away'* from science Dainton (1968, p. 29-43). Although both reports had their strengths, I will argue in this chapter through a number of examples that the evidence presented by both Babbage and Dainton was insufficient to prove their respective claims of a *'decline'* in English science and of the *'swing away'* from science.

Chapter 4 Roberts Review

The political and global landscape prevailing at the turn of the twenty-first century is examined as a contextual framework for the commissioning of Roberts Review, *SET for Success* and published in 2002. The *Review* is firstly challenged against its assumption of future shortfall in the supply of scientists and engineers, and secondly, against its claim that the thirty-seven recommendations that concluded the *Review* and based upon its findings, would help to secure the necessary supply of STEM skills. I argue through the *Review's* own charts and tables that the evidence Roberts presented does not robustly support a claim of *'serious problems'* in the supply of graduates in some science disciplines. My argument concludes in a summary of the Roberts recommendations and a concern as to their possible effectiveness in helping to secure an adequate future supply of scientists and engineers.

Chapter 5 Evidence of supply for scientists and engineers in the UK 2002-2015

This chapter outlines the commercial economic background that prevailed at the start of the data collection period, and which may have begun to motivate the increased demand for a STEM skilled workforce. Recruitment levels as a proxy for the supply of STEM graduates are examined in this chapter. The findings, shown in a series of graphs and tables over a time-series data set, are examined to measure the level of change in intake numbers over the research period 2003 to 2015. The pre and post findings of the survey are also presented along with the analysis of the student recruitment patterns. The overall findings are summarised.

Chapter 6 Evidence of demand for scientists and engineers in the UK 2002-2015

The theoretical question of the supply and demand market relationship is considered and related to the workplace context. The strengths and weaknesses of the proxy indicators used to determine the level of demand are considered. Alternative arguments are discussed to the question of a skills mismatch between graduate and employer needs and for the employer claim of recruitment difficulties. The contemporary literature review is integrated within this chapter.

Chapter 7 Analysis of the LIYSF questionnaires

This chapter presents the analysis and results of the both the pre- and post-event survey questionnaires.

Chapter 8 Discussion and conclusions

The final chapter discusses the findings of the thesis and concludes with a summary of its main points and suggests ways the study might be extended for further study and research.

Chapter 2

Analytical framework and methodological approach

2.1 Introduction

The supply and the demand, for Science, Technology, Engineering and Mathematical (STEM) skills in the UK is the focus for this research study. The background to the empirical approach is provided by the evidence of selected historical assertions of a declining interest in the sciences in the 19th and 20th centuries, whereas the foreground consists of the statistical examination of 21st century claims of a shortfall in graduate supply against labour market demand. These approaches are supplemented by a comparative analysis of the findings of both a pre- and a post-event survey questionnaire of a sample of participants in the annual London International Youth Science Forum, the aim of which is to bring both UK and overseas students together in their shared science interests.

This study does not focus on the issue of gender in STEM. In compiling the statistical evidence about the supply of STEM graduates, both male and female graduate numbers were aggregated into overall totals from the data sources. This is not to disregard legitimate concerns about possible stereotypical gender-based attitudes, employment barriers or restricted career progression and other related gender issues, but rather to acknowledge that the area of gender concern in STEM is wide enough to justify a separate and dedicated in-depth study.

This study however is concerned with quantified estimates of the aggregate supply of, and demand for, STEM graduates in the UK. Although some of the possible implications for the employment of black and minority ethnic (BME) graduates particularly in the computer sciences, are touched upon in the discussion, this aspect emerged from the analysis of computer science graduate recruitment patterns, whereas the issue of gender did not emerge from the available data. However when gathering data via a questionnaire approach for example it was possible and appropriate to ask questions concerning gender. On this basis a request to respondents to specify their gender was included, along with age and home country in the LIYSF post-event questionnaire.

2.2 The Research philosophy and ontology of the approach

In seeking to answer the research question raised in this thesis a multiple method approach was adopted towards gathering and analysing data; none of those methods were considered as sufficient or definitive on their own, but rather as each contributing to an overall integrated analysis. For this investigation a realist approach, sometimes referred to as 'positivism', was chosen as the ontological basis underpinning the whole investigation. This particular approach takes as a given the existence of a set of facts that can be gathered and analysed, and can thereby contribute to explaining a particular set of circumstances. In this case, the collection and analysis of data were used to assess the changing relationships between the supply of and demand for STEM graduates in the UK over the period from 2003 to 2015. The approach is generally adopted in the domain of the natural and the physical sciences, but it also has important contributions to make to the social sciences; as in Durkheim, this thesis assumes the existence and accessibility of sets of 'social facts' (Durkheim, 1982). It offers a practicable approach, in what is largely a quantitative investigation, to drawing conclusions about the supply of, and demand for, UK graduate STEM skills, by drawing on the available statistical evidence, and by using two proxy indicators of changing levels of demand. The multi-method approach of the thesis is incorporated into an analytical framework to provide a contextual understanding of the issues and to infer relevant implications from the available data. The empirical approach was also useful for drawing inferences and conclusions from the statistical data produced by the two survey questionnaires.

2.3 The Identification and analysis of historical literature as secondary data analysis

Against the background of persistent perceptions that the supply of science and technology graduates in the UK is likely to be inadequate for the future growth of the economy, considering historically similar assertions of a decline in the levels of interest in science and technology can help to contextualise contemporary concerns.

Goodwin suggested that secondary data are often undervalued as a research tool (2012). This may have been more so in the past, but today vast amounts of data are collected, compiled and archived in a such as way as to allow researchers easy access via online search engines, such as *Google Scholar, Eric, Oxford Dictionary of National Biography,* and others. As an empirical exercise, secondary data analysis of primary data offers a practical method of systematic analysis into archived material that might once have taken considerable time and effort to locate (Johnston, M., 2014, p. 1). Although archived material can be examined for new insights and thus considered as a source of primary data, the intentions of this approach is to analyse past literature as secondary data to help understand the persistence of a perception of a UK STEM supply deficit. A three-fold requirement of suitable literature was devised.

Firstly, seminal reports dealing with the study of the sciences were gathered. Secondly, documents were sought to gain a picture of national science across the years. Thirdly, care was taken to select seminal contributions to the literature. This would allow their influence to be considered in relation to contemporary concerns. Through an online search using the criteria outlined above, three reports dating from the 19th, 20th and 21st centuries met the stipulated criteria.

A biographical online search (*Oxford Dictionary of National Biography*) was also undertaken to understand the differences and similarities between the three authors and their reports. Since the three reports expressed concerns about the levels of interest in science and technology in the UK, it was also possible from this approach to consider whether the reputations and influence of these authors were likely to have been sufficient to influence policies, practices and perceptions about science and technology over the following years by suggesting, for example, that interest in science in England in the first third of the 19th century had declined (Babbage, 1830); that there was a swing away from science in sixth-form students in the late 1960s (Dainton, 1968); and that STEM graduate numbers would be insufficient to meet employer demand in the future (Roberts, 2002).

2.3.1 The analysis of the historical literature

Since the study perspective took an empirical approach, a deductive process could be employed in examining the available data (Saunders et al., 2007). This was achieved by analysing the evidence, anecdotal and statistical, offered to support the various claims and concerns. They were systematically examined using inferential reasoning to identify the implications of the evidence adduced in each report. The analysis was then compared with arguments from existing literature where the same three reports of Babbage, Dainton and Roberts, had been examined. The findings were contrasted or corroborated by supplementary commentary, or evidence such as Granville in 1830 and Reingold writing with Moll in 1968 to challenge Babbage's claim of decline; Duckworth's hindsight approach in 1974 to Dainton's 'swing away', and for Roberts: Cole, Rikowski, Hatcher, Hirtt, and others, in 1999. This was often contemporary to the period examined, but also included, hindsight accounts of events.

2.3.2 HESA recruitment data

Two approaches were made to address the statistical data on the supply-side with two proxy indicators. The first proxy for STEM graduate supply was the annual estimates of the levels of recruitment over the period 2003 to 2015. For this exercise, the official data tables from the Higher Education Statistics Agency (HESA) for the whole period in question were compiled into a series of tables and graphical plots from which estimated totals for recruitment were based on the numbers attending their first year of higher education (HE). Figures were gathered at both the individual discipline level and summed into the aggregate of all STEM subjects. The recruitment estimates were based upon first year HE entry data, rather than enrolment data, to take into account the fact that enrolment numbers included those who enrolled for more than one course, thus distorting estimates of the number of recruited students. The data analysed included both full and part-time students, and first-year undergraduates and postgraduate students.

2.3.3 HESA Outcome (qualifications awarded) data

The 'outcome data', as the second proxy indicator, were approached in a similar way. Undergraduate degree numbers, which included those awarded first and second class undergraduate degrees, were summed on an annual basis for the thirteen years of the research period and combined with the estimates of those awarded postgraduate degrees, including the doctoral qualification, to reach a final aggregate estimate of the supply of STEM-trained graduates. Again the totals included both full and part-time graduates.

Counting attrition levels in the HE courses, between admission and graduation, was unnecessary, since the outcome would be evident from the final estimates of the numbers of STEM degrees awarded) at the conclusion of the under-graduate and post-graduate degree programmes. In toto, they provided annual estimates of the overall supply at the end of each academic year. Growth and decline in recruitment and outcome for each STEM category were also tracked annually over the period 2003 to 2015.

2.4 The analysis of recruitment patterns from HESA data

One unexpected outcome of compiling the recruitment data into a graphical form was the emergence, in some cases, of quite specific recruitment patterns for particular subject areas seen in the plots, rather than an increasing or declining trend curve. One particular example of the recruitment pattern was noted in the recruitment of medical doctors. For this discipline there was a prior expectation that the graph would show an upward trend in recruitment in line with a rising UK population. Instead the graph showed that recruitment levels had flat-lined for NHS doctors over the thirteen years of the study, despite current concerns about the availability of medical doctors particularly in general practice. This finding holds implications for NHS recruitment policies (NHE, 2016).

Taking an analytical approach to understanding the mechanisms behind the recruitment patterns involved a further search and examination of literature sources and web-based advice and career guidance sites, including government sites, for prospective students of specific types of STEM courses, particularly in the medical and veterinary sciences for issues such as costs incurred in initial professional training, life-time costs of NHS professional training and bursary information (where the life-time costs of medical staff have implications for government budgets).

Background literature and reports were also accessed to seek an explanation for the striking decline over the research period in recruitment to the computer sciences. This approach revealed a suggested demographic profile of an average computer science student as well as some empirically observed implications affecting their earning potential and employment prospects (see Shadbolt, N. 2015, 2016). Linking research with a theoretical explanation suggesting employers and those involved in recruitment to employment tended to appoint those individuals sharing characteristics such as cultural, background, educational achievements interests, and so on (Rivera, 2012; McPherson et al., 2001), offered a further insight to help explain a possible causal influence of the declining trend seen in the recruitment pattern for the computer sciences. In this way insight and explanation for the patterns of STEM recruitment were inferred which indicated some unexpected constraints imposed on recruitment in STEM occupations as discussed in Chapter 5.

2.5 The ‘Demand-side’ literature

In considering an approach to estimating levels of demand for STEM graduates, a search was conducted to examine how demand in the STEM labour market was addressed in the literature. While the approaches to current demand were restricted to earnings, vacancy levels, and questionnaires, projections of future levels of demand were based largely on assumptions about future benefits that could accrue to those possessing STEM skills. The majority of the reports (particularly the *Working Futures* report series (Wilson, et al., 2003 to 2024), focused on future employment projections for a decade ahead. They were based on econometric models and a range of past variables, such as the qualification levels of the workforce, and past employment records from the series of Labour Force Surveys. Also included in the forecasts were caveats about the limitations in forecasting, which were seen by the Wilson group as conditional on some contextual variables remaining constant over time. It was also noted that the estimates produced in the government-sponsored *Working Futures* series were reproduced in several other demand focused literature and reports reinforcing influence of the approach and the projection figures.

2.5.1 Testing Demand projections

Wofking Futures employment projections for the period 2004 to 2014 had time-expired allowing an opportunity to test the level of accuracy of the earlier forecast. This involved comparing the projected employment figures, either growth or decline, and the projected direction of change for the various occupations examined, with *Employment by Occupation* data produced by the UK office for National Statistics (ONS) over the same period. Where the results differed from the projections, a number of explanations were sought in the relevant literature, which included among others, a summary of business conditions for 2015 by the *Bank of England*, and the impact of the 2009 financial crisis.

2.5.2 A critical approach to the use of proxies in estimating levels of STEM demand

In examining a sample of the literature, some of the limitations of the approaches to estimate levels of demand for particular types of STEM skills became evident. Investigating levels of labour-market demand can only pursued indirectly, as levels of demand are typically implied rather made explicit. Since the research strategy had adopted an empirical approach, the task was to seek proxy indicators of prevailing levels of demand. Vacancy rates served as one type of proxy indicator; it appeared to be the most straight forward approach in offering estimates of levels of demand. That approach relied however on sourcing comprehensive vacancy data. In this there was some frustration.

2.5.3 Vacancy rates as proxy indicators of Demand

Access to official vacancy data collected by the *Office for National Statistics* (ONS) was barred, despite my status with ONS as an authorised researcher, by security entry barriers to protect data deemed by the ONS to be 'sensitive' (discussed below in section on 'Limitations'). A source was located, following a further search, in an online employment agency which was also informed government about employment statistics. The agency provided month-by-month vacancy estimates. It was then possible to compare those data with graduate-supply data. This approach however was not a straightforward comparison in that the graduate data were available only on an annual basis. Nevertheless the comparison was useful where the monthly vacancy rate (taken as an indicator of demand) was recorded in excess of the annual supply, an undersupply of STEM skills could readily be inferred.

Analysing other estimates of vacancy rates collected from 2005 to 2015 by the *Graduate Market High Fliers* group, indicated those occupations where vacancy rates had grown over the previous decade, and where they had declined. It was therefore possible to identify which occupations in 2015 were facing an unmet demand for science and engineering skills, and which occupations indicated closer matches between levels of supply and demand.

2.5.4 Salary levels as a proxy indicator of Demand.

Analysing estimated salary levels, available from various sources, as a second proxy indicator for prevailing levels of demand allowed comparisons to be made amongst the various STEM occupations, and between STEM and non-STEM occupations, by drawing on a tabulation of estimates of the highest twenty-five salaries occupational categories. That table also indicated which occupations appeared to be in a growing demand, and in which occupations demand appeared to have stabilised or declined.

In researching salary levels however it appears that salary levels as intended proxy indictors of STEM demand, are not always the prime consideration in seeking employment. Bosworth et al. (1996, p. 4) found that other factors influenced employment choices. Moreover under some circumstances, where companies operated within an internal labour market for example, paying externally competitive rates for new graduates in excess of internal pay rates was likely to be disruptive to existing company pay structures (Mason,

1999) and may have been avoided. Nevertheless, salary levels were useful in making comparisons between STEM disciplines and to indicate changes over time allowing patterns of growth or decline in some occupations to be indicated, and which could be related to levels of demand.

2.6 The 2015 London International Youth Forum (LIYSF) Event

Why LIYSF, and the implications for the supply of science graduates.

The London International Youth Forum (LIYSF) was chosen as a potentially useful source of quantitative and qualitative primary data collection to support the study.

Founded in 1959 LIYSF was conceived as a means to overcome the animosity between nations left from the war years. Based initially on home-to-home visits LIYSF has developed into a two week residential annual event held in London each year. Its aim remains to develop an understanding between students of all nationalities, and to instil, "... a deeper insight into science..." in its widest and most beneficial applications (LIYSF, 2017).

The informal science education event offered an opportunity to understand some of the factors not usually found in the classroom, such as guest speakers active in their various fields and visits to industrial sites, research facilities and academic research centres in London, Oxford and Cambridge, which might help to motivate young people to seek a career in science and engineering. As such, LIYSF and similar interventions, potentially have strong implications for the supply of science graduates. This was my particular interest.

Making contact with the LIYSF's director, Richard Myhill, I discussed the purpose of my research. Whilst the director felt it would not be practicable to observe the student groups as they moved around London venues and visits, I was generously invited to participate in the opening ceremony. I was also invited to a subsequent reception at which a randomly selected (so I was assured) subset of the 2015 LIYSF cohort would represent their countries acting as flag-bearers at the opening ceremony. This raised the prospect of an opportunity to distribute a pre-event questionnaire to the flag-bearers at the reception, for which I was given permission. In addition the director agreed to distribute a post-event questionnaire via the internet using the LIYSF database of the 2015 participants. Direct contact to all the participants was however not permitted, since it would have breached data confidentiality.

2.7 The questionnaires and the questions

2.7.1 Pre-event

The pre-event questionnaire made use of a Likert-type approach whereby respondents are asked to assign a level of agreement or value to a series of statements across a five-level scale. This was a relatively straight-forward questionnaire, and one which could be understood and completed quickly, even by students whose first language was not English. This aspect was important since the potential respondents were included in the reception to enable them to network and socialise among the guests and officials. The questions were constructed so as to establish a base line about pre-conceived career plans and attitudes towards science before exposure to the LIYSF event. Fifty questionnaires were handed out, and forty-eight were returned; a return rate of ninety percent.

A copy of the questionnaire with responses is included in Appendix B.

2.7.2 Post-event

The post-event questionnaire was designed to provide more detailed information concerning career plans and attitudes following the two week event. This questionnaire was designed as a series of questions with several possible answers for each question, to which none, any, or all could be selected. The post-event questions were about career plans and attitudes towards science, and they were formulated to compliment and compare with those questions set in the Likert-type questionaire before the event. The intention was to highlight any changes that may have taken place in the study, career plans and attitudes towards the sciences and engineering, during the LIYSF event. Of a potential target population of 450 participants, 105 responded; a response rate of twenty-four percent.

A copy of the questionnaires with responses is included in the Appendix B.

2.7.3 Distributing the Questionnaires

With the selection of LIYSF students as potential respondents beyond my influence, and the subset also, the practicalities of accessing the returning data without compromising respondents anonymity were considered. The University of Sussex's in-house IT service was unable, because of staff shortages, to create an online survey system for me. Instead an external source, namely *SurveyMonkey* was used, after consulting with colleagues for a suitable choice. The company was helpful and able to accommodate a three-way system between LIYSF as the distributors, the respondents, and myself as the analyst. The post-event questionnaire was based around a pro forma template provided by the company, which lent itself to the planned series of pre-set questions and the number of possible answer statements.

2.7.4 The Analysis of the LIYSF pre and post-event questionnaires

Answers to the pre-event questionnaires were analysed by summing the values in the options chosen by each respondent to allow specific patterns to emerge from the data. From this approach the most and least popular responses were identified.

The analysis of the post-event survey questionnaire was more complex. This was not due to the questionnaire's content, but from an administrative complication from the survey company in its construction of the on-line surveys. This restricted the size of a population sample to no more than 100 individuals per survey. With a target population of 450 (the LIYSF cohort for 2015), five separate surveys (4x100 plus 1x50) each with identical questions and answer options had to be constructed and distributed. The responses of the post-event questionnaires were converted to percentage values for each answer per survey question. They were then aggregated and averaged across all five surveys.

The questions and the respondents answers for both the pre and the post questionnaires are listed in Appendix B.

2.8 The strengths, constraints and limitations of the methodologies used

The strengths of the investigation have been in the multiple-methods approach, which allowed some of the main the findings to be supported through the triangulation of the several approaches and the diverse range of data sources.

Accessing official STEM vacancy data from the ONS, to provide proxy indicators for STEM demand levels proved challenging. I had applied for, and been granted, 'authorised researcher' status from the ONS to access their data collection. This had entailed explaining in some detail my research aims, however when the time came I was barred from access to the particular vacancy statistics, which were classified by the ONS as 'sensitive'. Access would have required a further application with greater details of my project proposal, a possible six week wait for approval, followed by a London-based course on the use of sensitive data research. In addition any supervisors involved were required to append the project proposal as approved and to attend the course. This approach was abandoned and alternatives sought.

Several were found and used. One major source was an online graduate employment agency with vacancies listed by employment categories on a monthly basis. However I had not appreciated what should have been the very obvious fact that the availability of the data was limited to the current month's vacancies. Although annual summaries were available at the year's end, they were an aggregated version of the annual figures and employment trends, without the detail to allow STEM-intensive occupations to be readily identified. The original intention was to produce a data table of vacancy numbers, that would be comparable with the numbers completing under-graduate and post-graduate programmes at the end of the academic year. This, perforce, was changed to November when the data were collected. Having missed the time of peak recruitment following graduation, the November data table could be expected to show a reduced vacancy rate compared to the summer totals.

Practical difficulties were also evident in the HESA data collection, where inconsistencies in the way data were collected and classified over time, presented obvious discrepancies in consecutive data tables, with some academic subjects added or removed. This made time-series data sets difficult to construct, and complicated the task of trying to identify statistical trends between consecutive annual data tables. This was dealt with by disaggregating the represented groups, to identify the figures for the additional and/or omitted data, recalculating the percentages to adjust to the differences and best-matching the results between the two consecutive tables to identify recent trends. This was both frustrating and time consuming, and somewhat concerning that the statistical continuity would be compromised. The difficulty in constructing a time-series data set from missing data or changes in the way data were collected and categorised, or made publicly available, was not unique to this study. Wilson et al., commented on similar concerns when compiling their projections in the *Working Future* report for 2004 to 2014 (see for example, the *Working Futures* report for 2004 -2014: Wilson et al., p. 82-84; 308; 321).

A similar problem of consistency and continuity was found in the 2010 changes to the *Standard Occupational Classification* (SOC) which was used to digitally identify occupations through a five group hierarchy. The changes moved some occupations between groups, as their working status evolved. Again, this had implications for consistently quantifying occupational growth or decline between consecutive data tables. This was dealt with by calculating the percentage differences before and after the changes in the groups and occupations affected, and adding the percentage difference to one table, while subtracting it from the other.

The pre-event LIYSF survey questionnaire had a number of advantages for both the researcher and the respondents; the questions were quick and straightforward to answer and it proved a useful method to collect data under time constraints. It was also straightforward to quantify and to analyse. One concern however was that the advantage of speed may be have been a compromise between maximising the response rates and seeking the greatest accuracy, detail, and thoughtfulness, of the responses. A potential disadvantage in the use of questionnaires for those whose English was not their first language was the question of misunderstanding both questions and answers. This is a situation not necessarily restricted to students from overseas. Particular attention therefore needed to be paid to the way the questions were worded (Wisker, 2008, p. 187-190). While both questionnaires were tested on friends and colleagues, this and the way questions were presented, represents a challenge to avoid misunderstanding and researcher bias (Brett Davies, 2007, 89-94).

A further constraint was seen in the post-event questionnaire in terms of the limitations imposed by the survey company that their (free) surveys could cover no more than a population sample of 100 individuals per survey. Meeting the target population required five identical surveys to be dispatched, and the responses summed and aggregated across all five surveys. While this was relatively straightforward to process, it was time consuming and cumbersome.

There were further limitations in respect of the 2015 LIYSF survey, in that the population used for the survey was clearly not representative of the wider population of students. LIYSF's criteria for the selection of participants included age (16-21), the requirement that those attending should already be studying science and have passed or about to pass the exams for university entrance. They must also be able to meet the considerable costs of attending and of travelling to the event in London. This meant that the results of the 2015 post-event survey questionnaire were not generalisable over the general student population. Moreover the respondents in the pre-event questionnaire though randomly drawn, were a sub-set of the 2015 LIYSF student participants, as they had been selected for additional duties at the opening ceremony. The resultant small sample size of the flag-bearers (11 percent of the total participant population), meant that this sub-group could not be assumed to be representative of the total LIYSF 2015 cohort population.

2.9 Summary

This study was conducted with the purpose of critically examining reports of historical and contemporary assertions of declining levels of interest in STEM subjects. The task of answering the research question was approached by compiling statistical evidence of supply-side evidence on STEM recruitment over a thirteen year period. 'Demand-side' estimates were based on two indirect indicators. Determining whether or not there was a sufficiency of supply is inevitably a relative concept. It can only be confirmed or refuted when compared with a corresponding level of demand.

The methodology chosen therefore needed to be able to utilise several empirical approaches, which included analysing the historical reports, and the statistical estimation of the graduate supply data over time, through the compilation of a time-series data set, the analysis of the recruitment patterns, and the use of proxy indicators to estimate levels of demand over a similar time scale, at both an aggregate and disaggregated levels.

In addition the methodology needed to be able to deal with the analysis of before-and-after questionnaires used to measure a level of change in UK and international students' plans and attitudes towards science study and as a career option, following their two week residential participation in the London International Youth Science Forum.

The multi-method research design, was also able to accommodate alternative approaches to be made in mid-research. This was useful where some avenues of research were found to be blocked, such as the ONS vacancy data.

The methodologies allowed the collection of multiple sets of relevant data, both quantitative and qualitative, which facilitated a level of understanding based on the statistical and analytical approaches to both STEM supply and demand.

The next chapter critically examines three examples of the historical literature to provide a contextual background to contemporary concerns of STEM supply and demand.

Chapter 3

Historical background to the research: Charles Babbage and Frederick Dainton

3.1 Introduction

> *'It is commonly acknowledged that an understanding of the past is fundamental to an understanding of the present. The analysis and interpretation of history provides an essential context for evaluating contemporary institutions, politics, and cultures'. 'The study of history provides us with a richly textured, substantive framework for understanding the human condition and grappling with moral questions and problems'.* Luttmer (1996).

Notable about the science supply and demand debate is its longevity, its historical origins and its evolution. Since this research study is concerned with the supply and demand of scientists and engineers in the 21st Century considering national concerns about science over-time is intended to set the contemporary arguments in context.

The value of looking back to the events of the past when considering the present appeared clear to Frank Luttmer, quoted above, but he is not alone in his evaluation of historical events. Haddon et al.'s., publication *What is the Value of History in Policy-making* (2015) brings the role history can play within the policy process up to date as to how officials can make use of policy-relevant historical research to inform contemporary policymaking today.

Examining the historical accounts of both the Babbage (1830) and the Dainton (1968) reports was to examine the level of evidence produced to support their respective claims of a declining interest in science. In so doing I thought to establish a base-line to approach to the later more recent material which includes the policy report of Sir Gareth Roberts in his *Review: SET for Success* (2002). The historical content therefore covers three particular time-periods chosen to illustrate the long history of discourse and debate about science and its changing role and importance in society. They are periods that sparked new directions each with a subsequent resurgence of interest and contribution from those with an expressed interest in science whether it was focused upon Babbage's 19th century perceived decline of science in England, Dainton's so called 'swing away' from science in the 1960s, or Roberts concern in the 2000s about a future supply of science graduates. The time periods are chosen also to reflect the controversy that has accompanied the evolution of the role of science in society and the way society has portrayed that role over time. A notable absence is any account of the supply of science skills during the second World War years against national demand. This extraordinary period noted for its scientific and technological advances is beyond the remit of this thesis. Of the three time-periods, reports from two of them, Babbage and Dainton are examined chronologically in this chapter, while the *Roberts Review* and the summary of the thirty-seven recommendations which accompanied his *Review* is dealt with in Chapter 4.

This chapter therefore is the first of the empirical core of the thesis. It is in two parts. The first focuses on the mid-19th Century at the time of Babbage, John Herschel, Davy and Faraday and others of significance in British science while the second examines Dainton's *Enquiry into the Flow of Candidates in Science and Technology into Higher Education* in 1968 and which led to his concern about a 'swing away' from science by students. It is interesting to note that Babbage and others were not the first to raise alarm about the standing of British science. This distinction fell to anonymous reviewers in the Edinburgh Review (1816, p. 98) and again in 1819, p. 392.

3.2 The Historical Debate

A decade or so after the *Edinburgh Reviews,* Babbage published[1] *Reflections on the Decline of Science in England, and on Some of its Causes* in 1830 where he called for widespread reform (see in particular Sections 2 and 12) in the way British science was practised and promoted. Articulated with biting criticism, Babbage railed against the Royal Society, its president Davies Gilbert, the Government for their perceived ignorance of any matters which pertained to science and their subsequent lack of encouragement and inducements for science and for those who dealt with its abstract elements, and against the universities for their lack of science education. Babbage's *Reflections* is said by some to have triggered a great reform in the country which affected many aspects of national life including the Church, the political system, the universities and the scientific institutions. The reforms spanned the period 1830-1850 and was formalised two years after the publication of Reflections by the Reform Act of 1832 (Dubbey, 1978; Hyman, 2007; Cardwell, 1957, p. 48).

The 1960s are also seen as a period that triggered discourse and debate about science and technology when discussion turned as much to the consideration of student attitudes towards those subjects and their future career plans as to the economic needs of the country for a skilled workforce. At that time government and academic concerns focused on the body of students noted in the Dainton committee report of 1968 (*Enquiry into the Flow of Candidates in Science and Technology into Higher Education*) as 'swinging away' from science at the point when students made their study and career choices. To what extent the 'swing away' could be determined by the evidence presented is a matter for discussion by some who claim that the Dainton Committee had misused Phillip's careful statistical analysis of the trend (Dainton, 1968; McPherson, 1969; Duckworth & Entwhistle, 1974; Phillips, 1969). Phillips concluded,

> *There has, in fact been no swing away from science common to all countries. Each has reacted differently to different educational influences* (Phillips, 1969).

Note that Dainton published *Enquiries* in February 1968, whereas, Phillips' thesis *(Changes in Subject Choice at School and University)* was not published until July 1969. Dainton however had early access to the thesis.

[1] Charles Babbage's publication, *The Decline of Science in England and on Some of its Causes*, referred to in this thesis is the eBook version produced by Project Guttenberg which was last updated January 25th 2013. This electronic version is without pagination. In order to identify the location of the references and quotations cited in the thesis the Sections and Chapters numbers are given to allow cross referencing.

Finally the literature is examined against more current literary contributions to the debate from the turn of the century. The *Roberts Review* published in 2002, commissioned as part of the government's economic strategy following the 2001 Budget, had instigated a further period of heated concern when it identified a number of serious problems in the supply of people with what was called 'the requisite high quality skills' where skilled workers were seen as 'contributing greatly to the health and wealth of the nation'. The *Review* also triggered a range of initiatives designed to encourage and inspire young people to develop an interest in studying science from their earliest days in education, in some cases from the nursery onward (Roberts, 2002).

3.2.1 The background of the supply and demand debate

Babbage's *Reflections on the Decline of Science in England, and on Some of its Causes* published in 1830 made an impression upon the British science community in the mid-to-late 1800s. Voicing a concern for the decline of science in England it saw the causes firmly rooted in the mismanagement of the Royal Society, and not least in its president Davies Gilbert and the society's council. Also accused was the government for its lack of appreciation and recognition of matters to do with science, and especially so for the individuals engaged in science when compared to the honours, occupations and titles bestowed upon men of science in the Continental countries (Babbage, 1830, Chapter II, Section 1 and 2, Appendix No.1) and echoing Brewster's own grievances [2] against the universities, for its shortcomings in supporting science progress (Orange, 1972).

Whether Babbage and *Reflections* published in 1830 influenced or accelerated the widespread reform of many of the British nation's systems and organisations under the new Reform Act of 1832 is not known. There had been after all a number of strenuous efforts to push for change across a wide range of industrial and political institutions by the British population encouraged and inspired not least by the French revolution in the18th century (Evans, 1994), and long before Babbage made his concerns about the state of British science known to the public. Even within the Royal Society Babbage's 'bitter printed attack' following as it did the public criticisms of the society by Babbage, John Herschel and Brewster, was toned down in the society's library and archives record to little more than having caused a 'great stir and considerable indignation' (Hall, 1992, p. 33-34) and any real reform of the society would be a slow and lengthy process (Hall (1992, p. 33-34), Atkinson (2009, p. 37)).

[2]See Brewster's review in the Quarterly Journal xliii (1830), pp 305-42 Charles Babbage, Reflections of the Decline of Science in England.

Nevertheless, the president Davies Gilbert was personally the target of much of Babbage's criticism for the state of affairs at the Royal Society (Babbage, 1830), and was cast out that same year after three years of the presidency. The importance of Babbage's *Reflections* to this review was its role in the persistent perception that science in Britain had suffered a decline in the early years of the 19th century.

The persistence was remarkable in that for all its apparent low key effect on the Royal Society which was the evident focus of *Reflections,* the report had two important failings in respect of the claim of a science decline. The first was that *Reflections* avoided any definition of what Babbage meant in referring to the 'decline of science'. Was it the quality of science produced, or a shortfall in the absolute or relative numbers practising science? Nor is it possible to draw a conclusion by interrogating the nature of any evidence produced in support of a decline. The second failing of *Reflections* is that it lacked concrete evidence of a science decline on any grounds. Moreover, there is some uncertainty in Babbage's usage of the word 'science', was he in fact referring not to science as we understand the term today but to the study of mathematics? These are the issues that form the basis of this section of the background literature review.

3.2.2 The Edinburgh Review

> *It is certainly a curious problem with respect to national genius whence it arises, that the country in Europe most generally acknowledged to abound in men of strong intellect and sound judgement, should, for the last 70 or 80 years, have been inferior to so many of its neighbours in the cultivation of the science which requires the greatest and most steady exertions of the understanding; and that this relaxation should immediately follow the period when the rarest of all mathematical discoveries had been made in that same country.* Anon, Edinburgh Review (1816, p. 98).

So said *The Edinburgh Review* of 1816. Three years later a similar attack on English science was added to the review of an astronomy paper where the reviewer noted with regret, that little had been contributed by Great Britain towards the natural sciences during the last century, *'where almost every thing that had been done had been by mathematicians on the Continent'.* Again the lack of contribution was attributed by the reviewer to the inferiority in the English nation's knowledge of mathematics. The *Edinburgh Review* added,

> *And, as proof of this inferiority, is adduced the fact, that the more extensive*

> *methods of analytical calculations have not been introduced into England till within these few years; and that the higher parts of the Calculus, as the method of partial differences, the calculus of variations, are even now unknown in the mathematical institutions of this Island.* Anon, Edinburgh Review (1819, p. 392), Foote (1951, p. 192).

As a reform journal of the Whigs (Foote, 1951, p. 192) it is a reasonable assumption that *The Edinburgh Review* would reflect the politics of its owners and its reviewers. In 1803 when the *Review* was first published the Tory government had been in power for twenty consecutive years with a brief break between 1806 and 1807 when the Whigs regained office. Against the backdrop of the French revolution and high food prices in Britain, a number of British reform groups emerged demanding radical change across all aspects of society, not least in the electoral system (Evans (1994, p. 1-5), O'Gorman (1984, p. 393)). Despite a growing public unrest, demonstrations and the anti-establishment press the Tory party would remain in power staunchly against change until the Whigs were finally re-elected in 1830 two years before launching the Reform Act of 1832. Ina Ferriss's unpaginated article describes the *Review's* critical and 'slashing style' of their articles and reviews (2002). To what extent, if at all, the political and the social landscapes at the time will have instigated or exaggerated the Edinburgh reviewers comments about national genius and analytical calculations is matter only for speculation. Notable however is that both the reviews, three years apart, express concern not of science in general but for British mathematics. Cardwell's observation adds a level of reinforcement to *The Edinburgh Review's* comments,

> *'An adherence to Newton's strict geometrical forms and to his fluxional notations meant that new analysis and rational dynamics as developed in France was neither taught nor understood in England. (Not until 1830 was any book on analytical methods published in this country)'* (Cardwell, 1957, p. 15).

3.3 Babbage: *Reflections on the Decline of Science in England*

As the 19th century advanced through the threat of a French invasion, the Napoleonic Wars, and the changes brought about by the British agricultural and industrial revolutions, Charles Babbage made his way through Cambridge where he demonstrated his skill in mathematics, via the Analytical Society which he helped to found with the aim of introducing developments from the continent into Cambridge mathematics, to the Royal

Institution, where he lectured in Astronomy, and so to the Royal Society in 1816. In 1820 he set up the Astronomical Society. In 1830 after spending time in Paris and Italy he published his book *Reflections on the Decline of Science in England, and on Some of its Causes* (ODNB, 2004; Encyclopedia Britannica, 2015).

The title of the book, Babbage reveals, was also the title of a work the chemist Humphry Davy had been engaged in before his death in May 1829 (Orange (1972, p. 15); Babbage (1830, *Preface*)). Babbage acknowledged this in *Reflections* by quoting the chemist's comments in a note appended to his last (completed) work, *Sir H. Davy's Consolations in Travel.* The barb, typical of Babbage's polemic approach by which *Reflections* became known, came when Babbage expressed the hope that in conveying Davy's comments and opinions 'to posterity' it would enable his contemporaries to forget some of the deeds of the President of the Royal Society (Babbage, 1830, *Preface*).

Although Davies Gilbert was the president of the Royal Society at the time *Reflections* was published and along with the Royal Society was subjected to severe criticism from Babbage, it is clear that Babbage also held Davy (who had been superseded in the presidency by Gilbert in 1827), responsible for many of the Societies ills in its effect on British scientific progress. But there were personal grievances too. One was apparent in Davy denying Babbage the Junior Secretaryship to the senior post held by Herschel and making it an *ex officio* position by giving it to the chemist John Children, the Librarian at the British Museum (Hall, 1984, p. 48). Nevertheless, Babbage was quick to make political use of Davy's comments by quoting them in *Reflections* to boost his own argument about the state of science in England. Davy had written,

> *'-But* [*sic*] *we may search in vain the aristocracy now for philosophers'. 'There are very few persons who pursue science with true dignity; it is followed more as connected with objects of profit than those of fame'.* Sir H. Davy's Consolations in Travel (Davy, 1829, p. 158).

Babbage also drew on what he referred to as the 'high authority' of his friend John Herschel to add support and credibility to the charge of decline in science. A few months before *Reflections* was published, Herschel's *Treatise on Sound* appeared in the *Encyclopaedia Metropolitana* (exact date unknown). Appended to the treatise was a melancholy note written by Herschel,

> *In England, whole branches of continental discovery are unstudied and indeed almost unknown by name. It is in vain to conceal the melancholy truth. 'We*

are fast dropping behind. In mathematics we have long since drawn the rein, and given over a hopeless race. In chemistry the case is not much better.' J. Herschel cited in *Reflections*, 1830.

Beyond Davy and Herschel there were others ready to show support for Babbage in his attack on the Royal Society although the polemical approach characteristic of *Reflections* was missing. David Brewster, the Scottish mathematician who had advised and encouraged Babbage in writing *Reflections* (Orange, 1972, p. 152-176), and had boosted its exposure through a substantial article in the pages of the influential *Quarterly Review* (Babbage, 1830, p. 305-342), the Tory publication which was set up in opposition to *The Edinburgh Review*.

Charles Daubeny, the English chemist, also wrote in *The Edinburgh Journal of Science*, largely in support of both Babbage and Herschel's argument that science in England was in a state of decline, took issue only with Brewster's 'overstating' the case by asserting that not a single discovery or invention 'of prominent interest' had been made over the previous fifteen years when Herschel, Babbage, Brewster himself, Prout and Henry, and Gilbert were the obvious exceptions to the remark (Daubeny, 1832, p. 103).

The exposure of *Reflections* drew support from a number of sources. Some like Daubeny agreed in part, while others like Brewster published almost forty pages (under a newly spelt title) of *'Reflexions on the Decline of Science in England, and on Some of its Causes'* the *The Quarterly Review* (1830). Others, Dalton for example, more cautiously agreeing that among Babbage's bitting criticism there was some truth to his concerns and his notion of spurring the Royal Society towards greater efforts to see, among other issues, the society become more productive and representative of the science population (Hall, 1984). Granville argued against Babbage, but nevertheless had his own criticisms of the Royal Society. Like Babbage's list of members printed alongside the number of papers they submitted to the Society's *Philosophical Transactions* (see *Reflections,* Appendix 3), Granville made a series of tables of the demographics of the Society's membership with its contributions and saw that many (as Babbage had) had made little or no contribution towards the Society's reputation (Granville, 1830).

There were also those who rejected out of hand Babbage's argument of decline. One example appeared in the Mechanics Magazine in yet another review of Babbage's *Reflections*. In refusing to recognise any substance in the claim of a decline in science, the anonymous reviewer of the magazine defied any reader to identify a period in history when all the departments of science had enjoyed a richer and more successful history in the practical applications than at the present time. One point the Mechanics Magazine stressed was the dissemination of practical knowledge,

> *We do not believe there is a country in the world in which mathematical knowledge (to which we apprehend Mr Babbage more particularly alludes) is to a certain extent, and with a view to its practical bearings, so widely diffused amongst the middle and lower, that is the industrious classes, as it is in England.* (Mechanics Magazine (Anon), 1831, p. 227-229)

The interest of this review lies in the reviewer's perspective. By the time the first Mechanics Institute was opened in Edinburgh in 1821, the mathematics and principles of Newton's physical laws had time to disseminate to the middle and lower classes, as the reviewer put it, to those best able to make practical use of them. The spread of knowledge however would entail a time lag and it is likely that those same individuals would have been unaware of any hiatus in the development of academic mathematics.

In hindsight, historian Nathan Reingold (1968) holds Babbage's *Reflections* responsible:

> *...in large measure for the assumption that science in Great Britain was in marked decline in the early decades of the (19th) century, an assumption rarely subject to exact analysis although widely held.*

Reingold makes the point that Babbage's writings both published and unpublished are difficult to evaluate historically due their mix of 'good sense and violent personal passion' in combination with Babbage's recording of 'petty incidents and personal experiences'. As such neither approach proved nor disproved that science in the 1800s was in a state of decline either in absolute terms whereby fewer individuals were believed to be practising science in Great Britain (or more specifically in England since Babbage set the boundary in the title of his publication) or in relative terms when compared, for example to the Continental countries (Reingold, 1968).

Nevertheless (Reingold, 1968, p. 60) acknowledges that a similar dilemma still faces the contemporary researcher of his own 'modern' generation despite the greater abundance of statistical data available for analysis. In doing so he tempers his criticism towards Babbage's reliance on qualitative evidence by suggesting it would probably be impossible to write precisely about the state of science 'as a whole in any Western nation in the modern period'.

Reingold adopts a similar leniency about the difficulty of precise writing as did Gerard Moll who also used a qualitative approach to challenge Babbage's alleged decline in science in England (Reingold, 1968, p. 60). Moll, a friend of both Davy and Faraday, was the Dutch Professor of Physics and Director of the Observatory at Utrecht who wrote a critically forensic dissection of Babbage's argument (edited by Faraday and published in the Edinburgh Journal of Science) under the pseudonym of 'A Foreigner'. Moll saw the flaw in the argument from Babbage's initial premise,

> *Before we can follow Mr. Babbage's long list of complaints we must pause a moment in consideration of the assertion that science is declining in England. This harsh sentence, however admits of several interpretations and Mr. Babbage has not informed us which is that which he adopts. Is it his opinion that science is stationary in England, whilst it is making rapid strides on the continent? Or does he wish to give to understand that really a retrograde motion takes place in England; that although upon the whole science is more widely diffused at present in England than formally, there is a lack of scientific men of the first eminence able to be put upon a par with the most renowned foreigners?* (Moll & Faraday, 1831, writing as 'A Foreigner').

One notable example of Moll's approach is in considering Davy's remark about the aristocracy's dearth of philosophers, which Babbage made use of in supporting his argument for decline. Moll accepts the broad truth in Davy's lament but suggests that unless the same is shown for other classes this offered no support to Babbage's claim (Moll & Faraday, 1831). Cardwell added to Moll's reasoning by observing from his 1950s perspective, that the dominance of an aristocratic society which prevailed at the time of Babbage's and Moll's publications under the longstanding Tory government, and where a literary education was considered as an upper class education, 'was not and never had been one which was favourable for the advance of science' (Cardwell, 1957, p. 8-9).

That the aristocracy tended not to favour the study of science was a point Babbage and Granville [3] (who drew upon Babbage's figures at times) were both well aware of in their separate criticisms of the demographics of the Royal Society membership where

[3] A.B. Granville was a physician and a contemporary of Babbage and Fellow of the Royal Society. Although he criticised *Reflections*, he also produced his own critique of the Royal Society, in his publication *Science without a Head* (1830). In it he employed a statistical approach to the question of science progress by tabulating the societys membership into social and professional categories such as the Naval Officers, the Army Officers, Clergymen, Lawyers and Medical Doctors and so on, to establish the level of contributions each group had made towards improving the natural knowledge of the society. In considering his table of

traditionally a majority of the members and council were elected not on their contribution to science but rather on their social standing leaving the Society at times as no more than a gentlemen's club (Babbage, 1830; Granville, 1830, p. 93, p. 111).

Babbage's claim of 'decline' however is clearly problematic on two important issues. Firstly, as Moll had asked, what did Babbage mean by science decline? Although *Reflections* runs to six chapters and three appendices, it is not clear from his writing, whether he was referring to a quantitative decline in the numbers practising science, or whether it was the quality of science produced that he perceived to be declining, or indeed both, and whether Babbage saw any decline in absolute terms or relative to some unit of comparison in Great Britain or abroad. The second issue is the lack of evidence to support any of the above options. In this, Babbage's introductory remarks tell something of his own confusion in the matter,

> *The causes which have produced, and some of the effects which have resulted from, the present state of science in England, are so mixed, that it is difficult to distinguish accurately between them. I shall therefore, in this volume, not attempt any minute discrimination, but rather present the result of my reflections on the concomitant circumstances which have attended the decay, and at the conclusion of it, shall examine some of the suggestions which have been offered for the advancement of British science* (Babbage, 1830).

One area of confusion that may have become clearer after explanations from Hyman (1996) and Hall (1984). Where Babbage speaks of science, we are reminded that the definition of 'science' in Babbage's time is likely to differ from the 21st Century understanding held today. Not until around the 1830's, possibly following *Reflections*, did the word science come to adopt similar meaning to the wide range assumed by the seventeenth-century term 'natural knowledge' (Hall, 1984), while the name 'scientist' was unknown until coined by William Whewell in 1840 (Williams, 1961). If there is an absence of evidence for a general decline in the number of individuals practising 'science' in *Reflections,* was Babbage really lamenting the quality of British mathematics and its effects on the physical sciences when he spoke of 'decline'? His involvement in the Analytical Society in Cambridge for the cultivation of mathematics (Dubbey, 1978) and the attempts to bring the analytical mathematics of the Continent to England suggests that this may have been

the aristocratic membership he noted that of sixty three Temporal Lords, not one was recorded as having made any contribution (page 35).

the case (Becher, 1980; Enros, 1983). Babbage's following statement also included in his introductory remarks in *Reflections* adds some weight to this notion,

> *To trace the gradual decline of mathematical and with it of the highest departments of physical science, from the days of Newton to the present, must be left to the historian* (Babbage, 1830).

My argument therefore is that Babbage's 'decline in science' referred not to a general lack of interest in science as the term 'science' is largely understood today, nor to a concern for a future supply of scientists via any university graduate pathway (as the type of problems that might be wrestled with today) but were more likely to be the quality of British mathematics and to those practices and endeavours that depended upon mathematical analysis. Dubbey (1978, p. 10) offers the following from a historical hindsight. Again Dubbey's opinion is clearly a subjective view, but it does have the virtue of naming names,

> *The period between 1800 and 1830 was not a brilliant one for British mathematics by any standards. The decline which had begun early in the eighteenth century was continued. Very little original work of any great merit was accomplished and it is difficult to name a single British mathematician of this time whose work is still remembered. By contrast, these were the years of great advance on the Continent. Gauss was producing his best work, while in France, Lagrange, Laplace, Legendre, Cauchy, Fourier, Poisson, Monge and Poncelet to name a few prominent names, were all active. Who were the contemporary British mathematicians who compared with these? The same question was asked in 1830 by A.B.Granville, but he had a ready answer: 'Ivory, Woodhouse, Morgan, Herschel, Babbage, Later, Christie, Barlow, Gompertz, Whewell, Allman, Peacock, Lubbock, Bromhead and Groombridge'. This was a list that evidently satisfied its compiler, but bears no comparison with the Continental mathematicians* (Dubbey, 1978, p. 10).

This explanation however suggested a new issue of controversy in the question of a science decline in England in the 19th century in the notion that the quality of British mathematicians since Newton's time was not after all necessarily viewed as the problem. Rather it was suggested that the mathematical talent since Newton's time had been misdirected into more 'trivial pursuits'. Dubbey, for example, refers to an anonymous writer in the Edinburgh Review sharing a concern over the alleged dearth of mathematicians in

England, not, as the writer asserted, on account of a lack of talent, but on mathematicians having been diverted into pursuits such as 'the Ladies Diary' where 'many curious problems, not of the highest order, but still having a considerable degree of difficulty' were proposed and answered by a 'great number of ingenious men' (Dubbey, 1978, p. 14). The English mathematician, physicist and theologian, Reverend Baden Powell, a century and more earlier had come independently to a similar conclusion,

> *It is not twenty years since we have begun to perceive that we were far behind all the rest of Europe in these sciences; not from a want of abundance of first-rate talent, but from a misapplication of that talent to unworthy objects, at least to such as were not of a nature calculated to lead to any great advance in the state of knowledge* (Powell, 1834, p. 367-8).

Mathematics over this period was according to historian Dubbey, little more than a 'sharpening the wits', referring to the Clarendon Report [4] of 1864 which looked back at the first thirty years of the 19th century as a period when the teaching of mathematics in public schools had been almost non-existent (Dubbey, 1978, p. 14). Nor was misdirection or misapplication of science talent the only rationale called up to explain Babbage's so-called science decline. Next to be called into question was the quality of mathematical teaching at Cambridge over the first thirty years of the 19th century, which in Dubbey's opinion,

> *'Served no useful purpose when measured against the French system which encouraged extensive mathematical study as a necessary preliminary for engineering applications with great success in practice and theory'* (Dubbey, 1978, p. 19).

While Babbage failed to define his perception of a decline in science, or to produce convincing evidence of its authenticity, or indeed to outline any criteria against which an independent judgement about any decline in science might be attempted, Jarausch (2002),

[4] Unlike the United States, which by the 1830s of Babbage's Reflections, was already in the process of establishing a common public (state) school system for all citizens, England, thirty years or so later was still immersed, in terms of education, within the social class system. It followed then that the Clarendon Report published in 1864, was commissioned to focus upon the nine great public schools (which included Eton and Rugby). The Taunton Report of 1868, and the Endowed Schools act of 1869 dealt with separate institutions for the middle classes, while the Newcastle report of 1861and the Elementary Education Act of 1870 provided educational facilities for the masses (Gillard, D., 2011, Ch. 3)

examines table of career statistics of Oxbridge men over the early-to-late 19th Century (see Table 3.1)

Table 3.1: Careers of Oxbridge Men in the 19th Century

	Year of admission									
	1818/19		1848/49		1878/79		1897/98		Total	
Career	N	%	N	%	N	%	N	%	N	%
(1) Landed	123	15.5	105	11.8	145	9.8	82	4.8	455	9.3
(2) Church	410	51.7	438	49.2	453	30.6	298	17.3	1599	32.7
(3) Professions	56	7.1	71	8.0	279	20.0	357	20.7	763	15.6
(4) Teaching	16	2.0	65	7.3	167	11.3	275	16.0	523	10.7
(5) Government	18	2.3	45	5.1	87	5.9	283	16.4	433	8.9
(6) Business	6	0.8	13	1.5	54	3.6	153	7.8	208	4.3
(7) Unknown	164	20.7	154	16.3	297	20.0	293	17.0	908	18.6
Total	793	16.2	891	18.2	1482	30.3	1723	35.2	4889	

Source: Figures are recomputed from M.Curthoys, 'Oxford and the Nation: The Careers of Oxford Men, 1800-1914', in *History of Oxford*, VI , Table 1 and 2. Cambridge figures are in Ringer, *Education and Society*, 236. Key: *Landed* - Landed and independent means; *Church* - clergy and other religious work; *Teaching* - higher education, school teaching; *Government* - armed forces, government service; *Business* - commerce, finance, industry, engineering; *Unknown* - died young, unknown. Source: Jarausch (2002). The term *Professional* is not explained in this table, but it is likely it refers to those practising law or medicine (see Ringer (1979, p. 236) and Jarausch (2002) below).

Table 3.1 presents a view of a steady and consistent increase in the absolute numbers of graduates taking up a range of employments over the period 1818/19-1897/98 (Jarausch, 2002; Ringer, 1979), in all occupations bar the first, second and last categories listed. That is, the Landed, the Church and Unknown. These data as explained by Jarausch, indicate the results of interrelated developments (2002). Firstly that the occupation of the landed proprietor declined in relative terms since the number of estates was seen as unlikely to be subjected to any significant change. Secondly, that the Church became disadvantaged by a growing secularism and the development of teaching as a separate occupation. Thirdly in those categories that showed growth, the law and medicine professions shared considerable rise in numbers until the late 1800s when growth plateaued in relative terms at around 20 percent. A situation Jarausch (2002) suggests was due to increased competition among practitioners.

A further development was in the expansion of tertiary and secondary education. This encouraged greater numbers of university men to opt either for an academic life or to enter into the teaching profession. Expanding too was the establishment of the civil service into local, national, and state bureaucracies which attracted a growing number graduates both in absolute and relative terms. The final development considered by Jarausch as the century drew to a close, was a slow but steady growing acceptance of the educated individual to enter commerce or industry which began to forge the link between education and practice (Jarausch, 2002; Ringer, 1979).

These data do not establish evidence for Babbage's decline of science (or mathematics for that matter), but they do indicate an increase in most cases in both absolute and relative terms (with the exceptions referred to in Table 3.1) of students at Oxford and Cambridge completing their studies and entering employment. If there was a decline in science in the mid-19th century it appears to be against a general trend of growth in Oxbridge student numbers and against a rising trend in population growth in England (Source: Census ONS) However we might also note in an era when statistical data are scarce, Cardwell (1957, p. 55) includes a brief data series (lacking a cited source) of the mid 1800s (see Table 3.2) which shows a falling off in the numbers of artisans and mechanics attending two of the Mechanical Institutes. Over the period 1839 -1852 for example, the Leeds Institute shows a reducing number over thirteen years in the numbers attending the mathematics classes. Over the same period a reduction over time was reported in those attending the Leeds Institute chemistry classes. Somewhat paradoxically over the same period Cardwell reports membership in the Leeds Institute had increased tenfold although he offered no comparison data. Cardwell's 1957, p.55 figures given for Manchester as the second of the two examples show a reduction in the numbers of those attending physical science classes over a similar timespan albeit over a slightly earlier time period (Table 3.2).

Whatever the reason or reasons, Cardwell offers a range of possibilities for the fall-back in numbers. Among them were included a defective educational system which failed to overcome the illiteracy of the intended artisans and mechanics, the inclusion of abstract subjects such as astronomy and atomic physics classes while the more practical classes on economics and politics were excluded. Further considered was a lack of incentives such as certificates and diploma on completion coupled with a lack of recognition from employers as to the value of the classes. Finally, what Coates (1841), as Secretary of the Society for the Diffusion of Knowledge, called the invasion of the Institutes by the middle classes, who were interested in science but not necessarily active, was thought to have resulted in a form of class snobbery which added to other factors was thought to drive the workers away (Cardwell, 1957, p. 55). On the other hand and more prosaically, it may have been on occasions no more than the difficulty in engaging a permanent lecturer, or a natural progression towards the wider utility of the Mechanics Institutes as a public library, a circumstance which affected a number of the Institutes. Both alternatives were offered in further explanation of the fall-back in class attendance by Cardwell (1957, p. 56-57).

Table 3.2: The decline recorded in the numbers attending science classes in two Mechanics Institutes: Leeds and Manchester during the Mid-19th Century

Institution	Dates	Subject	Attendance Numbers
Leeds	1839-1852	Mathematics	36-24
	1839-1852	Chemistry	19-13
Manchester	1835-1849	Physical Sciences	235-88

Data Source: Cardwell, 1957:55

Cardwell produces in Table 3.2 figures from two of the Mechanics Institutes indicating a reduction over time in the number of individuals attending classes.

As seen earlier Cardwell offers a range of possible explanations to account for the reduction in numbers. Since the numbers reduce over time however, we might infer that a lack of interest (for whatever reason or reasons) in those for whom the classes were designed, were instrumental in bringing the classes to an end.

Table 3.2 therefore adds a further layer of complexity to the difficulty of substantiating Babbage's claim for a decline of science in England in the 1800s, and raises a point of sympathetic comprehension for Babbage's early pronouncement in *Reflections*,

> *The causes which have produced, and some of the effects which have resulted from, the present state of science in England are so mixed, that it is difficult to distinguish accurately between them.* Charles Babbage, 1830.

3.4 The Dainton Report and the 'swing away' from science

Over time the argument for a perceived 'science decline' evolved from the nebulous state of science in England in the 1800s, to a newly defined alarm for science in the 1960s, the so-called ‘swing away’ from science by young people in the United Kingdom. It gave rise to a number of papers and reports about the supply pipeline of science graduates. Seminal among them was the *‘Enquiry into the Flow of Candidates in Science and Technology into Higher Education’* where the term ‘swing away’ came into popular usage. Established by the *Council for Scientific Policy* the enquiry, chaired by Frederick Dainton, was published in 1968 and became popularly known as the *Dainton Report*. The expression ‘swing away’ caught attention in encapsulating a concern for the future of science and science education, and triggered a number of lively responses (Duckworth & Entwhistle, 1974; Duckworth, 1974; Newall, 1969; Butcher, 1969; McPherson, 1969).

Dainton, was himself a chemist and the Vice Chancellor of the University of Nottingham. He was also a Fellow of the Royal Society as Babbage had been, and he chaired a committee for the *‘Enquiry’* made up of six individuals from a variety of educational backgrounds where a majority were from the Department of Education and Science (Dainton, 1968).

Dainton’s brief was to examine the evidence for an alleged swing away from science in the sixth forms of secondary schools at a time when the universities had expanded their science and technology departments. In 1966, a year after the enquiry had been commissioned, an interim report by the committee was positive about the ‘buoyant growth of science and mathematics in schools up to the General Certificate of Education in science’. Two years later the opinion had been reversed. Dainton reported,

> *‘Now that we have carried out a more substantive analysis based on the choice and performance of the individuals we find that the qualified optimism of our earlier report has not been sustained. We find that science and mathematics are, relatively, losing ground in the sixth form. Since 1960 the proportion of school leavers specialising in them has declined in relation to other subjects of study and specialisation’* (Dainton, 1968).

Unlike Babbage, the *Dainton report* produced a quantity of statistical data in support of a concern about a ‘swing away’ from science wherein a number of plots and tables are available. Table 3.3 and Figure 3.2 help to illustrate their findings.

Table 3.3 shows a period of growth over 1962 to 1965 in the number of pupils in the Science Group their first year of A levels followed by a stabilisation and a gentle decline in the numbers over the following two years until 1967. Ignoring Dainton’s projection figures, it is possible to offer some explanation of the decline. By consulting the ‘Pupils at School’ chart (Figure 3.2) we see that while the relative number of pupils in school at

Table 3.3

	At January -Thousands					
	1962	1963	1964	1965	1966	1967
Science group	32.7	35.9	40.1	38.4	37.5	36.5
Non-science group	38.3	45.3	54.5	55.9	58.3	61.3
Mixed group	7.8	9.4	12.4	14.3	15.3	18.4
Total	78.8	90.6	107.0	108.6	111.0	116.2

age 16 in the chart shows a continuing upward trend, the absolute figures of 16 year old Pupils at School level out in 1965 and follow a slight downward curve that mirrors Table 3.3 and continues downward from 1966 until 1968 before an upward turn and a period of sustained growth over the next decade.

Although the evident correlation between Table 3.3 and Figure 3.2 does offer an explanation for a decline in the number of pupils in the Science Group, it is not sufficiently robust to prove the case. Nor does it help to explain the question of a relative decline in the Science Group numbers compared to the Non-Science group and to the Mixed Group over the years in question. Also to be explained is the difference in the growth patterns of the Science Group, which show a greater annual increment from 1962 to 1965 than the rate of subsequent decline. Although again a mirroring effect between the growth figures until 1965 in Table 3.3 and the number of pupils at school shown in Figure 3.2 is noted.

Despite Dainton's statistical resources there were challenges to the assertion of a 'swing away' from science by young people. Among the first challengers of the argument were the science teachers who expressed their views at the Conference of the Association for Science Education. Newall (1969) whose research interest centred upon attitudes to science and to scientists, attributed the swing, if there was indeed a swing, mainly to the 'complexity of the subject matter of science and to the sheer hard work' needed in its study. A similar decline in the number of pupils studying foreign languages had also been seen suggesting the subject was also perceived by pupils as difficult. There was some evidence offered in support of the suggestion that difficulty was a factor in the 'swing away' when a link between the so-called swing and the mean academic aptitude scores of pupils taking both foreign language and sciences subjects was noted (Duckworth & Entwhistle, 1974). However a cross-sectional survey of student attitudes by the University of Lancaster found that the question of difficulty did not necessarily indicate a lack of interest in the subject matter. Rather this was seen as having implications for teaching (Duckworth & Entwhistle, 1974).

Butcher (1969) also from the University of Lancaster, had investigated the evidence for the 'swing' in a Scottish follow-up study. He agreed with Newell's doubts about the extent of the phenomenon, suggesting any decline was relative rather than absolute. He pointed out that the facilities for science had expanded more slowly than other facilities and that this was echoed at the sixth form colleges. The implication being that the limited resources affected either the level of science interest among students or restricted the opportunity to practice science. Moreover, according to Butcher's understanding of the follow-up study:

> *'When one turns to the causes for the swing, to the extrapolation of the trend, to proposed remedies (or indeed whether any remedy is required), no such aggrement exists'* (Butcher, 1969).

While Butcher was investigating the Scottish follow-up study, an unnamed group from Lancaster University was questioning the interpretation of the official statistical evidence presented by the Dainton Committee and concluded that it was heavily dependent on assumptions about pupil attitudes towards science. When the group re-examined the circumstances of the swing it was thought any confusion could be attributed to the question of defining the way the swing was measured. For example methods might include measuring the proportion of students entering the science facilities of a university (Butcher, 1969). This of course would be dependent upon a variety of factors, including the number of places made available to students in any year. A more straightforward approach was suggested to measure the number of A level passes and compare the result with the total number of passes across all subjects. A further difficulty was pointed out by Duckworth and Entwhisle in determining the popularity of courses among students, to make a comparison year by year one must be sure that the comparison is between identical situations. Duckworth & Entwhistle (1974) argued for example, it should be asked,

> *'Was the six form of 1970 equivalent in all respects to the sixth form of 1963, and if not were the differences likely in themselves to have exacerbated the swing?'*

One area of difference within the classroom was the widening choice of subjects becoming available to students one of which saw the mixed art-science combination become increasingly accommodated within the school timetable. Other changes in the sixth form make-up between 1965 and 1970 was an eight percent increase in the number of boys compared to thirty per cent more girls (DES, 1970, Table 25), almost four times greater. If, as McPherson from the Centre for Educational Sociology at the University of Edinburgh suggested, girls were less likely to opt for science this would be reflected in the overall figures as a swing from science (McPherson, 1969).

McPherson also voiced doubts about the validity of Dainton's 'swing away' when a study by Phillips (1969) which covered the period 1955 to 1964 and examined the relationship between the school curriculum, university entrance requirements and subject choice over a wider geographical area (which included The Netherlands, Germany, France, England and Wales) concluded:

> *'There has been no swing away from science common to all countries. Each has reacted differently to different educational influences'* (Phillips, 1969).

The *Dainton Report* highlights two further issues linked with the Duckworth and Entwhisle, the McPherson and the Phillips argument that had been recognised by Dainton as likely to affect the supply of science graduates in the late 1960s in England. First was the reduction in the number of students in the secondary school 'science streams' which prepared students for university entrance. This according to the *Dainton Report*, had decreased from 42 per cent of the total in 1962 (the total is taken as the total number of students eligible by age and ability to be included in the science stream), reducing to 31 percent by 1967 (Walsh, 1968).

Secondly is the demographic trends of the time. For example after the 1950s UK 'baby boom' there was a decisive downward trend in the birth rate followed in the mid-1970s by a small and brief upturn according to World Bank figures for the period. A trend mirrored to a lesser and greater extent by the US and by Germany respectively. As Walsh observed (1968) the smaller birth generation would effectively reduce the numbers feeding into higher education (Figure 3.1).

The question of demographics in terms of the potential proportion of students likely to continue their studies in the sciences and in engineering presents a core variable with strong implications for the future supply of science graduates. We can see from Figure 3.2 that seventeen to eighteen year old students feeding into today's HE were drawn from a relatively low birth rate generation. This naturally limits the pool of young people available for higher education.

This is a point examined by Dorling in considering the global effects of population change on higher education (Dorling cited in The Economist, July 2014, and in the Times

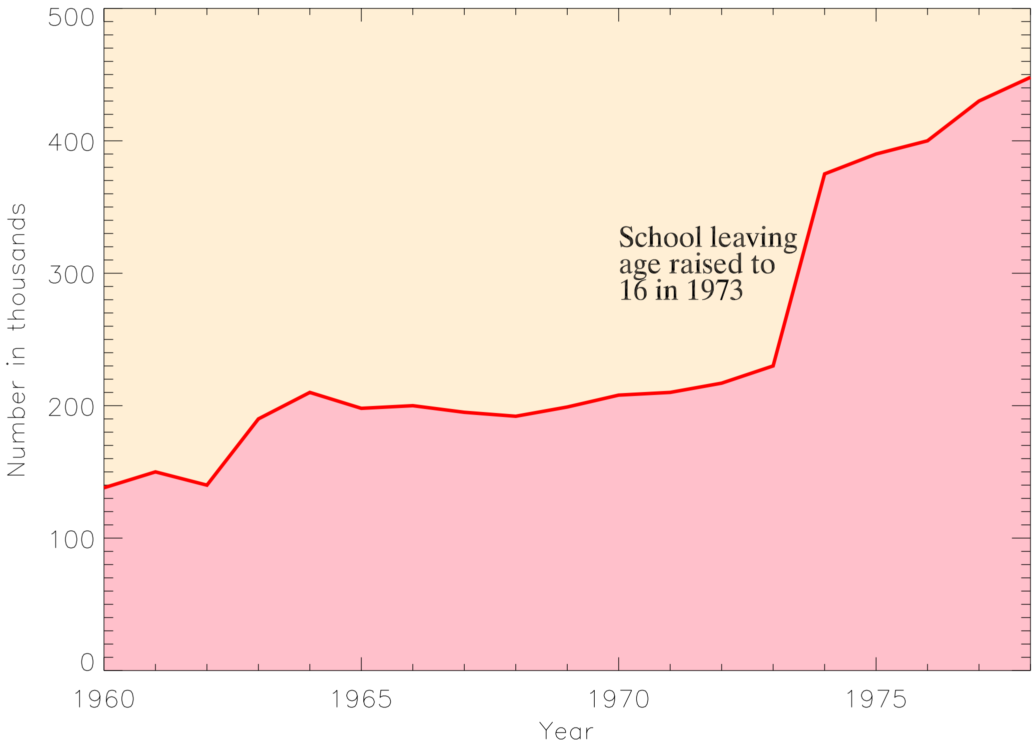


Figure 3.1: Pupils in Schools at age 16. Source: House of Commons Parliamentary Papers Online

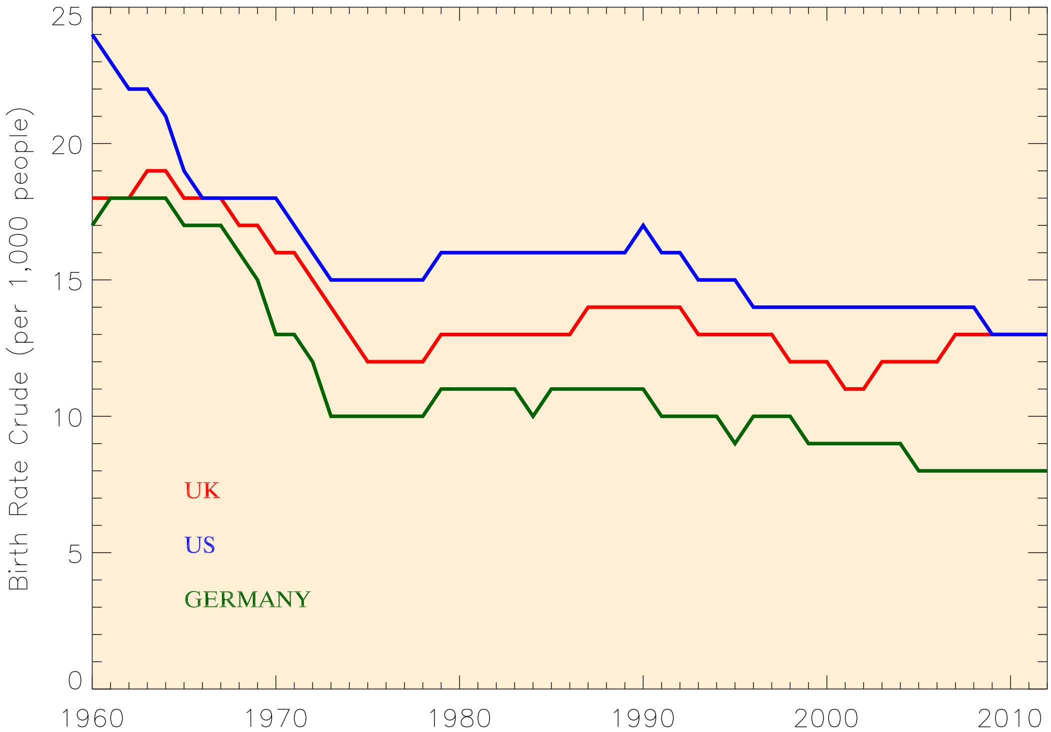


Figure 3.2: Birth Rates, crude (per 1,000 people), UK, US and Germany up to 2010. Source: World Bank accessed 2015

Higher Education (THE), July 2013). As a human geographer he reasoned among other possible explanations that the 'baby peak' of the 2000s may be correlated with the dramatic increase in the number of young people going to university in the 1990s and delaying childbirth until after graduation. Meanwhile, Figure 3.2 shows a levelling of the birth rates from around the mid 1970s after a sharp drop from a peak in the early 1960s. Where birth rate demographics play as an important part in the availability of young people for HE, Dorling views this as represented over time in the greater or lesser availability of young people as the population changes (Dorling, 2013, 2014).

From the Nineteenth Century's 'decline of science' and Dainton's 'swing away from science' seen in the 1960s and 1970s, the *Roberts Review* (see the following chapter) was commissioned at the time of the 2001 Budget. The review (*Set for Success*) was published in 2002 as part of the Government's strategy to improve the nation's productivity and innovation as key factors for the UK's future survival and growth against global competition. There is a notable difference however in the narratives employed in the Dainton report and in *Roberts Review* when discussing the effect of any decline in the numbers of young people choosing to study the sciences.

Whereas the Dainton report showed a clear appreciation of the wider implications of a reducing 'stock' of scientific and technical manpower in addressing the government's concern, his narrative portrays an ideology for the role of science education that places equal weight to both the interests of the country and its citizens. Dainton concludes,

> *Scientific interests in young children are a natural expression of their curiosity about the world; they have a right to the opportunity to nurture such interest. Whatever the subsequent careers of boys and girls now at school may eventually be, they should for their own sake know and appreciate something of the aims, techniques and achievements of science and technology* (Dainton, 1968, p. 2).

Dainton's claim for a 'swing away' from science remains as did Babbage's 'decline in science' in some doubt about its existence. On this occasion not in the lack of statistical evidence as it was in Babbage's time, but through the volume of statistical data and the perspectives, complexity and plausibility of its arguments. It may be however as Reingold suggested earlier in the chapter when discussing the approaches of Babbage and Moll, an almost impossible task to write precisely about the state of science 'as a whole in any Western nation in the modern period' (Reingold, 1968). Once again the state of science in the UK had been held up for examination without a clear consensus for the outcome leaving the argument of a decline in science unresolved.

Chapter 4

Roberts Review: *SET for Success* and summary of his thirty-seven recommendations

4.1 Introduction

The Roberts Review, *SET for Success* was brought into existence at a time when the election of the New Labour Government in 1997 placed enormous importance upon education, particularly in the higher education sector. It was a time of the emerging global economies such as the BRIC countries (Brazil, Russia, India and China) and the implications in terms of the competitiveness for the UK and the Western nations began to be seen, certainly as one of opportunity, but also one of uncertainty (Archibugi & Pietrobelli 2003 p. 863; World Trade Organisation (WTO) and International Labour Organisation (ILO),(WTO, ILO, 2011, p. 8). It was coupled with an understanding of the importance of technical and scientific creativity and innovation as the way forward for UK industry and business in an increasingly global market, and amid an overriding concern that the UK workforce and its graduates, especially its science and engineering graduates, may not be fit for purpose, present and future (Roberts, 2002, p. 1)

The *Review* itself was commissioned on the back of the New Labour party's 2001 Budget and published in 2002 as one of the first of a series of reports (see also for example, *Choosing Science at 16: The Influence of Science Teachers and Careers Advisors*, *Science and Innovation Investment Framework 2004-2014; Next Steps, 2006; A Review of the Governments Science and Innovation Policies,* Lord Sainsbury in 2007; *Report of the STEM Review, DEL, DE, 2009; Maths and Science Education: the Supply of High Achievers at A Level*, produced as part of the Government's strategy to improve the performance of UK business at a time of a growing awareness of the extent of the challenges of global competition (O'Neill, 2001; EC, 2000, European Commission).

Roberts inquiry however showed none of Babbage's fire or forcefulness, nor of Dainton's idealism for the role of science education. Instead concern for an anticipated shortfall in the future supply of scientists and engineers was presented as an unemotional and practical acceptance of a disconnect between:

> *'...this strengthening demand for graduates (particularly in highly numerate subjects) on the one hand, and the declining numbers of mathematics, engineering and physical science graduates on the other, is starting to result in skills shortages'.* Source : Roberts (2002, p. 3).

The rhetoric of *SET For Success* was couched almost exclusively within the framework of business and the economy (Cole, Hatcher Hirtt and Rikowski, 1999) and although this approach attracted a degree of criticism in the responses of the Cole, Rikowski, Hatcher and Hirtt, and others (1999), the rhetoric and focus of the *Review* cannot be understood independently of the economic concerns for the competitiveness of the UK in an increasingly globalised market. As such the *Review's* specific function was to address the question of a future supply of UK scientists and engineers by examining the educational supply pipeline against governmental concern that the nation's economy would be constrained by any shortfall in its skilled workforce. Roberts made clear the focus and implications of the government's concern:

> *'Continuous innovation is the key to the future survival and growth of businesses operating in what are an increasingly competitive global markets. Although not all innovation is based upon scientific R&D, the need for human ingenuity in making discoveries and creating new products, services or process means that the success of R&D is critically dependent upon the availability and talent of scientists and engineers'.* Source : Roberts (2002, p. 1)

The Review's approach therefore was focused those subjects which traditionally involved R&D activity (Roberts, 2002, p. 1) They included:

- biological sciences,
- physical sciences,
- engineering,
- mathematics

- computer science [1]

In 2002 when Roberts was voicing his concern about the levels of UK spending on its R&D in comparison to the US and Japan, China had already begun what Freeman and Huang called its ‘great leap forward’ across a number of indicators which included enrolment in tertiary education and R&D spending, (see Table 4.1 and Figure 4.1) which contributed and defined the country’s progress in science and engineering over the decades of the 1990s and 2000s, (Freeman & Huang, 2015, p. 30). Although the Review may have been commissioned under conditions of concern for the UK’s economic growth, a point Roberts himself acknowledged, he had it appeared, overlooked China’s economic growth potential in the wider globalisation of nations.

Table 4.1: Millions of Enrolments and the Shares of Enrolments in Tertiary Education by Area of the World 1970-2010

Area	1970	1990	2010
World	29.4	67.6	177.6
Developing	16.0(54%)	41.0(61%)	136.5(76%)
China	<0.1(0%)	3.8(6%)	30(17%)
India	2.5(9%)	5(7%)	20.7(12%)
US	8.5(29%)	13.7(20%)	20.4(11%)
Other Adv	4.9(17%)	12.9(19%)	23.7(13%)

Source: Cited in Freeman & Huang (2015, p. 22)
Data source is UNESCO, Institute for Statistics, online files 2010. Tables 15, 20A.

Table 4.1 was likely to have increased concern about the UK’s own graduate production numbers, with particular implications for the domestic supply of scientists and engineers in addition to a more general uncertainty about the implications of the emerging economies for the UK.

[1] Roberts notes that in concentrating on these five particular disciplines it is recognised that other areas, arts and humanities, and consumer-led demand, for example, are also important in terms of creativity and innovation (2002, p. 1).

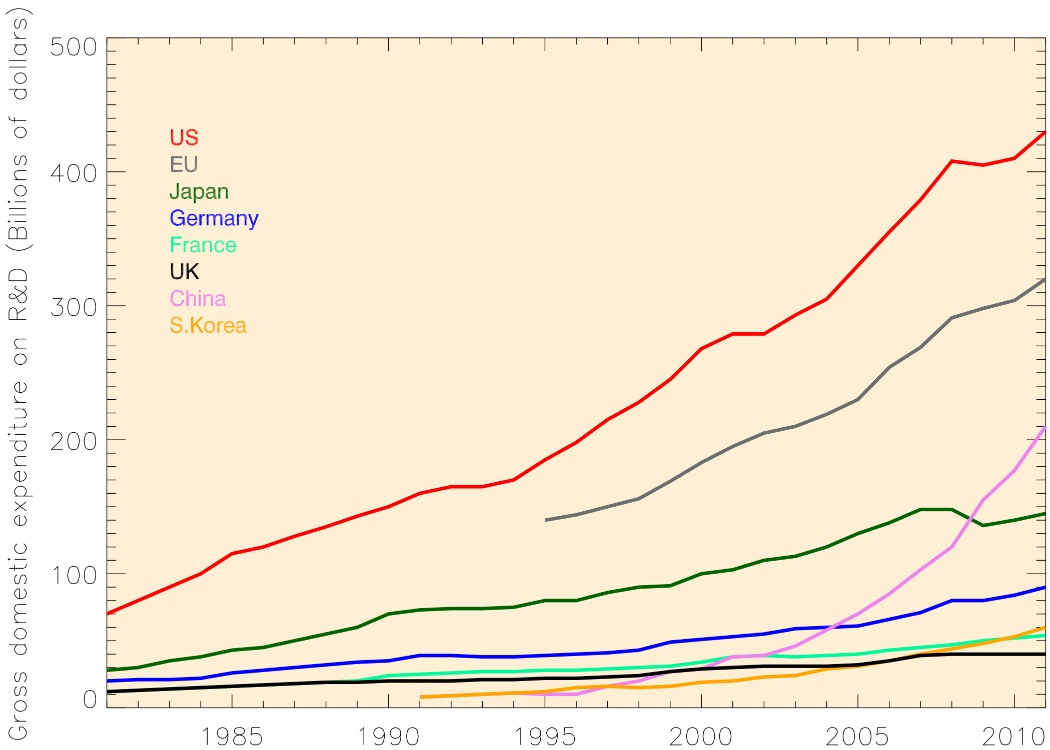


Figure 4.1: Gross Expenditure on R&D, by Country and Area, 1981-2011.

Cited in Freeman and Huang, 2015:30: Source: Figure taken from Science and Engineering Indicator (2014). Data source: OECD Main Science and Technology Indicators (2013/1). PPP (Purchasing Power Parity). Data is not available for all countries for all years.

Figure 4.1 is colour coded to make the identification of each country or areas R&D progress easier to follow. If the graph is viewed in black and white, the curves can be identified by matching the order in which they appear in the key. In terms of global competitiveness China's rapid economic growth in the steep upward curve from the late 1990s until the 2000s; a potential that appeared to have been overlooked by the *Review* who at the time saw UK's market competitors in science and engineering R&D innovation primarily in the US and Japan.

4.2 Roberts portrayal of labour-market supply and demand of scientists and engineers

Roberts begins with the justification and purpose of the *Review*, first in the challenge of attracting the brightest and most creative minds to become what he termed generically as 'scientists and engineers', and second in establishing whether there were likely to be a sufficiency of scientists and engineers with the required skills to exploit the Government's increased investment in scientific research. This is how Roberts laid out his argument to the (then) Chancellor of the Exchequer Gordon Brown, in the *Review's* Foreword:

> *The Review has identified a number of serious problems in the supply of people with the requisite high quality skills. They are not equally spread across science and engineering; indeed, the aggregate number of students with broadly scientific and technical degrees has risen in the last decade. However, there have been significant falls in the numbers taking physics, mathematics, chemistry and engineering qualifications. These downward trends combined with deficiencies in transferable skills among graduates, could undermine the Government's attempts to improve the UK's productivity and competitiveness. Furthermore, these discipline related problems will have negative implications for research in key areas such as the biological and medial sciences, which are increasingly reliant on people who are highly numerate and who have a background in physical sciences. Source*: Roberts (2002, Foreword iii).

Roberts raised several points of contention in his letter to the Chancellor in the *Review* of 2002 where conflicting or insufficient evidence appeared to have been presented to support his claim for a shortfall in skilled science and engineering graduates against labour market demand.

The first relates to what Roberts referred to in 2002 as 'serious problems' both in the number and in the quality of graduates in the sciences and engineering. While he conceded there was growth in those graduating with *'broadly scientific and technical degrees'*, his wording to the Chancellor was strangely reticent in mentioning that the majority of science and engineering graduates among the UK's supply were primarily in the biological sciences, and in engineering and technology, and computer science, according to Roberts own evidence as presented in Figure 4.2

Since these specific discipline areas had been singled out in the *Review's Foreword itself* (2002, p. ii), and listed as key disciplines for R&D activity in the *Executive Summary* (2002,

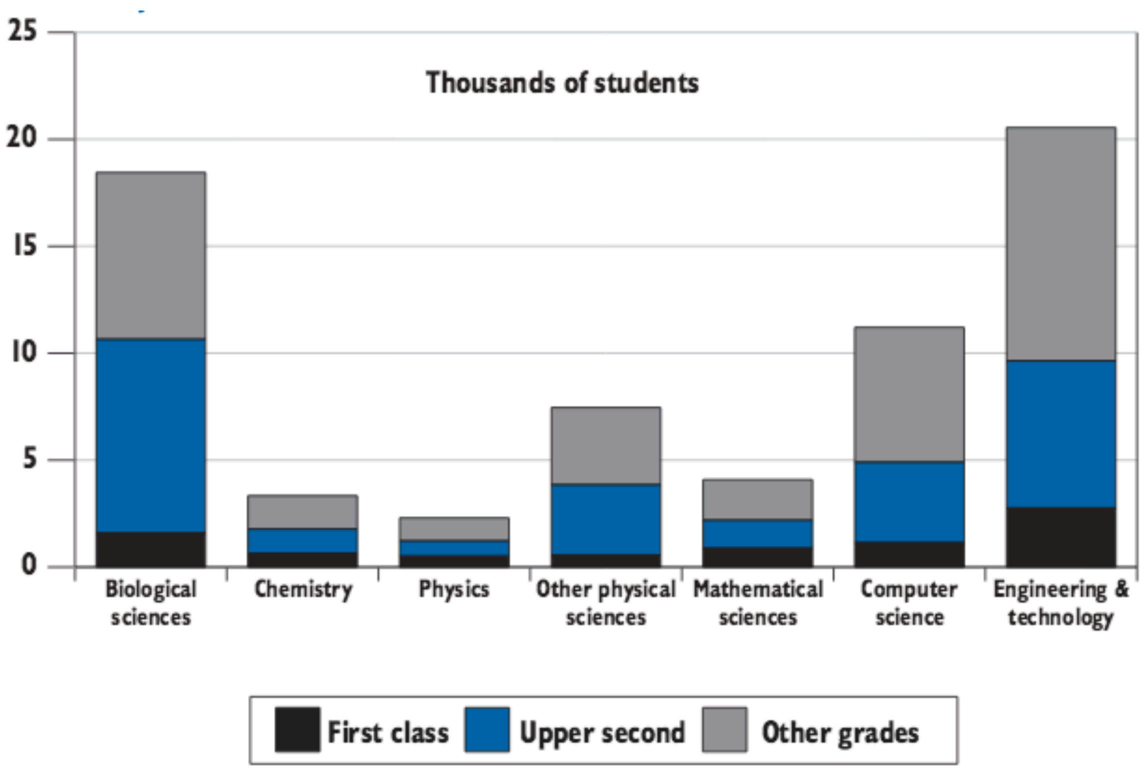


Figure 4.2: Students graduating with a first degree in STEM subjects 2000.
Cited in Roberts, (2002, p. 22): Source attributed to HESA

p. 1) it would have been expected that these areas of growth would have been specifically noted as positive indicators by Roberts for the supply of graduates and postgraduates in subject areas of R&D importance for the nation's economy. Instead they appear to have been downplayed by Roberts who instead lamented the relatively lower uptake in the physical sciences and mathematics (Roberts, 2002, Foreword iii).

But even here, in Roberts concern for the number of physical sciences and mathematics graduates, there was some question as to his appreciation of the roles and functions of physics and mathematical disciplines. Not, it appeared for any implications low graduate numbers might have held for physics and mathematics researchers and their employers, and perhaps for the financial services which are known to attract graduates with mathematics and physics degrees, (a point Roberts himself makes in the *Review*, 2002, p. 25), but instead, if Roberts is to be understood, for the support to the biomedical and medical sciences. To re-quote Roberts on this point, *'Furthermore these discipline-related problems will have negative implications for research in key areas such as the biological and medical sciences which are increasingly reliant on people who are highly numerate and who have a background in physical sciences'* (2002, Foreword iii).

This was apparently no error of editing. Roberts reiterated this particular point later in the *Review* when again discussing the implications of a serious future shortage of engineering and the physical sciences:

> *'Given the increasing importance of interdisciplinary and multidisciplinary research, these trends in engineering and the physical sciences could also affect research in other areas, for example, the biological sciences'* (Roberts, 2002, p. 19).

4.3 Student demand for science courses

When Roberts evidence in Figure 4.2 is re-examined it is seen that of those students graduating with first degrees in STEM in the year 2000, the combined engineering and technology category made up the largest graduate group at 21,000 graduates. The biological sciences was the second largest group with 18,000 graduates, while 12,000 computer science graduates made up the third largest group. However, of the overall picture of skills supply as Roberts perceived it, he had this to say to the Chancellor at the beginning of the Review:

> *The Review has identified a number of serious problems in the supply of people with the requisite high quality skills. They are not equally spread across science and engineering; indeed the aggregate number of students with broadly science and technical degrees has risen in the last decade. However, there have been significant falls in the numbers taking physics, mathematics, chemistry and engineering qualifications.* Roberts (2002, p. iii).

This was a point he emphasised later in the Review:

> *In recent years the number of science and engineering students in the UK has been increasing, mainly on the strength of growth in biosciences and computer science. However this growth masks a steady weakening of demand for courses in the physical sciences, engineering and mathematics.* Roberts (2002, p. 22).

A degree of tension becomes evident in the Review however when comparing Figure 4.3 with Figure 4.4. Figure 4.3 for example averages a percentage change in school leavers demand for various STEM courses over a five year period using HESA data. This particular approach over time makes it difficult to see whether the weakening in demand for engineering and technology, and the mathematical and physical sciences was a gradual process

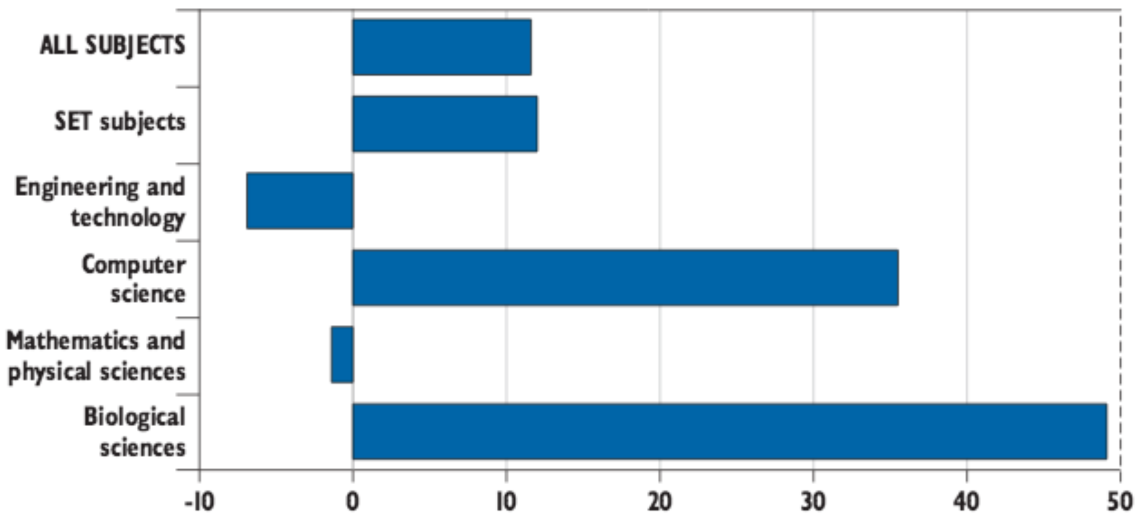


Figure 4.3: Students graduating with a first degree in STEM subjects, percentage change 1994-95 to 1999-2000. Cited in Roberts (2002 p. 23): Source: HESA

or arose at some discrete point - and for some specific reason - between the start and finish of the data collection. Figure 4.4 differs in that it provides a snapshot account for both the start and finish years of data collection at 1994-95 and again at 1999-2000. This allows a before and after figure to be obtained from data sourced from UCAS. With the unit of analysis in entrant numbers in thousands for Figure 4.4 the results were recalculated into percentages to present a like-for-like comparison with Figure 4.3.

It is noted that greater interest in the biological courses coincided with the duration of the Human Genome Project which started in 1990 and completed in 2001. However the high rise in demand for the biological sciences irrespective of a possible agent, and for computer science also dwarfs what Roberts reported in the *Review's Foreword* as *'significant falls'* in the student numbers taking engineering degrees (7 percent) and in mathematics and technology (3 percent) suggesting his claim, where based upon his own data in Figures 4.3 and 4.4, appears to have been exaggerated.

4.4 Labour Market Demand for Scientists and Engineers

Roberts relied upon several approaches to determine the question of employer demand in the *Review* for STEM graduate skills. The first is seen in the usage of the term 'demand'. Whereas this thesis focuses primarily upon the supply of scientists and engineers against a labour market demand, Roberts also saw the issue of demand from the perspective of student demand for certain university courses as an indicator of which disciplines would

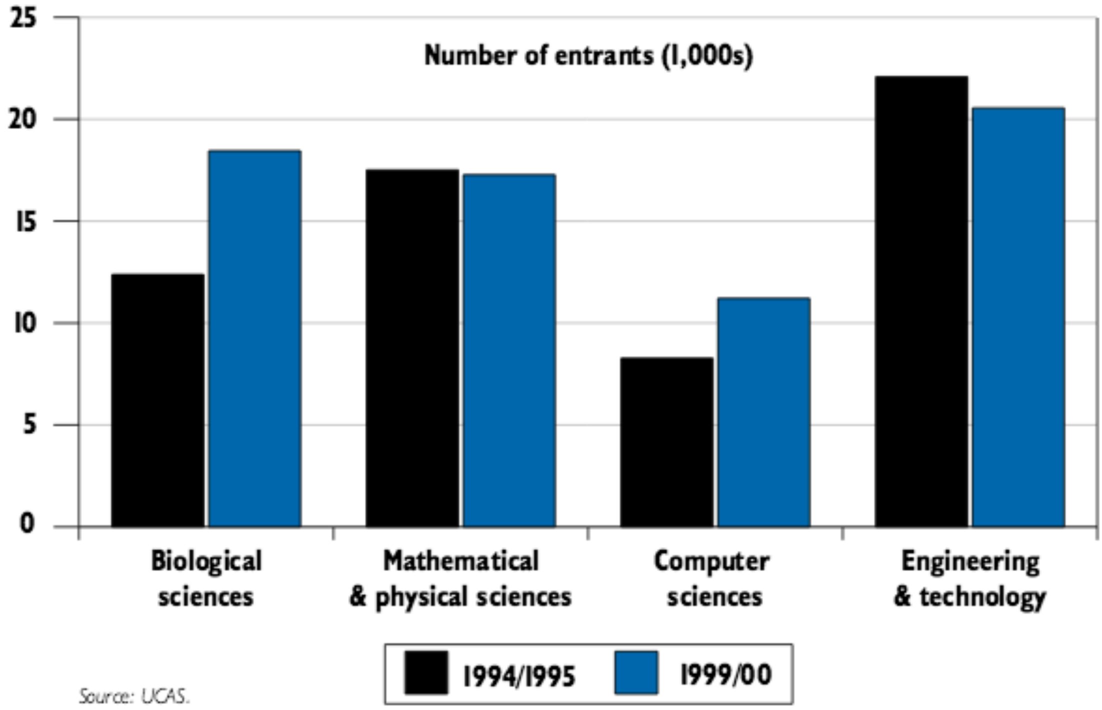


Figure 4.4: Changes in numbers of entrants onto STEM courses at 1994-45 and at 1999-2000. Cited in Roberts (2002 p. 23): Source: HESA

be likely to face future graduate shortages (Roberts, 2002, p. 22). The section above in examining levels of student demand in relation to Roberts claim of 'significant falls' in mathematics, the physical sciences and engineering, has already indicated which science courses appeared to be most in demand over the five years between 1994/5 to 1999/00. A further look at Roberts data in Figure 4.2 also shows the most popular science and technology choices for first degree candidates in the three to four years (dependent upon the length of the degree course) prior to their graduation in 2000. The figure suggests the subject choices of the graduates of the year 2000 echoed the popularity of the biological and the engineering and technology courses of the previous five years and the lesser demand for chemistry, physics, the mathematical and other physical sciences at that time. While a numerical discrepancy between two data sources, HESA and UCAS is observed, the overall picture in terms of the popularity of some STEM courses over the others remained over the five years in focus, with some uncertainty about Roberts portrayal of the extent of the less popular subjects.

The *Review* also sought evidence of employer demand for STEM skills by other approaches. Of the demand for example from employers both in the UK and overseas Roberts observed:

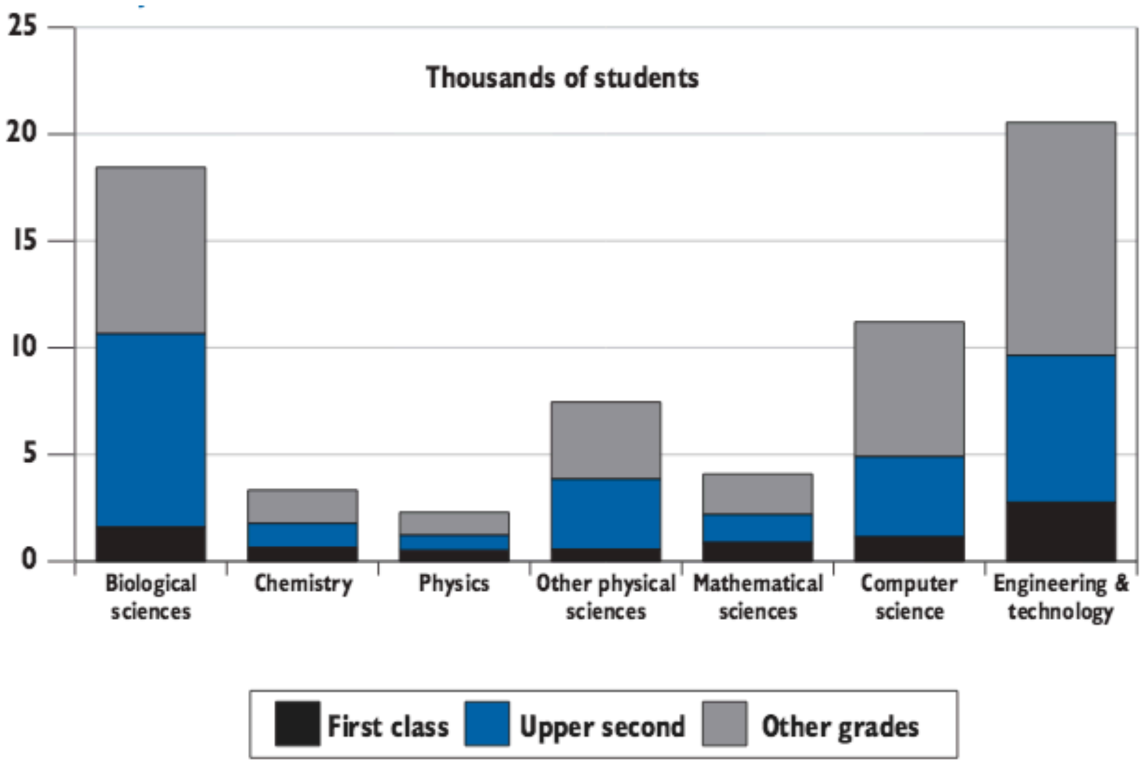


Figure 4.5: Students graduating with a first degree in STEM subjects 2000. Source: HESA

> *Scientists and engineers in the UK are in demand from a wide range of sectors, not just from higher education or from businesses looking for R&D workers. In particular, recent years have seen an increasing demand from financial services sector for highly numerate graduates and postgraduates. Increasingly, scientists and engineers are also in demand from businesses and universities in other countries.* Roberts (2002, p. 25).

And, in terms of the recruitment of scientists and engineers:

> *Other research which included a survey of 23,000 employers across the economy, found that over one-third of employers need more and higher levels of problem solving, communication and IT skills than they did 5 (sic) years ago - in addition to a continuing strong demand for specialist information and communication technology (ICT skills).* Roberts (2002, p. 25), sourced from the Research Report from the National Skills Task Force, June 2000.

The *Review* in examining the first destinations of science and engineering graduates, reported that over half of the new STEM graduates enter primarily R&D based employment as Figure 4.3 shows. Moreover the number of graduates entering the biological

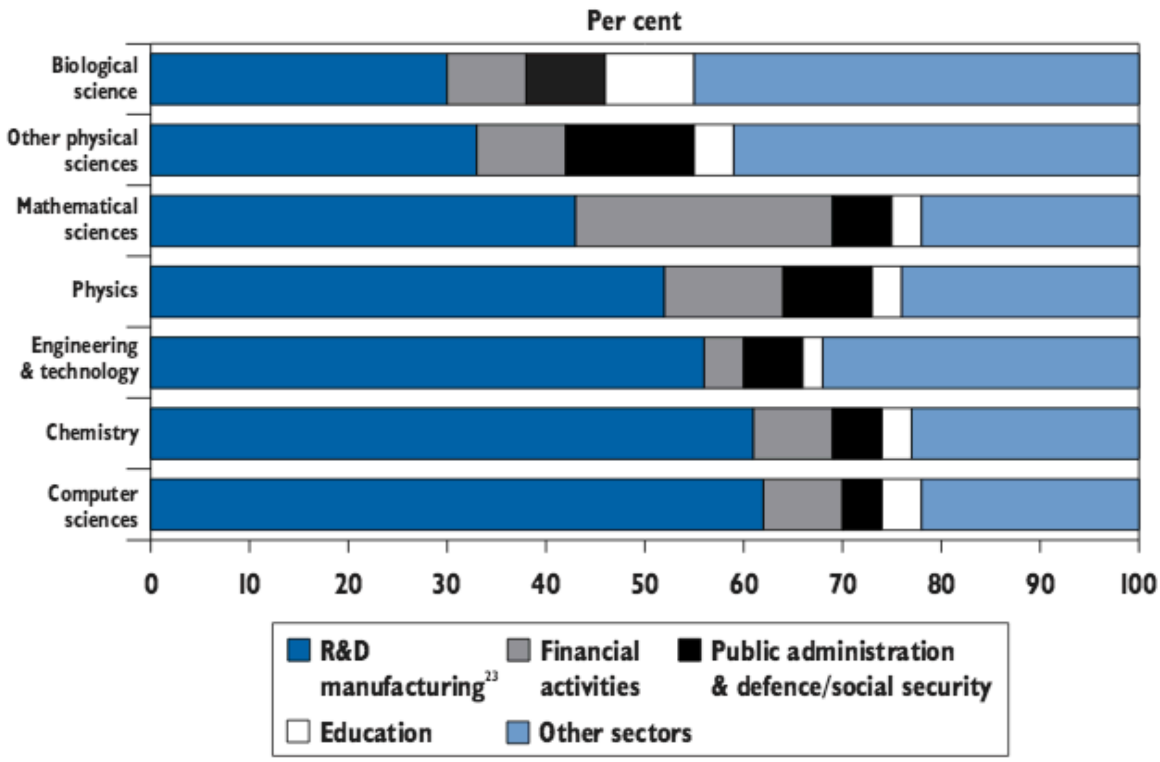


Figure 4.6: First destination for first degree graduates entering employment in 1999-2000. Cited in Roberts, (2002:26): Source: HESA

sciences and 'other physical sciences' are relatively lower in the year 1999-2000 than the other subject areas, particularly chemistry and computer sciences (p. 25).

Figure 4.6 shows the destination of first degree graduate scientists and engineers using HESA data. It also raises questions in that it was not made clear to which specific HESA data Roberts referred to in compiling the chart. This is not untypical of Roberts statistical evidence presented in the Review. Two potential candidates are identified in two tables (1a and 9b) from a wealth of HESA statistical data, for the year 1999-2000.

The first is HESA Statistical First Release (SFR) 46, data table 1a titled, *First Destinations of Full-time Home and Domicile Students Obtaining HE by level of Qualification Obtained and Gender, 1999-2000.* Table 1a deals with 'destination' in terms of whether the graduate is in employment in general but not in the specific disciplines as given in Figure 4.6.

The second is the HESA data Table 9b for the year 1999-2000. This is titled, *All Students Obtaining First Degrees at UK Institutions and Entering Employment in the UK by Standard Occupational Classification and Subject Area 1999-2000* and although Table 9b provides a breakdown of destinations and includes several of the classifications referred to in Figure 4.3, such as chemistry, financial activities, public administration, defence/social security, and R&D manufacturing, neither of the identified tables fully replicate the categories given in Figure 4.3. Roberts himself had commented (2002, p. 27) upon the difficulty of disaggregating data when speaking of salary increases against skills shortages (discussed below), but there is an added difficulty when attempting to follow Roberts argument where the source for the data was cited in the *Review* only as HESA or UCAS. This is particularly important since it is seen that there are numerical or statistical differences offered for similar situation between data sources.

4.5 Salary levels as an indicator of demand

Nevertheless Roberts purpose in including the data from Figure 4.3 data was clear in illustrating a differential between the number of students graduating in science subjects and in calling attention to the relatively low numbers of graduates in mathematical sciences and physics in the year 1999-00. In considering the question of 'demand' Roberts suggested that since these graduates were likely to be in short supply, a 'strengthening demand' for their skills would be expected to show up in increased recent salary levels (Roberts, 2002, p. 27). Citing Figure 4.7 Roberts claimed:

> *'. . . presents data from the Labour Force Survey, which shows that graduates with degrees in computer science, mathematics, engineering and technology, and the physical sciences do indeed attract higher salaries than graduates in the biological sciences or the social sciences'* Roberts (2002, p. 26).

Figure 4.7, replicated from the *Review* (page 27), shows a Labour Source survey and the salary levels as at March 2001 related to a range of disciplines. Missing from the figure however is any indication as to whether these data refer to starting salaries for first degree graduates or postgraduates, whether the categories refer to the subject studied, or the industry in which there were employed. Furthermore, Roberts offered no indication as to whether the data represented combined figures for the whole of the UK in 2001.

As the data stands, and within the limitations described, Figure 4.7 appears to offer support for Roberts model of a labour supply and demand market whereby an inverse correlation exists in terms of salary paid dependent upon the availability of labour supply against the level of employer demand. This market model, as Roberts apparently understood it, is based on general economic theory applied to the labour market. This posits that those skills in short supply would attract a higher wage premium, while those with

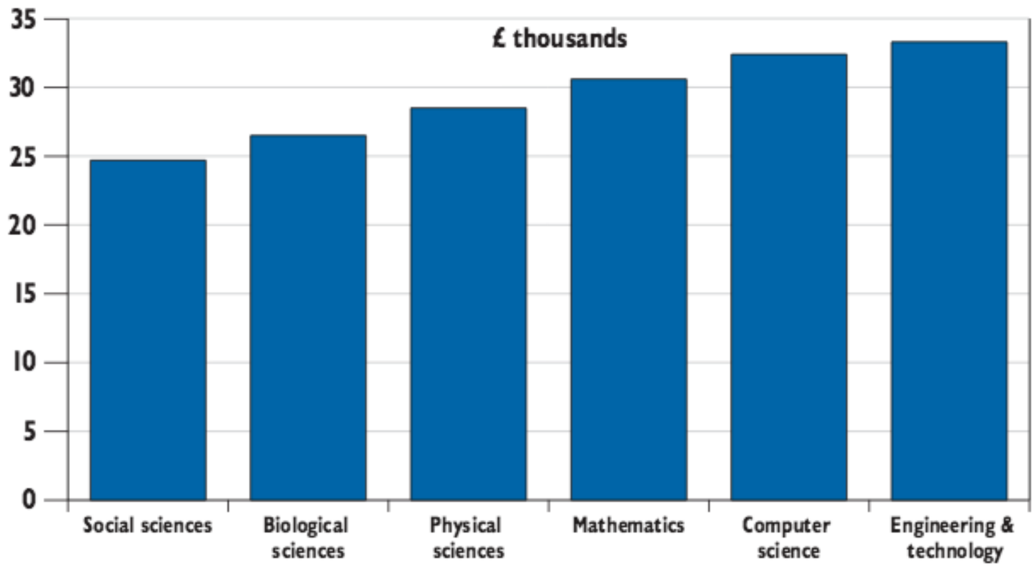


Figure 4.7: Graduates average gross salary in primary job, 2001.Cited in Roberts (2002:27): Source: Labour Source survey, March 2001

skills that were plentiful in the labour market could expect a lower wage (PRAXIS, 2004, p. 1).

Figure 4.3 appears consistent with this model to an extent by presenting the percentage gain and loss in terms of graduate numbers within the science subjects over a five year period ending 1999/00. According to Roberts, those graduate disciplines showing negative growth in Figure 4.3 such as engineering and technology would consequently be in short supply in the labour market. Where those particular skills were in demand by the employer they would therefore attract a higher wage premium, whereas those graduating with a first degree in the biological sciences could expect a relatively lower salary rate since there would be a greater supply available in the market.

Based upon the data presented in Figures 4.7 and 4.3 Roberts argument appears to hold for engineering and technology, areas Roberts had seen with a potential for R&D, and for mathematics and the physical sciences. It holds also for the biological science salaries when comparing data between Figures 4.7 and 4.3 which shows high growth in graduate numbers against relatively low salaries within the science salary ranges over the five year period from 1994/5.

The inverse correlation however breaks down in the *Review* when comparing Figures 4.7 and 4.3 for computer sciences. Figure 4.3 shows strong comparative growth in the number of graduates over the period 1994/5 to 1999/00 while Figure 4.7 illustrating salary levels for 2001, shows computer science graduates as enjoying relatively high salaries where basic economic theory suggests that wages fall against excess supply (PRAXIS, 2004, p. 1). There are several possible reasons for this apparent anomaly. For example despite the high growth recorded in computer science graduate numbers, at the time the figures were compiled there may have been a continuing and increasing demand for skilled labour in the field. The apparent breakdown of the economic theory could also be attributed to a function of the supply demand relationship in that wage rates tend to fall more slowly in response to an excess of supply compared to wage rises in response to demand (Benjamin et al., 2002, p. 579). It may be therefore that the salary figures given for computer sciences represent a lag time before salaries reset according to prevalent market conditions.

However these points were not explored by Roberts as a possible explanation for the apparent salary anomaly identified in the labour supply and demand market model for computer science. He did however in referring to Figure 4.7 acknowledge that there was room for some uncertainty in the salary level results between the subjects depicted. He explained it this way:

> *'These differentials are in part related to the higher proportions of men taking computer science, mathematics, engineering and technology and the physical sciences; men on average earn more than women. However these subject-related salary differences still exist even after taking into account these gender issues'.* Source: Roberts (2002, p. 26 see footnote).

There were other uncertainties left without comment by Roberts. For example Figure 4.3 refers specifically to first degree holders, whereas Figure 4.7 speaks only of 'graduates'. In the absence of information to the contrary the graduates salary figures referred to may include post-graduates or even PhD graduates. If this were the case wage levels would reflect composite rates, skewing the relationship between Figure 4.7 and 4.3.

Using salaries as a proxy to determine employer demand for certain worker skills is not a new approach. But the mechanism is not as straightforward a process as Roberts had implied in attempting to determine the level of employer demand. Taking the variables of the labour market, such as education and skill levels, subject, age and experience into account, and where the information offered is imperfect, leaves doubt as to whether the veracity of Roberts claim for a shortfall in skills against employer demand is sufficiently established by the evidence he presented. The uncertainty is further aggregated when considering the evidence presented in Figure 4.7. Roberts attributed this data to the 'Labour Force Survey (of) March 2001'. The survey however became known as the 'Quarterly Labour Force Survey' (QLFS) in 1992. Moreover Roberts gave the citation date as March

	Annual percentage change (1980/81-1996/97)	Annual percentage change (1996/97-1999/00)
Senior specialist	1.0	3.8
Technical specialist	1.7	2.4

Source: Research & Development Rewards, Reward Group.

Figure 4.8: Real-term increases in median salary for technical and senior R&D specialists. Cited in Roberts (2002, p. 27): Source: Labour Source survey, March 2001

2001. The QLFSs as the name implies are dated inclusively over the quarterly period, for example 'January to March 2001'. However using the title of Figure 4.7 as a search term on the QLFS and associated websites, the Office of National Statistics (ONS) and the UK Data Service, Roberts citation for Figure 4.7 returned no ready results.

Roberts turned next to the *'Research and Development Rewards, Rewards Group'* for Figure 4.8 in support of his argument that salary increases were associated with labour demand (and according to the table dependent upon status):

> *Emerging shortages in the supply of scientists and, caused by strengthening demand for them to work in both R&D and elsewhere, would also be expected to show up in recent increases in scientists' and engineers' salaries. Figure 4.8 shows that the annual salary increase in real terms has risen substantially in the last few years compared to 1980s and early 1990s.* Roberts (2002, p. 27).

This is a table that leaves much unsaid. R&D covers many subject areas and not all of them are within the STEM classification. Roberts himself recognised that the innovation and creativity associated with R&D was not restricted to science and engineering companies, but was likely to include the arts and humanities (2002, p. 1, footnote). In this instance there is no indication as to where the figures were drawn from, or the size of any sample base used. It is not noted whether the table represents salaries averaged across a number of institutions, or an example of a single case study. Again I was unable to easily locate the source of the data in Figure 4.8 via Roberts citation which appeared to be routed through the Croner consultancy company.

4.6 Economic Activity Rates

Still on the issue of establishing the extent of labour market demand for STEM skills Roberts produced Figure 4.9 showing an increase in average gross weekly pay in real

Subject	Percentage change
Natural scientists	0.4
Of which: biological scientists	*−1.9*
Engineers and technologists	4.1

Source: New Earnings Survey (various years).

Figure 4.9: Increase in average gross weekly pay in real terms, 1994 to 2000. Cited in Roberts (2002, p. 28) : Source: Labour Source survey, March 2001

terms and Figure 4.10 which focused upon the percentage of workers active in STEM subjects.

The economic activity rates as shown in Figure 4.10 were used as a means to compare employment rates in this instance between the various STEM subjects where the activity rates are defined as the proportion of those of working age who are either employed or seeking employment. Roberts explained how this worked to determine what he referred to as 'emerging shortages' in STEM, and therefore as an indication of the level of demand, in that Figure 4.10 contrasts the economic activity rates for those with different postgraduate qualifications and presents a picture consistent with the salary data given in Figure 4.9. In this he observed that:

> *'Engineering, physical science, and particularly mathematics postgraduates are more likely to be economically active than those with postgraduate qualifications in the biological qualifications, computer sciences, and the social sciences'.* Source: Roberts (2002, p. 28)

Figure 4.10 shows differences in economic activity (i.e. those in employment) between the various disciplines. Mathematics postgraduates in this figure are shown as the most economically active at 96 per cent. In Roberts argument this should therefore firstly indicate a greater demand for mathematical skills compared to those at the lower end of the scale, for example, computing or chemistry postgraduates. Secondly, in following Roberts argument about skills supply and labour market demand, mathematicians should therefore command a higher salary compared to the other STEM disciplines. However it is difficult to follow Roberts argument that Figure 4.10 is consistent with the salary data shown in Figure 4.9, since mathematics is not included as a category in the table. Nor are the other Figure 4.10 disciplines included unless natural scientists are taken to apply to

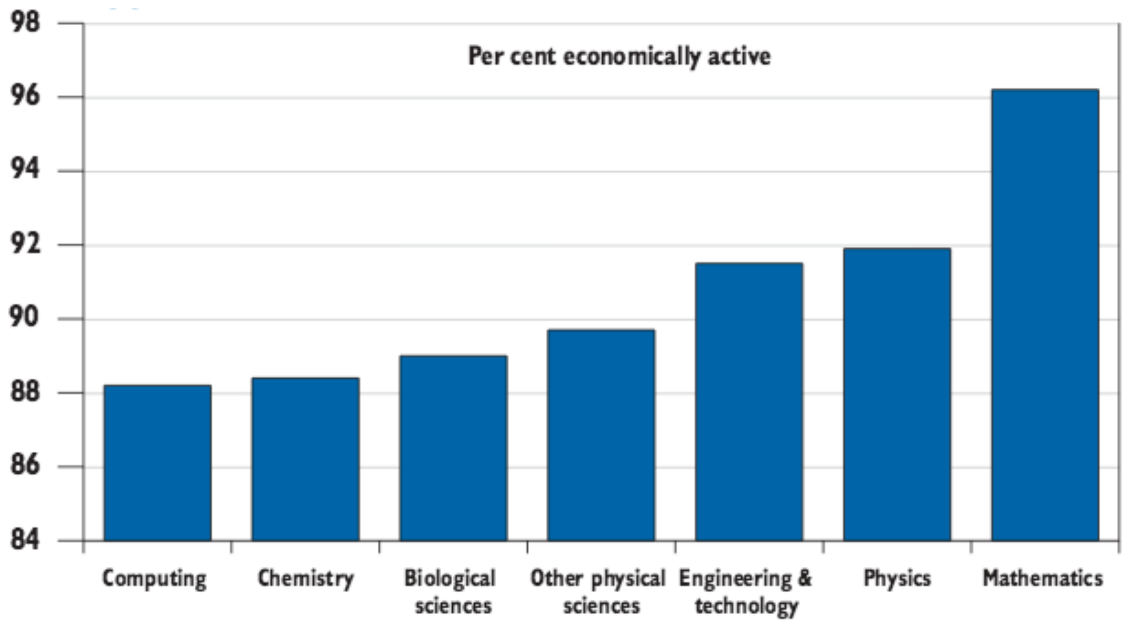


Figure 4.10: Economic activity rates for STEM postgraduates 2001. Cited in Roberts (2002, p. 28): Source: Labour Source survey, March 2001

them all, including biology, but excepting mathematics and engineering and technology. The engineers and technologists who were the only category common to both table and figure were positioned only as the third most economically active group in Figure 4.10. However Roberts appears to argue this positioning provides a clear relationship with the largest percentage wage change shown in Figure 4.9 and thus provides an evidence for his argument.

I would contest Roberts comparison between Figure 4.9 and Figure 4.10 by suggesting that all that can be drawn from the data presented is the order of economic activity of the STEM subjects in the one instance, and the percentage change (plus and minus) in the gross weekly wage over the period 1994 to 2000 (after inflation was taken into account) for the engineers and technologists, and the natural scientists, of which the biologists were included as a subset in the other.

Roberts Review: Set for Success runs to 215 pages and includes 64 figures. A forensic examination of all figures is beyond feasibility in this thesis. Those figures and tables that have been subjected for particular scrutiny in this section have not been selected for the purpose but rather for their pertinence to the subject under discussion in this chapter, that is in support of Roberts perception of a shortfall in the supply of skilled STEM scientists and engineers and of an increased and increasing demand among employers for high quality STEM skilled workers.

4.7 Roberts additional approaches to the question of supply and demand.

If assessing the levels of labour market demand is less straightforward than the demand and supply labour market model might imply, the stocks and flows involved in any attempts to balance the two states add to the difficulty of determining supply needs. The science and engineering supply chain was Roberts obvious approach to the question of the STEM labour supply. In this much of his research was focused upon science and mathematics education in schools, further education, and university science and engineering education. It included also in response to employer concern that the problems in graduate recruitment was not only a question of numbers and high quality subject specialisation, but a need for 'transferable skills'. In this Roberts argued for a requirement to encourage integration between universities and the business and economic needs of industry along with employers attitudes to the staffing costs involved with R&D activity.

On the needs of academia the *Review* examined the role of the funding bodies, PhD stipends, researcher contracts and salaries, and the issues involved in attracting and retaining highly skilled graduates in employment in academia. Roberts put forward a number of recommendations to address what he saw as the issues which would act detrimentally to a smooth progression from schooling to employment in academia or the STEM industries. A summary of the *Roberts Review* recommendations is included at the end of this Chapter.

At the other end of the working life spectrum was the question of retirement from STEM careers. This was generally expected to be at the age when the state retirement pension was payable. When the *Review* was published in 2002 it was set at age 60 for female workers and at 65 for males. This gave Roberts investigating the demographics of the STEM workforce in academia, the opportunity to calculate a figure for both inflow and outflow of workers, and the percentage change involved over time, and to attempt a forecast of assumed need over the following decade.

Roberts, using the inflows and outflows of engineers and mathematicians to the *academic* workplace as examples, says of Figure 4.11:

> *The modelling predicts a significant shortfall in the number of academics with an engineering qualification: the predicted necessary inflow in 2010 is 222 per cent greater than the actual inflow in 1998. In part this can be ascribed to the age profile of the 1998 stock- nearly 20 per cent of engineering staff were over the age of 55. However, the recent pattern of recruitment reflects relatively*

	Actual 1998 inflow	Forecast need in 2005	Percentage change 1998-2005 %	Forecast need in 2010	Percentage change 1998-2010 %
Biological sciences	511	407	-20	415	-19
Chemistry	133	143	8	129	-3
Physics	124	153	23	140	13
Other physical sciences	169	118	-30	128	-24
Mathematical sciences	144	213	48	192	33
Computer science	361	302	-16	314	-13
Engineering	498	632	27	610	22
Total	5,871	5,271	-4	5,337	-3

Source: HEFCE (forthcoming) Academic staff in higher education: trends and projections.

Figure 4.11: Actual and forecast inflows by STEM discipline 1998, 2005 and 2010. Cited in Roberts (2002 p. 159): Source: HEFCE, Academic staff in higher eduction: trends and projections.

> *static student numbers, leading to recruitment levels below that necessary to sustain the stock of staff. Other factors are also at work. Engineers tend to enter the academic profession at a later stage than average (probably due to work in industry and/or greater postdoctoral opportunities) and tend to retire earlier than average (probably due to the greater range of alternative employment available).*
>
> *The modelling also suggests that about 33 per cent more mathematicians will be needed in 2010 to maintain the 1998 numbers. Here the essential problem appears to be the relatively low inflows prior to 1998, which were below replacement levels.* Roberts (2002, p. 159)

A policy change that Roberts was unable to take into account at the time was the phasing out of the fixed retirement age in 2010 and which may have affected the base stock numbers after this time. A further consideration for the supply of technical STEM workers that Roberts may have overlooked in his explanation of Figure 4.11, and in his concern for falling numbers in STEM, was that of apprenticeships.

Where Roberts had apparently based his premise of a shortfall in the number of STEM workers and engineers on the number of students following an academic pathway to their qualifications those students who chose the alternative apprenticeship, City and Guilds,

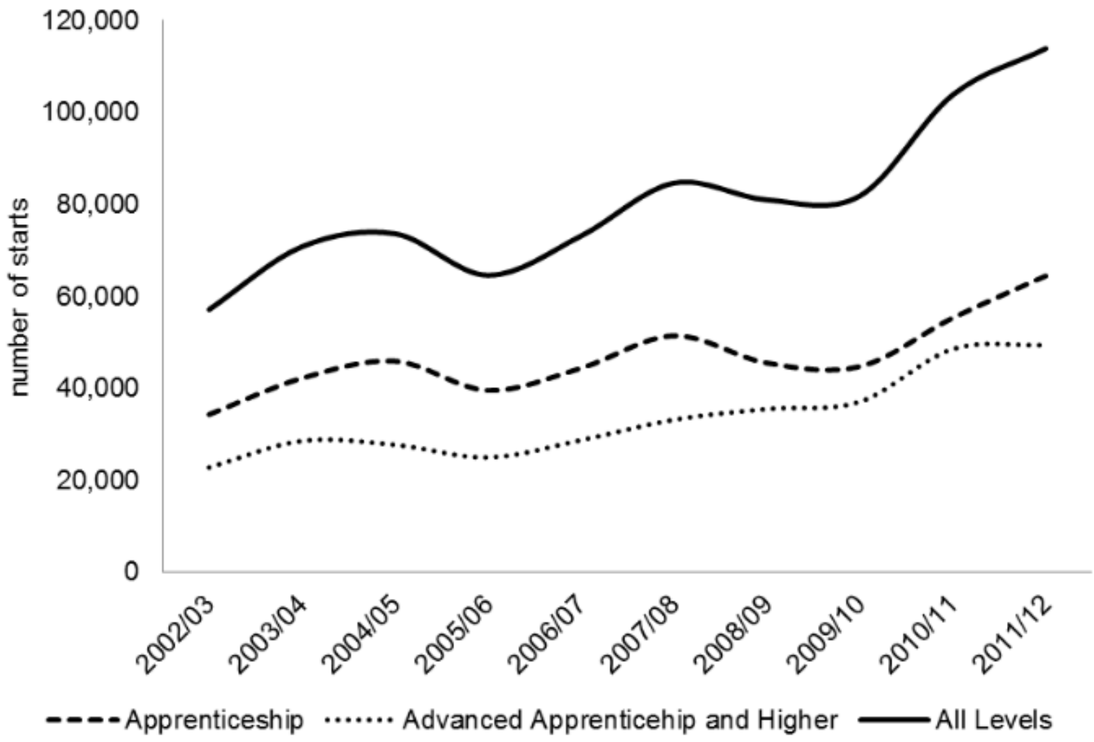


Figure 4.12: Number of Technical Apprenticeship Starts Cited in Technical Apprenticeships 2014 p. ix, BIS Research Paper number 171.

Note: Gov.UK: Apprenticeship (level 2) equivalent to five GCSE passes, Advanced (Level 3) to two A levels, Higher and degree apprenticeships (level 4 or above) leading to NVQ level 4 & above or foundation degree.

BTEC, HNC route etc. were not included in Roberts Review supply data. However it appears that STEM related apprenticeships would have been able to make a notable contribution to the number of STEM workers, if the term 'Technical' as Figure 4.12 is headed, included the sciences and engineering:

Figure 4.12 shows the number of apprenticeship 'starts' over time ('starts' appears to be the standard approach to recording enrolment) which shows an overall rising trend over time which may not have been visible to Roberts at the time the Review was published in 2002. Figure 4.12 shows at that time already over 2,000 'starts' at the advanced apprenticeship level and over 3,000 at the (intermediate) apprenticeship level.

One problem that may have acted against the positive consideration of apprenticeships in Roberts STEM investigation may have been questions about the quality of general interest apprenticeships which Lanning (2011, p. 15) saw as mainly in the 'low-skilled service sectors' such as health and social care, business and administration, and retail. By

2009-10 for example, customer service was seen as the most common apprenticeship sector with less than a third undertaken at level three or above (Lanning, 2011, p. 15). Figure 4.12 however, cited in the Business, Innovation and Skills (BIS) research report into the need and capacity to deliver STEM related apprenticeships in England, focuses on the Technical STEM qualifications. Nevertheless, it remains, according to their Research Report (BIS, 2014, p. vii) that the numbers of those who completed an apprenticeship in industries which employ a relatively high ratio of workers with science, engineering and technology-related skills have steadily fallen in recent times. The implication is that despite a regular cry among some employers (for example, the Confederation of British Industry's (CBI) Skills and Education Surveys) of the need to increase the supply of STEM skilled workers, few appear to seek those who have completed a STEM and technical apprenticeship qualification (BIS, 2014).

This is a situation which encourages the notion that Roberts at the time of the *Review* may have been in a position to positively encourage the development of the STEM apprenticeship scheme among his wide ranging Recommendations (which are examined later) in seeing the need to improve the overall supply of STEM skills.

4.8 The mobility of STEM workers

When considering the stocks and flows of the STEM workforce, one important area where the supply of scientist and engineers were likely to be in constant flux, as Roberts reminded, is that the UK is not the only employment destination for many UK scientists and engineers (Roberts, 2002, p. 17). In 2002 in the Review he spoke of international migration and the effect on UK universities and businesses:

> *There is widespread concern that some of the best scientists and engineers are leaving the UK to work abroad - a trend that is commonly referred to as a 'brain drain'. Some evidence of this is found, although, in fact, more scientists and engineers locate to the UK than leave the UK. However it is vital that universities and businesses compete with their counterparts abroad through offering attractive and well-paid career structures and working environments.*
> Source: Roberts (2002, p. 17).

Roberts was surprisingly low key about the general international interchange of STEM researchers although he did appear to recognise that there could be a positive aspect for the UK in the international interchange of scientists and engineers. Nevertheless his approach does suggest a certain tension in his view of an expanding globalised market. Where the exchange of goods, services and capital might have been understood and accepted, he appears to exhibit a concern about those domestic researchers who locate abroad. Despite an apparent acceptance of the benefits of international exchange, in referring to what was once known as the 'brain drain' he issued a 'vital' warning to universities and businesses to look to their pay and resources to retain and attract researchers. However, following the *Review's* consultation processes with industry which highlighted the lack of knowledge about the new work permit arrangements within the business community, Roberts did make a recommendation:

> *'. . . that the campaign (to raise awareness) be extended to cover the business community, including small and medium-sized businesses engaged in R&D. Through this more UK business will be able to draw upon world wide scientific expertise in driving forward their R&D'.* Source: Roberts (2002, p. 17).

This statement was countered somewhat when Roberts also reported that the Government had already campaigned to raise awareness in the higher education institutions and in prospective overseas students of the new improvements to the work permit system. It appears, that on the question of worker exchange Roberts felt more able to accept the inflow of students and researchers to the UK than their exit.

The *Robert Review* was set up as part of the move to improve of the UK Government's productivity and innovation performance. Central to this was the need to assess the supply of STEM workers that Roberts referred to generically as 'scientists and engineers'. The question of demand was, but to lesser extent, also examined by Roberts in this chapter, along with a wide range of issues felt to be hindering the smooth progression of the production of scientists and engineers through the academic supply chain. This was set against a measure of past enrolment levels using data from the Universities College and Admissions Services (UCAS) and the Higher Education Statistics Agency (HESA) and others.

My argument is that despite the source credibility of many of the citations, the *Review* can be criticised either for the inadequacy or the interpretation of some of the evidence presented to establish a robust labour market demand against which to set the supply concerns. As it stands evaluating the effectiveness of the *Review* and its recommendations as adequate or sufficient to maintain and develop any identifiable shortfall in the supply of highly skilled workforce is frustrated. The claim therefore of a labour market demand that outstrips the supply of scientists and engineers based upon the *Review's* evidence remains questionable.

4.9 Summary of the Roberts Review recommendations

Roberts concluded the *Review's* investigation with a total of thirty-seven recommendations predicated on the perception of 'disconnect between a strengthening demand for highly numerate graduates, and the declining numbers of mathematics, engineering and physical science graduates and on Roberts assumption that recent trends would continue. Roberts 'disconnect' was a seen as a shortfall in the supply of highly skilled scientists and engineers both at the beginning of the 21st century when the *Review* was first published, and in an anticipation of future science and engineering skill requirements.

All thirty-seven recommendations are summarised in this section of the chapter. They are numbered as they appear in the *Review*, chapter by chapter. For example (2.1) indicates the first recommendation of the second chapter. Since I have already argued earlier that evaluating the evidence presented in the *Review* to support Roberts claim of a shortfall in the supply of skilled scientists and engineers is not feasible without firmly establishing the level of labour market demand, all thirty-seven recommendations are therefore examined and summarised, some individually and some linked, for any content that will have a bearing on Roberts concluding argument that the *Review* and the recommendations would:

> *'... help to secure a strong supply of people with science and engineering skills. The Review believes that will be a crucial element in achieving the Government's agenda for raising the R&D and innovation performance of the UK to match the worlds best'.* Source: Roberts (2002, p. 202).

The *Review* exhibited a clear purpose. Foremost it was intended to help secure a strong supply of people with science and engineering skills to support the UK's future economic prosperity. In this it was to address those areas in the supply chain (primary and secondary school, through to A-level and the undergraduate degree, to PhD level and beyond to the R&D employer) that might either inhibit young people's interest in science and engineering in the early years of schooling, or discourage those set upon a science pathway in later years, in continuing with their science and engineering studies.

Roberts first recommendation therefore was in engendering an interest in young people and particularly to encourage more girls into science and engineering. In this the *Review* referred to a study by Baroness Greenfield commissioned by the Government for recommendations as to how to bring about a 'step change' in the rate of participation of women. The participation too of black and minority ethic (BME) groups was questioned about the reasons behind the differences in achievement and participation in the sciences and engineering between white and ethnic groups. Again the Review had no answers to this but recommended a full Government investigation (Recommendations 2.1; 2.2)[2].

Roberts next turns to teachers and teaching. Recommendation 2.3 was for primary school teachers to be given greater subject-specific training in the physical science subjects and mathematics in their initial training and with options for on-going training through Continuing Professional Development (CPD) to improve their confidence in teaching these subjects. Roberts called also for increased renumeration and initiatives to encourage the enrolment of teachers of subjects in short supply, such as mathematics, science, ICT and D&T.

There were similar recommendations for secondary schools in terms of pay and incentives and training for specialist subjects and increased support to trainee science teachers (2.4). On the matter of recruitment, Roberts recommended more attention to be paid to applicants' areas of specialisation to support teaching across the individual sciences at higher levels (2.5) and with CPD linked to the possibility of participating in industry or university based research (2.6). On the question of high pupil-to-staff ratios, an area Roberts believed to adversely affect the quality of science and D&T education, the provision of teaching assistants was recommended. This offered the opportunity for an innovative approach in a 'major new programme' which would see undergraduate and postgraduates, skilled and trained and paid (competitively) to support main school teaching alongside the 'Researchers in Residence' scheme [3], with what Roberts called an 'ambitious target' set by the Government for the number of scientist and engineers recruited to the scheme by 2005. The role of the teaching assistant itself to be defined locally by the teaching establishments, schools, universities and students - but guided by the Government (2.8).

With enhanced teaching capabilities, the condition of teaching spaces was considered by Roberts (2.7), school laboratories needed to be not only fit for purpose but were understood to play an important role in encouraging science and D&T study. This recommendation saw the Government and the local education authorities charged with prioritising

[2] Roberts Review, Annex A

[3] *The Researchers in Residence* scheme matches researchers across all disciplines with schools. Funded by the Research Councils UK (RCUK) and the Wellcome Trust, the schemes was started in 1994. Source: The Training Group, undated.

investment to ensure buildings and spaces were brought up to a standard set against Ofsted [4] measurements.

The secondary school curriculum for science according to Roberts called for a number of recommendations for change and modernisation to make it more appealing to pupils particularly girls:

> *'The science curriculum - particularly in the physical sciences-is not at present, sufficiently approachable to all pupils between the ages of 11-16. This is a significant factor in discouraging girls.' The Review therefore welcomes both the QCA's* [5] *on-going work to modernise the science curriculum and the Government's Key Stage 3 strategy'* [6]*. These are important elements in making the study of science more attractive to pupils, and in turn, helping to enthuse pupils to study science and related subjects at a higher level. The Review recommends that the Government ensures that these changes deliver significant improvements to the way that the sciences (particularly the physical sciences) are taught.'* Recommendation 2.9. Source: Roberts (2002, p. 192).

Precisely what Roberts meant by referring in his statement above to the science curriculum as not 'approachable' is not further explained in the *Review*. Nevertheless Roberts saw (and included it in his recommendations) that teacher support and training would also be needed to optimise a modernised curriculum to appeal to all pupils but again, he gave an emphasis that the science curriculum should hold an appeal for girls. Next considered was the transition from GCSE to A levels and here Roberts acknowledged that there were proposals and consultations already being discussed if not fully addressed by the QCA in considering the GCSE science and mathematics transition to AS and A-levels. Recommendation (2.10) was that the Government should give further consideration and take suitable action conducive to a smooth transition between the skill levels.

This led onto the question of difficulty some apparently felt in studying the sciences. To this, Roberts dismissed any suggestion that this should mean 'dumbing down' or 'levelling out'. Where there was difficulty in pupils achieving high marks in those subjects Roberts referred to Recommendation 2.11 which suggested that, 'this needs to be corrected ... without compromising the core knowledge and skills needed for studying science and

[4] Ofsted is the Office for Standards in Education, Children's Services and Skills

[5] QCA is the Qualifications and Curriculum Authority

[6] The Governments Key Stage 3 strategy referred to Ofsted's evaluation of the implementation of Key Stage 3 for the second year 2001-02

engineering courses in higher education'. But as to how this was to achieved in practical and pedagogical terms, Recommendation 2.11 was silent.

On the issue of the curriculum and a growing profusion of policy initiatives for enhancing the science and engineering areas of the curriculum, Roberts recommended that access be streamlined to a single recognised channel through which teachers could both assess and access the wide resources available to enthuse and encourage pupils into an appreciation of science and engineering (2.12). Linked with this was Roberts final recommendation for secondary schools, that of approaching pupils negative perception of science, mathematics and engineering as potential career choices. Seeing a need to ensure pupils were given accurate informations about jobs in this sector, Roberts recommended (2.13) the Government with others in the scientific and technical fields set up a 'small central team of advisers' to give positive advice about the opportunities that come from studying science and engineering and the range of jobs in the scientific and technical fields, and the question of reward.

As Roberts worked his way through the scientist and engineer supply chain the recommendations offered for the primary and secondary levels were largely focused upon the means, practical, as in teacher training, teaching assistance, curriculum modernisation and the informal initiatives and the improvement of science spaces for practical lessons. It was also 'affective' in terms of evoking an emotional response in seeking to enthuse pupils by affording easier access to more informal science based events, on smoothing the transition between GCSE and A-levels to enhance the school science experience, and on seeking to improve the appeal of science and technology especially to girls, and also in encouraging the wider participation of black and ethnic minority groups in the sciences. In all, the linear approach demonstrated a clear purpose to encourage more pupils to study science to a higher level.

Now an interesting shift in the *Review's* approach emerged. Following on from the formal years of education, pupils, now referred to as 'students' by Roberts, are enrolled in a science or an engineering training programme in a further education college or university. The focus changed from the question of how to engender science and engineering interest and inspiration in school pupils, to the question of how to retain undergraduate science and engineering students to ensure their progression to further study and R&D careers. Roberts dealt with this in his recommendations against what he evidently viewed as potentially negative indicators for the retention of a sufficient supply of skilled graduate and postgraduate scientists and engineers.

As in the school transition period between GCSE and A-levels, the move between A-levels and degree level study was seen as a point of potential difficulty for undergraduates. Roberts view was that modularisation of A-level courses meant the new undergraduate cohort exhibited a wide variation in their subject knowledge particularly notable in mathematics which underpinned the physical sciences and engineering courses. Roberts recommended (3.1) that this be dealt with through a greater integration between A-level awarding bodies and the HE sector firstly by adjusting their respective courses and secondly by the introduction of HEI 'new entry support courses' and e-learning programmes both of which he recommended should be funded by Government. This is what Roberts had to say about dealing with transition:

> *"... The Government should in three years time review progress in reducing the gaps between A-level and degree-level courses to ensure that students are not discouraged from studying these subjects, and retain interest in them - and take further action as necessary.'* Source: Roberts (2002, p. 194).

That concern about science undergraduate student retention was uppermost in Roberts mind was clear, although Roberts made no mention of identifying any similar difficulty affecting the transition between the first taught undergraduate degree and a postgraduate degree, or indeed the transition between taught or research based courses and the PhD programme. Roberts further specific concerns for undergraduates called for greater innovation in the undergraduate science and engineering course structure with the teaching content reflecting the latest developments in science and engineering. Ideally lecturers should have gained practical experience of work environments beyond the Higher Education Institutions (HEI) to ensure teaching was both attractive and relevant. With this criteria Roberts recommended a closer association between university staff, including those involved with students career advice, and business and industry (3.6; 3.2).

On the subject of the PhD programme however, Roberts exhibited a change of approach in largely shifting away from student centric issues, this time to a greater consideration of the perspective of the employer. Where he did make recommendations however on behalf of the student he suggested that the PhD programme for full time students should be funded over an increased period of three and a half years. Moreover that the stipend should both be raised, and applied differentially to encourage recruitment in those subjects in demand to 'better reflect' the market (4.1). The *Review* would also welcome any forthcoming extension of the PhD maintenance award to EU students where they added to the quality and quantity of UK research - and therefore to the economy (4.4).

Roberts prime concern however was now turned to the perceived needs of the graduate employer. Here the recommendation was centred on the need for 'transferrable skills' which Roberts felt should be 'considerably strengthened' to the extent that PhD funding should be linked and conditional upon students' training meeting stringent minimum standards. This was to include at least two weeks of funded and dedicated training annually which concentrated on transferrable skills. A further recommendation (4.2) was that HEIs and other institutions should reward good supervision of PhD students and 'to reflect these issues in their human resource strategies and staff appraisal processes'. There was additional recommendations as to the question of the quality of PhDs':

> *'Furthermore, in order to reassure employers of the quality of PhD students, as part of these standards the Review recommends that institutions should introduce or tighten their procedures for the transfer of students to the Phd. In particular, the Review believes that HEIs must encourage PhD projects that test or develop the creativity prized by employers.'* Recommendations 4.2; 4.3 Source: Roberts (2002, p. 196).

Roberts recommendations also covered postdoctoral researchers and those scientists and engineers engaged in R&D. This included the postdoctoral career pathways. In academia for example, a lectureship might be achieved via a new prestigious Fellowship Scheme, limited to around 200 per year with an attached outreach role as a Science or Engineering Ambassador over a five year period. For the industrial experience Roberts recommended that HEFCE and the research councils might evaluate schemes such as The Research Assistants Industry Secondment scheme run by the Engineering and Physical Sciences Research Council (EPSRC) as the basis for encouraging researchers into industry and as a means of knowledge transfer, recommendations 5.1; 5.2.

The question of salaries both for postdoctoral research contract workers and tenured academic posts was raised. Roberts was clear of the need to increase salaries, and of the need to apply salary differential particularly to reflect those 'engaged in research of international quality, where market conditions make it necessary for recruitment and retention purposes'. Recommended also was a call for government to help with increased funding to allow universities to respond to market pressures. This is assumed to be related to the labour supply and demand market since Roberts continues, *'As a first step, The HEFCE funding currently dedicated to the human resources strategy* [7] *should be made permanent'.* Recommendation 5.5.

[7] HEFCE Human Resources Strategy is an initiative for universities titled: 'Rewarding and Developing

The employers role in recruiting and retaining workers in R&D was included in the *Review's* recommendations with a number of issues raised that needed addressing in order to optimise recruitment and retention of the best science and engineering graduates for R&D. Roberts started with the recommendation (6.1) that R&D should be considered not as a cost but an investment in business. On this footing he recommended that initial pay and bonuses for R&D were to be improved if they were to compare favourably with the pay rates of other sectors. Salary progression was also seen as a factor in retaining skilled staff where 'evidence' suggested that salary progression for scientists did not compare favourably with other sectors. Lacking too was an attractive career structure, with issues such as:

> *'... short-term contracts, low levels of job responsibility, few chances for progression within R&D and poor job design (e.g. jobs that do not use their skills to the full)'.* Source: Roberts (2002, p. 199).

Linked to this was the need for training and continuing professional development with both the time and resources to allow researchers to keep their professional skills updated through recommendation 6.1. 'On the question of recruitment Roberts highlighted the need for improvement by increasing prospective employers marketing methods and by a greater effort towards widening their contact with students. Roberts also saw it as the responsibility of potential employers to improve the perception of research and development posts among students and researchers, and furthermore, to plan their skills requirements ahead of time, recommendations 6.1; 6.3.

Other factors Roberts saw as necessary for improved recruitment, included the recommendation that Government should set up a R&D employers' group to support, monitor, and to act as a driving force in not only taking the *Review's* recommendations forward, but also in playing a key role in a skills dialogue between business and universities, recommendations 6.2; 6.3; 6.4; 6.5.

Finally and relevant to the question of the supply of scientists and engineers was Roberts reminder to business that the government had made certain improvements to overseas students work permit scheme. This Roberts advised would give employers the opportunity to seek out employees with 'worldwide scientific expertise' to drive their R&D forward.

Staff in Higher Education'. The aims are to install good practice guidance on workforce issues: Source: HEFCE, online updated last October 2015

4.10 Conclusions

Roberts recommendations offer some interesting education approaches such as the teaching assistants scheme, and the idea that accessing the initiatives for enhancing the curriculum should be channelled through a single access point. These are straightforward and simple approaches to streamline access to a wide and varied range of initiatives.

It is also notable that some of Roberts concerns such as the apparent lack of transferrable skills of graduates are still being reported by employers (via annual CBI Education and Skills surveys, for example) as issues of concern for today.

Roberts recommendation too for greater integration and collaboration between HEI and business still appears to be an ongoing work-in-progress. But the initiative that those whose interests eventually combine in a desired common outcome should seek a closer association could equally apply to those bodies responsible for the various sections of the academic pathway, thus addressing any disconnect in transition points between the various academic levels. On the question of transition between boundaries was a notable absence of any specific recommendations to assist prospective engineers in dealing with the complexities of acquiring their qualifications through of range of available pathway options. This included the lack of any mention of the MSc degree or of the apprenticeship scheme, among the recommendations.

This appears to be something of an oversight by the *Review* in that a consideration of the transition effect between academic levels may have held (and possibly still does) implications for engineers particularly for those engineers who opted for the academic pathway and who chose to terminate their studies at the MSc level amid some conflicting advice as to the wider value of the PhD award in the profession (see for example the engineering employment agency *'Targetjobs'; The Guardian,* 24 January 2014; 20 January 2015).

It must be remembered however that the Roberts *Review* is being reviewed itself more than a decade after its publication and may now appear naive in some respects. The question however of whether the *Review's* recommendations have been successful in helping to ensure a 'strong supply' of people with science and engineering skills as Roberts had claimed remains debatable since the perception of a shortfall in STEM skilled graduates persists. While the government approved all 37 recommendations there remains a question as to whether they were all implemented. Finally, and notable in the body of the *Review*, there is little if any indication that the recommendations, irrespective of any effect, were evidence based.

Chapter 5

Evidence of supply for scientists and engineers in the UK 2002-2015

5.1 Introduction

In 2002 the Roberts Review, *Set for Success* discussed the adequacy of the supply of UK STEM skills to support the government's future economic programme for the nations international competitiveness. A number of concerns about the supply chain were raised by Roberts and a number of recommendations made to address them. A decade and more later concern about the UK graduate supply with the required STEM skills persists (CBI, 2008-2014).

This chapter examines empirically the supply of UK STEM skills at the graduate and the post-graduate levels over the period following Roberts *Set for Success* in 2002 until 2015 to determine to what extent, if any, the claims and concerns about a crisis in recruiting STEM graduates fits with the supply chain data.

5.2 Collecting the Data

The data for the time-series reported below were drawn from a range of Higher Education Statistics Agency (HESA) tables at three census points chosen to track students progression through the Higher Education system. While UCAS, the Universities and Colleges Admission Services, collects data about the large majority of applicants and acceptances to full-time undergraduate higher education (UCAS, 2013, *End of Cycle Report* p. 5), data tables produced by HESA record both enrolment numbers and the number of students who had actually started in their first year of HE study. In this case 'First-year' figures were used rather than enrolment data since HESA advisory notes to their data tables emphasise that students can be enrolled on a number of study programmes and the number of enrolments therefore would exceed the number of students (HESA, *Students in HE 2004-5 Definitions*). HESA also collects data relating to outcome qualifications for both undergraduates and postgraduates along with the destinations of leavers. The focus for this chapter is upon the empirical examination of the supply of STEM skills over time, and HESA data appeared for this purpose to be better-suited to produce a time-series data-set than those from UCAS.

The STEM subjects referred to in this thesis are those identified by both UCAS and HESA and categorised using a coding system known as the Joint Academic Coding of Subjects (JACS). Under this classification, ten macro headings cover the STEM subjects as identified by HESA in their data tables. The headings can be further disaggregated to a number of specialist subjects within each discipline, but for this investigation of the supply of STEM skills, they were examined using the macro headings listed. There is one exception, namely, *Architecture, Building and Planning.* This group identified as it is with the building sector tends towards a degree of volatility which is not representative of the broader economy. Although the numbers for this group are included in the graphs, the recruitment pattern is not analysed.

- Subjects Allied to Medicine
- Biological sciences
- Physical sciences
- Mathematical sciences
- Engineering & Technology
- Veterinary Science
- Computer Science
- Agricultural & Related Subjects
- Architecture, Building and Planning

For the remaining JACS determined STEM subjects data for full and part-time STEM students are considered in this chapter against the non-STEM total of first-year undergraduate and postgraduate figures over the period (2002-2015) under examination. The academic output by estimates of full-time and part-time STEM students was determined by the HE qualifications. Finally HESA's 'destination of leavers' data of UK HE graduates and postgraduates were examined over the same period, 2002-2015. This produced a time-series insight into the early further study or employment choices for graduate and postgraduate university leavers.

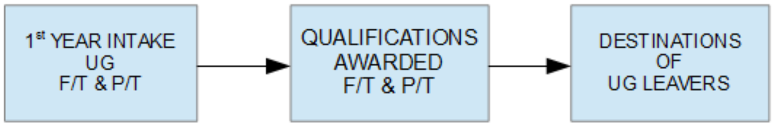


Figure 5.1: A diagrammatic model of the census points along the UG STEM supply chain at which data was collected. Source: Own interpretation of the data collection approach.

Data collected for both undergraduate and postgraduate students at these three census points indicated in Figure 5.1 inform the HE plots presented in this chapter, except where otherwise noted.

There are a number of vocational routes to gaining STEM skills; they include on-the-job training, apprenticeships and others. The data for those areas however are not readily available. Using graduate and undergraduate degree qualifications as proxies offered a greater level of reliability although HESA raised caveats about the robustness of its data where institutions had over or under-reported student numbers or awards, or miss-reported student classifications. The data collection for this thesis was also challenged in providing statistical cohesion between time periods. This was due to changes in the way HESA collected its data and in the way data were presented under a changing range of headings. In this case intake figures in HESA data collection tables were 'matched' to run consecutively by following the overall intake trends over time.

5.3 UK Competitiveness, Innovation and STEM skills

When Roberts made his argument in 2002 (*Set for Success*) for strengthening the supply of high-level STEM skills to support the nations future economic interests in a rapidly expanding international market, the nation's competitive advantage in the international market in the late 20th century had been based according to Porter and Stern on the processes of restructuring, lowering costs and raising quality. Porter and Stern, writing for the *Global Competitiveness Report 2001-2002* saw this approach as an integral component of improving operations but considered it no longer sufficient on its own as a competitive strategy for advanced countries with high labour costs and access to global markets. Instead the way forward - and to keep ahead of rivals - was understood to be through the ability to "...create and then commercialise new products and processes." Porter & Stern (2002, p. 2); Freeman & Soete (2004, p. 2); Schumpeter (1939, p. 83).

Competitiveness in the 21st Century, Porter and Stern argued, would depend on a nation's capacity to innovate. In turn innovative capacity was dependent "...in part on the technical sophistication and the size of the scientific and technical labour force in a given economy". To further press the point, they added: "The foundation of a nation's common infrastructure is its pool of scientists and engineers available to contribute to innovation throughout the economy." (Porter & Stern, 2002, p. 5).

Although Roberts (2002, p. 1), addressing government concerns about the adequacy of the supply of future high-level skills, considered scientists and engineers as essential to competitiveness, Porter and Stern saw science and engineering skills as just one cornerstone of an innovation strategy which encouraged investment and competition, provided ample risk capital, university research and high-quality information, underpinned by clusters of supporting industries and finally with ready and waiting sophisticated and demanding customers (Porter & Stern, 2002, p. 6).

What is clear however in calling for the pool of scientific and technical workers as Porter and Stern had done, and as Roberts had recommended to promote a plentiful supply of high-level skills (2002, p. 1), was that growth in their supply was not related in any measurable way to an existing labour market demand. Instead, the call for a ready supply of what would later become known as the STEM workforce was seen by both Roberts, and Porter and Stern to be linked to an envisaged future demand to be determined by the success of innovation strategies which included utilising scientists and engineers to achieve national economic growth. In such a paradoxical scenario Porter and Stern's call for a pool of available scientists and engineers implied that the authors perceived the supply pool as a passive resource waiting to be recruited to the cause. They were not alone in that presumption. A decade later the Confederation of British Industry (CBI), highlighted a similar suggestion based upon their 2012 annual *Education and Skills* survey findings when they reported that 37 percent of responding employers would have been encouraged to become more involved in the apprenticeship scheme if there were Government support which allowed them to train more apprentices than required "for the wide benefit of their supply chain or their sector as a whole." (CBI, 2012, p. 19).

In the year 2002 however the number of research scientists in the UK business sec-

Country	Scientists	Population	Country	Scientists	Population
Finland	12.2	5176	Austria	3.9	8110
United States	10.2	275423	Netherlands	3.6	15920
Japan	9.8	126919	Austrailia	2.4	19157
Sweden	7.7	8871	Slovinia	2.0	1988
Luxembourg	6.8	441	Spain	1.8	39927
Russia	6.6	145555	New Zealand	1.7	3831
Belgium	6.2	10254	Italy	1.6	57728
Norway	6.0	4491	Slovak Republic	1.6	5401
Canada	5.9	30750	Czech Republic	1.4	10272
Germany	5.5	82168	Hungary	1.4	10024
Singapore	5.3	4018	Romania	1.4	22435
France	5.1	60431	Poland	0.8	38646
Denmark	4.5	5338	Portugal	0.7	10005
Ireland	4.4	3787	China	0.7	1258821
Korea	4.2	47275	Greece	0.5	10558
United Kingdom	4.2	59756	Turkey	0.2	66835
Taiwan	4.2	21777	Mexico	0.1	97221

(a) (b)

Figure 5.2: Business Sector Research Scientists (Per thousand Industrial Workers) for the year 2000 OECD and Non-OECD countries

Data are for the year 2000 or the previous available year.

Population figures are in 1000's Adapted from Table1: Innovation, Diffusion, and Trade (Eaton & Kortum, 2006, p. 31). Data Sources: OECD (2004) and Heston (2002)

tor was estimated to be relatively low compared to some countries. Eaton and Kortum examining the relationships between innovation, diffusion and trade in 2004 published a table (Figure 5.2) *Business Sector Research Scientists*, indicating the number of research scientists employed by industry on a country-by-country basis for the year 2000 as a proxy measure for the level of research intensity per country. Of thirty-four countries included in the table, the UK was listed at number sixteen, between Korea and Taiwan with those three nations each showing just 4.2 scientists for every thousand industrial workers. Heading the table was Finland with 12.2 research scientists per thousand, almost three times more than those employed by the UK (Eaton & Kortum, 2006).

The *Business Research Scientists* table (Figure 5.2) showed, in descending order, the number of research scientists employed in the business sector across thirty-four countries as an indicator of the level of research intensity in the year 2000 of each country listed (OECD, 2004). While Eaton and Kortum suggested that most research was carried out in the USA and Japan, a direct correlation between population numbers and research intensity as measured by the number of research scientists employed in the business sector was weak since the table also showed those with considerably smaller populations such as the Nordic countries, Luxembourg and Singapore as being research intensive when judged by the number of research scientists employed in the business sector (Eaton & Kortum, 2006, p. 31).

Eaton and Kortum's table was one approach to gauging the potential competitiveness through the research and innovation activity of countries. The 2000 *Global Competitiveness Index Report* also examined the question of the competitiveness of nations by reflecting more widely across a range of variables to determine how well a country would be able to respond the challenges of globalisation (Porter et al., 2000). Schwab, of the *World Economic Forum* and contributing to the *Index Report* described three variables thought to be notable in determining "whether countries belonged to a group of innovators or adopters." (Schwab et al., 2002, p. 7 *Preface*). The first variable was in the weighting given by the Index Report to technology as a key driver of sustained economic growth. In measuring sustainability, second under consideration were standards of living which were seen as linked to the quality of the natural environment. A third factor was the international monetary situation and the, then, recently introduced Euro (in 1999). When these factors had been taken into account the table of results for the *Global Competitiveness Index Report*, ranked the UK eighth out of fifty-eight countries (Porter et al., 2000, p. 11).

The purpose of noting the UK's ranking in the two survey reports above was not primarily to draw a comparison between rankings, or between surveys where the differences in ranking in these two examples were obviously dependent upon the survey criteria. It was to suggest that despite the higher ranking of the UK in the *Global Competitiveness Index Report*, the nation's relatively lower ranking in the *Business Sector Research Scientists* survey may have contributed to the growing concern of the government about a link between the number of scientists and engineers employed in UK industry, and the nation's fitness for international competitiveness. That the government were concerned about maintaining the UK's position in the global market was evidenced in the *Roberts Review (SET for Success)* commissioned as it was by the Government against the criteria that the UK's supply of scientists and engineers, "...should not constrain the UK's future research and development (R&D) and innovation performance" (Roberts, 2002, p. 1).

Further fears about the UK's global competitiveness were raised by HM Treasury's publication of the Lambert Review of Business-University Collaboration of 2003 which observed that a long-term concern for the UK had been “Britains poor record in turning its established strengths in basic research into marketable products and commercial success . . . ” (Lambert, 2003, p. 15). One explanation for this apparent failing in commercialising innovation had already been suggested by the OECD in a benchmarking report of 2002 which examined the relationship between UK industry and science. The report claimed that top managers of UK-owned firms were less likely to have a scientific educational background than their US or French counterparts. Managers in those countries according to the report were more likely to have both a PhD (presumably in a science-related subject although this was not stated in the report) and a Masters in Business Administration (MBA). UK firms therefore tended to lack the capabilities “. . . to absorb science . . . ”. In turn this reflected “. . . the rather low level of R&D carried out in most (UK) companies” (OECD, 2002, p. 71).

By 2003 the Lambert Review saw reason for some optimism. Not in terms of competitiveness or increased STEM numbers but in increased public spending on R&D to increase innovation and productivity throughout the economy. Positive indicators included plans in the Governments 2002 Spending Review to increase the Science Budget’s previous spending levels by an average of ten percent over the coming three year period. Included too were plans by other government departments “to spend significant amounts on science, engineering and technology; and a greater proportion of the labour force, including managers, to be educated to degree level” (Lambert, 2003, p. 22).

Portraying the relationship between students and the universities as one in which the key purpose of the interaction was fundamentally about the value of education itself, Lambert had stated: “The Review recognised that the role of universities is to educate students, rather than to train them for the specific needs of businesses.” Lambert added, however, “But it is important for the UK economy that students leave university with skills relevant to employers” (2003, p. 107).

The question of the relevance of graduate skills to the needs of employers was an area that Roberts had already identified when he observed in his *Review, Set for Success,* that a strengthening demand for graduates in highly numerate subjects against what he saw as a declining number of those graduating in mathematics, engineering and the physical sciences. The discussion below examines that supposed decline. Roberts further argued that graduate science and engineering education did not appear to support the transferable skills and knowledge demanded by employers (Robert’s Review, *Set for Success*, 2002, p. 2).

Over time the increasing pressures of international competition came to bear on Higher Education to meet the more specific needs of business. The pressure was driven by a number of interested bodies including the *Confederation of British Industry* (CBI) particularly from 2008 onward when the CBI introduced the annual *Education and Skills Surveys.* This publication lobbied the Government year-by-year about the difficulties experienced by some employers in recruiting sufficient numbers of STEM graduates with the required skills not only in their specialist science discipline but in the so-called employability skills (CBI, 2008, *Education and Skills Survey* p. 22). The CBI and its annual surveys would become a key driver for a range of policy initiatives by both the state and the private sector to increase the UK supply of science and engineering graduates.

5.3.1 Undergraduate Supply-side Evidence

In a changing economic climate where concern about maintaining global competitiveness through science and technology-led innovation was assuming a greater importance, by 2002 as Figure 5.3 shows, the number of students opting to study STEM subjects had begun to slowly rise.

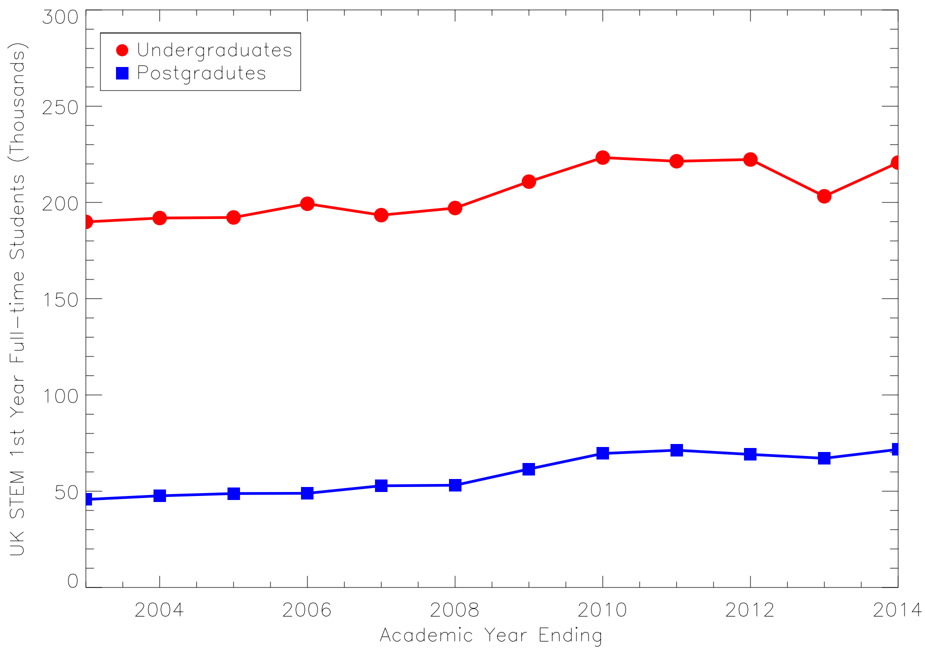


Figure 5.3: Estimated Total for Full time First-Year Undergraduate & Postgraduate Numbers for All STEM subjects 2003-2014

Data source: HESA tables listed in Appendix A

While both full time first-year undergraduates and postgraduate STEM numbers followed a similar upward trend from 2002 (Figure 5.3) this levelled off in the undergraduate data by 2009 until a sudden dip observed at 2013. This was coincident with the three-fold increase in undergraduate contributions adopted by most universities in England to take effect for the 2012/13 academic year (Gov.UK 15th December, 2010). The downward shift of the undergraduate numbers quickly reversed the following year (2013) returning to the levels of 2010 and 2011 and continued in their upward trend.

For the postgraduate full time first-year numbers the upward trend though clear and definite was seen as a more gradual and consistent process. The dip in 2013 data for in the undergraduate data was observable in that of the postgraduates but less pronounced, although the recovery in 2013 equally quickly recovered but whereas the undergraduates resumed their upward growth to 2014, the postgraduates figures levelled out at the beginning of 2014.

The difference in the way the upward trends are presented between the undergraduate and the postgraduate data, particularly the more discernible dip observed in the first year undergraduate in 2013 may be explained in part by making a reasonable assumption that some, but not all, postgraduates returning to HE were insulated from fee increases by being awarded bursaries or scholarships which included funding for postgraduate HE fees. An example is the 1+3 ESRC (Economic and Social Science Research Council) scholarship, which includes funding for both MSc and PhD study.

5.4 Analysing the recruitment patterns

Examining HESA STEM full-time undergraduate data

Undertaking an in-depth analysis of the quantitative data relating to the supply of STEM graduates throughout the higher education section allowed the number of incoming STEM students over-time to be considered against the non-STEM cohort in both relative and absolute terms. This enabled the numbers to be considered against the perception of a crisis in the recruitment of STEM graduates. The analysis also allowed a comparison with the supply of graduates with labour market demand (so far as 'demand' was able to be assessed). This aspect of the analysis is discussed in the following chapter about demand.

The analysis considers the progress of each of the examined STEM subjects in turn although there is some cross referencing. It starts with the *Biological Sciences*.

5.4.1 Data Analysis

The first undergraduate year was taken as the first census point in the STEM graduate supply chain. Figures 5.4 and 5.5 therefore chart the numbers recruited among the incoming undergraduate students of the STEM study subjects over the period 2003-2015. The ten STEM subjects are divided into two groups of five and shown in paired data plots (Figures 5.4 and 5.5) to assist the clarity of the findings.

5.4.2 Biological sciences

Notable in Figure 5.4(a) was the sharply rising popularity of the *Biological Sciences* [1]. over the other STEM subjects with the exception of *Subjects Allied to Medicine* Figure 5.4(b). Of the incoming full-time first-year entry STEM undergraduates studying the biological sciences between 2003 and 2015, the steady increase in their number from the beginning of the time-series graphs in 2003 was interrupted by a brief drop in 2013. This was also seen across the majority of the STEM subjects with two exceptions: *Medicine and Dentistry*, and the *Veterinary Sciences*. They are discussed below.

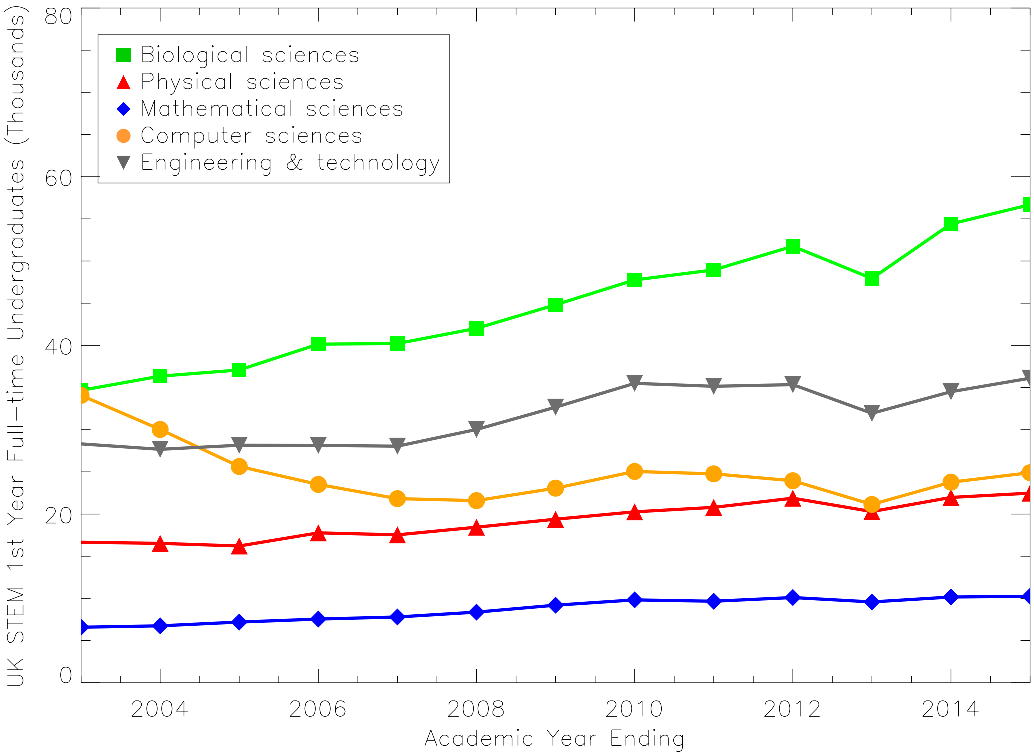
The drop in numbers at 2013 coincided with the introduction of the increased tuition fees from 3,000 to 9,000 that all students, not just those studying STEM, were required to contribute toward their higher education (see Figures 5.4 and 5.5). By the end of the time-series however in 2015 the growth of numbers for the Biological Sciences had not

[1]STEM subjects (and STEM subject combinations) as used by HESA and categorised under the JACS coding system, are italicised in the text

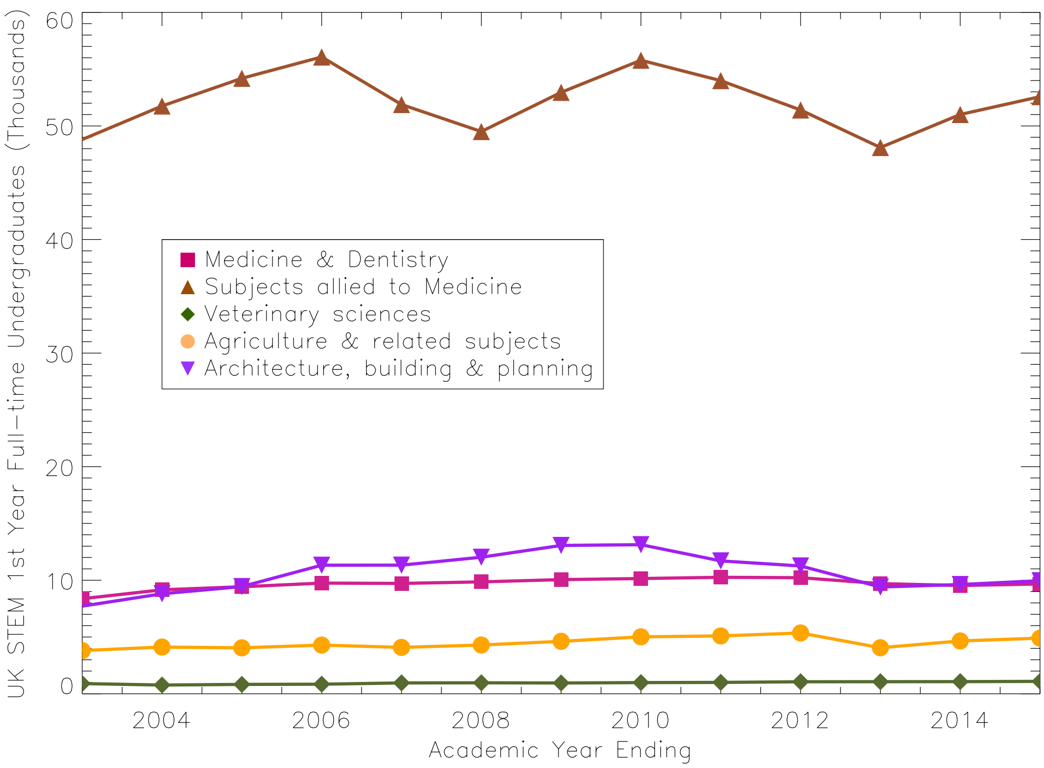
only recovered sharply but had increased by 63 per cent, from around 35,000, in 2002 to 57,000 in 2015: Figure 5.4(a).

Figure 5.5(a) shows the number of part-time undergraduates for Biological Sciences rose dramatically in 2003-2004 from 4,000 to 9,000 representing a 125 percent increase in numbers. A sharp drop however of 1,000 part-time students in 2008 may have reflected the financial constraints global recessionary period 2007-2008. The loss was quickly recovered the following year with an upward trend that fell again at the 2013 point the year tuition fees increased, before assuming a downward trend which continued until the end of the time-series data with part-time student numbers of 11,000. This produced a full-time equivalent (FTE) [2] of 5,500 full-time STEM students.

[2] Full-time equivalent (FTE) data is described as representing the institution's assessment of the full-time equivalence of the student instance during a reporting period (HESA Student Definitions 2012/13). It is generally assumed that a FTE of 1.0 is equivalent to a full-time worker or student, while an FTE of 0.5 signals half of a full work or school load.



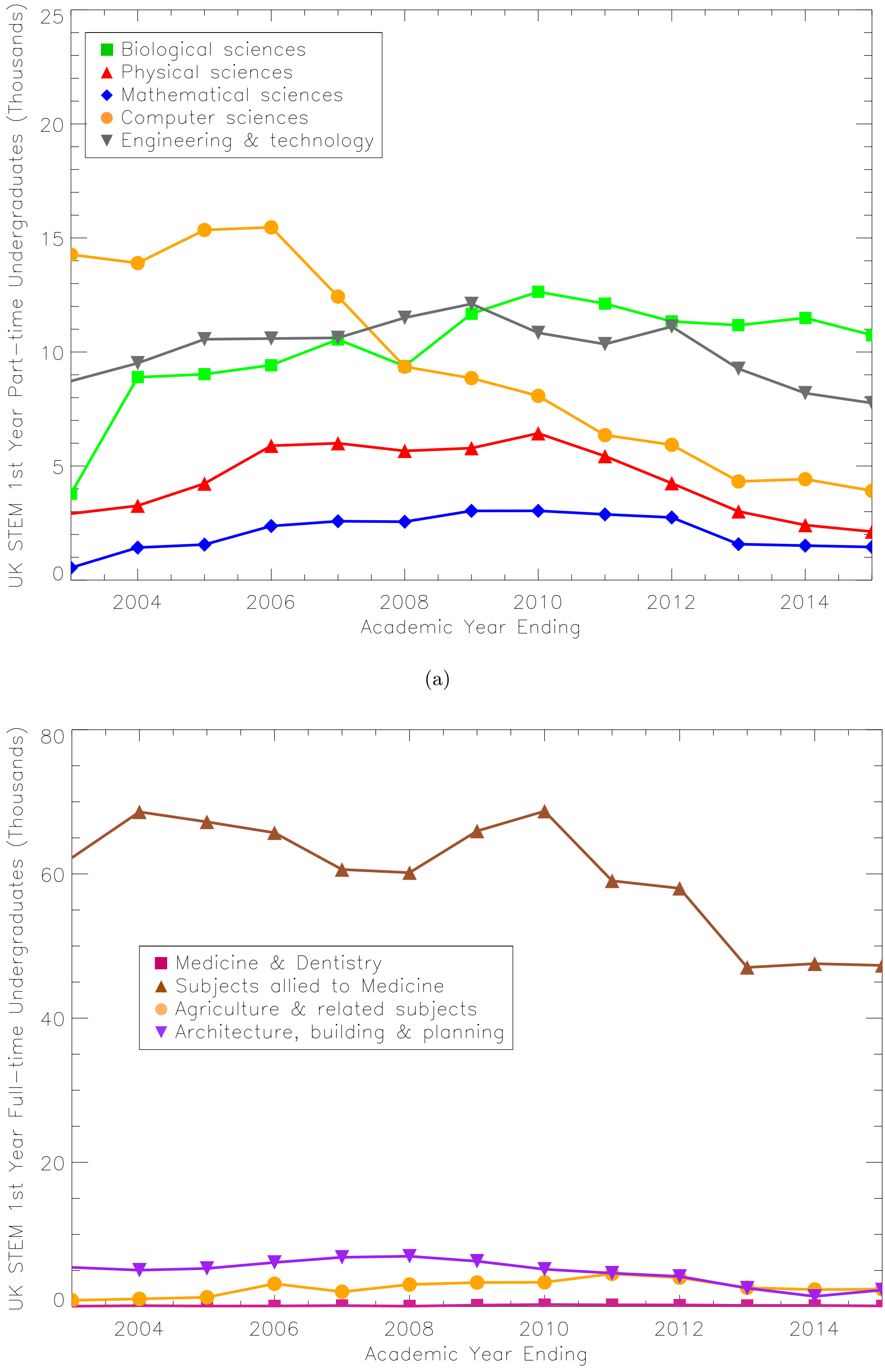
(a)



(b)

Figure 5.4: (a) and (b) UK STEM 1st Year Full-Time Undergraduate Students 2003-2015

Data source: HESA tables listed in Appendix A



(a)

(b)

Figure 5.5: (a) and (b) UK STEM 1st Year PT-Time Undergraduate Students 2003-2015 (Veterinary figures negligible)

Data source: HESA tables listed in Appendix A

5.4.3 Subjects Allied to Medicine

Associated with the biological sciences are the *Subjects Allied to Medicine*. The category incorporates a diverse group with over eighty subcategories. They cover subjects such as pharmacology, toxicology, optometry, midwifery, mental health services, acupuncture, neuroscience, psychology, nursing in all its specialist applications, and many others including make-up, beauty therapy and hair services. The full-time first year incoming students numbers for this group were also high, starting in 2002-3 at just under 49,000 and rising overall to around 56,000 by 2015: Figure 5.4(b). Plotting the data however produced an unusual pattern as Figure 5.4(b) shows. Equally spaced along the time-series data were two distinct downturns alternating with two distinct rises. The first peak in the data at 2006 followed a downward trend to the 2008 with a loss of around five thousand students. The pattern repeated with a second upward trend which again reached 56,000 in 2010 and a downward turn to 2013 followed yet again by a third rising trend to the end of the data-series in 2015.

Although most STEM subjects reflected a drop in first year student numbers at the 2013 mark, including the part-time STEM students, (see Figures 5.4 and 5.5), the repeating pattern seen in Figure 5.4(b) in the numbers of full-time students for Subjects Allied to Medicine suggested that regular rise and fall pattern in numbers was not related solely, if at all, to the question of increased student fees. Given the breadth of the subject material covered by the category, it was difficult to see a mechanism which would universally affect all its varied sub-categories and account for what appeared to be a periodicity in the rise and fall of first-year students numbers for these subjects.

One candidate for a mechanism was the recessionary period ushered in by the so-called 'global financial crisis' of 2007-2008 (Acharya, V. and Philippon, T. and Richardson, M. and Roubini, N., 2009). With nursing as one of the largest subcategories of *Subjects Allied to Medicine*, the popularity of nursing as a degree course (McGhee, 2015), coupled with the Department of Health requirement for new nurses to be educated to degree level from 2013 (BBC News, 2009), the incoming students numbers to *Subjects Allied to Medicine* were relatively high as Figure 5.4(b) showed. The popularity of nursing may also have been encouraged as a degree subject since student nurses did not pay (at that time) their own tuition fees (Gov.UK, 2016).

As such the intake numbers for nursing, and of the other health and social care professionals included among those *Subjects Allied to Medicine* was, and remains, an area where numbers are historically constrained by budgetary considerations, and as such are subjected to tight governmental control (NHS, 2016a). Table 5.1 shows the estimated totals for those health and social care professionals associated with *Subjects Allied to Medicine*.

Table 5.1: Estimated training costs of health and social care professionals (Allied to Medicine) 2015
Source: Unit Costs of Health and Social Care 2015, Personal Social Services Research Unit (PSSRU)

Professional	Working life in years	Total investment (estimated)
Physiotherapist	24.3	£69,161
Occupational therapist	23.5	£69.161
Speech and language therapist	24.7	£71,663
Dietitian	23.3	£69,161
Radiographer	24.3	£74,206
Hospital pharmacist	27.6	£123,526
Nurses	15.7	£80,807
Social workers (degree)	8	£70,225

It appeared therefore that budgetary resources and recessionary times were likely to affect periodically, the numbers of nurses, and others within the health and professional category, recruited on degree courses. This would offer an explanation of the rise and fall pattern seen in Figure 5.4(b) for the *Subjects Allied to Medicine*. From this it might also be assumed that *Medicine and Dentistry*, through their similar association with the NHS, might equally be affected by periodic constraint leading to a similar rise and fall pattern in HE recruitment. This however was not seen in the data shown in Figures 5.4(b) and 5.5(b).

5.4.4 Medicine and Dentistry

Not only was the rise and fall pattern seen in for *Subjects Applied to Medicine* missing from the *Medicine and Dentistry* data, but the year-on-year intake numbers exhibited for the full-time graduates were remarkably consistent when plotted over the full data-set year-by-year from 2003-2015, although the small numbers recorded for part-time medical students showed a barely measurable increase from 2006: Figures 5.4(b) and 5.5(b). If the NHS approach to recruiting nurses, and with others associated with the NHS, was a result of workforce planning for *Subjects Applied to Medicine* as seen in Figure 5.4(b), then the recruitment approach for *Medicine and Dentistry* also seen in Figures 5.4(b) and 5.5(b) also required examination.

In 2013 the UK government announced an extra 30,000 more HE student places would be made available for the following year and a year later the cap on student numbers would be abolished altogether (Hansard, 2013, Column 1110). The relaxation of HE numbers however did not included those involved with health and social care professionals entering the National Health Service. Entry to *Medicine and Dentistry* for example, were, and remain, as in the nursing intake figures, under the shared control of the Department of Health (DH) and the Higher Education Funding Council for England (HEFCE). Under their authority medical and dental students are similarly treated in terms of constraining intake numbers. This reflects the costs to the NHS for training and equipment needs over time (see Tables 5.1 and 5.2).

Although medical and dental undergraduates now pay their own tuition fees for the first four years of a standard five year medical course, from year five onward tuition costs for the following years which includes foundation and specialist training, and as professional health staff, further training over their whole of their professional lives, are paid by the NHS Bursary Scheme (NHS, 2016b, Health Careers) with implications for the taxpayer although only those estimated costs associated with postgraduate training for medical doctors are known (PSSRU, 2015, *Personal Social Services Research Unit* p. 112). A breakdown of the estimated costs for doctors included tuition, infrastructure costs (libraries for example), costs or benefits from clinical placement activities, and lost production during training where staff are absent from their posts, and so on, (PSSRU, 2015, p. 112 ; p. 248-9). The estimated total costs involved in training doctors over their professional lifetime are shown in Table 5.2.

Table 5.2: Training doctors (Medicine) after discounting.

Source: Unit costs of Health and Social Care 2015, Personal Social Services Research Unit (PSSRU)

Note: The method of calculating post graduate costs was revised in 2005 following the introduction of training placement tariffs.

Doctors	Working life in years	Total investment (estimated)
Foundation officer 1	25	£296,051
Foundation officer 2	24	£311,960
Registrar group	20	£380,850
Associate specialist	18	£424,768
GP	16	£385,523
Consultants	16	£508,819

Where the funding budget is limited, strict control over intake numbers was seen as a means of controlling costs. Although the level of workforce requirements were subjected to periodic review, it appears that the supply of nurses, doctors and dentists are determined largely by financial consideration rather than responding to demand. This argument finds support in the 2012 *Review of Medical and dental School Intakes in England* called for by the Higher Education Funding Council (HEFCE), and the Department of Health (DH) in 2012 to consider whether current levels of supply were in line with predicted future workforce arrangements. The review by the Health and Education National Strategy Exchange (HENSE) devised a model in which future work scenarios were used to produce a model of future workforce requirements. This allowed the reviewers to assume a reasonable certainty about the supply of doctors but with relatively less confidence in the question of demand. While the model indicated that the future need for primary care staff was unlikely to be met by present numbers, the number of hospital doctors were likely to be in oversupply in the future. An oversupply of hospital doctors was seen by the reviewers as one which "...falls outside reasonably affordable projections". This led to the recommendation that there should be a two percent reduction in medical school intakes from 2013 until a further decision to change recruitment policy followed a further review (HENSE, 2012, p. 50).

For dental intakes, the complexity of the "system dynamics" was not seen to lend itself to forecast the future dental supply workforce. In such circumstances the recommendation was made that there should be no immediate change to the dental intake numbers (HENSE, 2012, p. 51). There are no data available for on-going training for dentists (PSSRU, 2015, p. 180).

5.4.5 Veterinary Sciences

While *Veterinary Science* numbers have not been controlled in the same way as the *Medicine and Dental Sciences*, numbers for university degree veterinary courses were also seen to be consistent over time as shown in Figures 5.4(b). Although the part-time numbers (Figure 5.5(b)) showed a slight increase around 2005-6, the general lack of growth in the subject area appeared to be largely related to concern by the British Veterinary Association (BVA) about the consequences of an oversupply of veterinary graduates against the needs of those already in practice and of a shortfall in resources leading to a lack of clinical opportunities for newly graduated students (BVA, 2013, p. 4). Moreover, according to the Royal College of Veterinary Surgeons (RCVS), the availability of sufficient academic staff to cover any increase in student numbers was also an issue for concern (BVA, 2013, p. 2). The nature of such constraints, self-imposed as it appeared by the profession although the RCVS denied having a mandate to control student or graduate numbers (BVA, 2013, p. 2), is reflected in the number of incoming HE students (consistently around a thousand per annum, Figure 5.4 b).

Was the BVA's concern about oversupply justified? There is some evidence to suggest the concern may be genuine when it is reported that the demand for places at seven of the UK Veterinary schools "vastly exceeds supply" (Ross, 2014, New Statesman). Where HE student numbers were no longer capped by government there was instead, so argued Ross writing for the New Statesman in 2014, a financial incentive for universities to respond to student demand for places regardless of future employment prospects for graduates at the end of a five-year study period. She highlighted the prospects for vets in Australia where in 2013 the Australian Veterinary Network reported that an average vet might earn the same as a "MacDonalds burger flipper" and where according to Ross, 30 percent of the graduates from the University of Melbourne (a consistently highly ranked university-www.topuniversities.com) found it impossible to find employment in the field. Source: New Statesman (Ross, 2014).

In terms however of adding to the supply of UK STEM skills, Lord Trees, Dean of Liverpools Faculty of Veterinary Science from 2001 until 2008, and the current Chair of the Royal College of Veterinary Surgery (RCVS) Science Advisory Panel, suggested an overproduction would encourage the skills and experience of veterinary graduates to more broadly benefit society, boosted as the UK numbers were "... by around six hundred vets each year ... coming into the country from overseas to register with the RCVS and practice in the country." (Cited in Ross, 2014, p. 3). Lord Trees describes a case whereby STEM interest and skills appear to have been in plentiful supply and perhaps, under exploited and possibly in need of an alternative direction.

5.4.6 Agriculture and related subjects

Recruitment numbers for first year undergraduates for *Agricultural and Related Subjects* were also seen to be at a relatively low number starting at around 4,000 in 2003 and rising gently to around 5,000 in 2012 and falling to 3,000 at the almost ubiquitous dip in this data-set at 2013, before recovering with a slight upward trend from 20014 (Figure 5.4 b). Low recruitment has been blamed in part on the wider effects of dealing with animal diseases such Bovine TB, BSE and foot and mouth disease leading to the destruction of millions of cattle. Dealing with consequences at "...enormous cost to farmers and the taxpayer" was suggested by (Bathurst, 2014) to have resulted in the loss of over 3,000 farmers to farming, in an industry DEFRA noted for its large numbers of self-employed, and the domination of small and micro businesses (2013, p. 14). Losses on such a scale and the evident difficulties the industry faced during and after the various crises appear to be a likely factor in curtailing intake numbers of agricultural students (Bathurst, 2014, *Young Farmers: why agriculture is booming,* Guardian Article, 4 October).

While Figure 5.4 (a) and (b) hinted at the possible beginnings of a slow recovery for full-time student numbers they were balanced with a downward trend for the part-time students in Figure 5.5 (a) and (b). Although this appeared to be at odds with Bathursts claim of a "booming" revival in interest in *Agriculture and Related Subjects* based in part on her argument that English farmland prices had been steadily rising, found some support in research by Knight Frank Residential Research that suggested the average value of English farmland prices had indeed been steadily rising over the last decade and more. This however may have reflected the scarcity of farmland for investment purposes rather than indicating a 'boom' in farming (McGrath, 2014, *UK faces 'significant' shortage of farmland by 2030,* BBC news 25 June).

Nevertheless, the question of attracting young people into farming and the associated disciplines was raised in a 2013 DEFRA review of the demand-side of farming calling for a fresh analysis to consider the numbers needed "...now and in the future" for Agriculture and the Related Subjects DEFRA's many recommendations to secure the future of farming, included the input of young people and the need to engage them with a positive perception of farming. This would require, according to DEFRA, to properly embed agriculture and it's related subjects within the National Curriculum's science, maths and geography disciplines. A further need was seen in the setting-up of a range of policy initiatives including apprenticeships and creative graduate schemes combined with essential business and management skills, within a recognisable professional qualification (DEFRA, 2013, *Future of Farming Review Report*, July 2013, p. 2).

Unlike the medical profession which, as seen in the notes to Table 5.2, has had preordained guidelines as to the length (in years) of their working life, agriculture appears to have no such parameters. Farmers are known to work into their old age and possibly to death (Agricultural Property Relief allows land or pasture to be passed on free of inheritance tax), This means that those brought up as children on a farm and intent on pursuing the family business are not only likely to have had early work experience but also (at the present time) the bonus of a working farm to which to succeed (succession farming) (DEFRA, 2013, p. 8, 9, 13 and 35).

This leaves little opportunity for those new to farming to find their way into the sector particularly where technology has played an increasingly major role in the day-to-day farming activities. The consolidation of business within farming has also reduced opportunities for those seeking a 'starter farm'. In addition, there is an increasing loss of council farms and rising agricultural land prices (Collinson, 2015; DEFRA, 2013, p. 8), and for many graduates, the possible debts of HE. For those interested in farming as a subject within *Agriculture and Related Subjects*, and in considering the research question of a possible crisis in recruitment to science and technology, it might reasonably be assumed that where farming is concerned, recruitment could indeed present a challenge, not at this time necessarily reflecting a loss of interest in the subject itself but in the challenging circumstances of contemporary farming. This might account in part for the low growth in intake numbers seen for the category in Figures 5.4(b) and 5.5(b). It also questions the recruitment levels to other disciplines that support farming such as engineering, agronomy, pest control, science, research and forestry and so on.

5.4.7 Mathematical Sciences and Physical Sciences

Figure 5.4(a) shows a rising trend over the time-series data set for both the *Physical Sciences* and *Mathematical Sciences* for full-time undergraduates. Notable is the dip at year 2013 for all subjects in Figure 5.4, as the year when undergraduate fees were tripled. While the fee rise 'dip' was seen across the majority of undergraduate subjects in Figure 5.4 the full-time intake undergraduate numbers for *Physical Sciences* and *Mathematical Sciences* appeared to be affected least of all. Starting salaries were examined for a possible explanation. Sourcing figures from the Government had disadvantages. Estimated median salary figures for occupation were produced for 2016 but they were listed under the Standard Industrialisation Clarification (SIC) codes which are too broad for this enquiry (BIS, 2016, Graduate Labour Market Statistics).

An alternative source was found in Adzuna, the job-search website which analysed 1,000,000 vacancies in June 2015 and compiled a list of the top five graduate degrees by annual pay. Their salary analysis found:

- Civil Engineering £44,851
- Engineering £42,837

- Computer science £41,950
- Mechanical Engineering £39,106
- Mathematics £39,019

However, as Anderson reported, according to *Adzuna*, location had as much influence on salaries as the degree subject with Cambridge paying the highest salaries for graduate workers, and Cardiff paying "significantly less" than the national average (calculated from Adzuna's regional figures) at £26,316 (Anderson, E., 2015, *Graduates earn £500,000 more than non-graduates,* Telegraph, 16th July). But sourcing salary figures for the *Physical Sciences* and *Mathematical Sciences* from the *Complete University Guide* for 2016 gave a different picture for annual salaries:

- Physics and Astronomy £24,976
- Mathematics £24,110

By coupling the physical sciences with astronomy, the salary levels were likely to be downgraded since astronomy as a subject is less likely to have a commercial demand outside academia when compared to the commercial opportunities available to a physics graduate, although of course the data handling and analytical skills of an astronomer will hold a high STEM labour market value. Similar salaries (around £24,000 in this chart) were also paid to *Civil Engineering and Librarianship and Information Management*, while the higher salaries were paid to *Dentistry* at £30,348, *Medicine* at £28,674, *Chemical Engineering* at £28,674, and *General Engineering* at £27,452.

Salary levels did not therefore suggest that they were sufficiently attractive to be the sole driver for the rising trends seen in the *Physical Sciences* and the *Mathematical Sciences*, or for the evident resilience of those two subjects to the introduction of higher fees in 2013 as Figure 5.4(a) indicates. Alternative motivators are likely to include interest generated by the popularity of television programmes such as the Big Bang Theory which appears to have fashioned a new 'sexy' image of the 'geek'. Included also are the various physics based documentary programmes presented by Professor Brian Cox of Manchester University. While to the best of my knowledge there is no formal evaluative evidence available to support this theory of influence in the physical sciences, there is much anecdotal evidence of the so-called 'Brian Cox effect'. Adding to science interest is the publicity given to the search for the Higgs boson particle at the Large Hadron Collider, the particle accelerator at CERN. Policy initiatives, such as the new Further Mathematics Support

Programme and the Further Mathematics Network, which it replaced, would also take some credit for the increase in mathematics interest.

5.4.8 Computer sciences

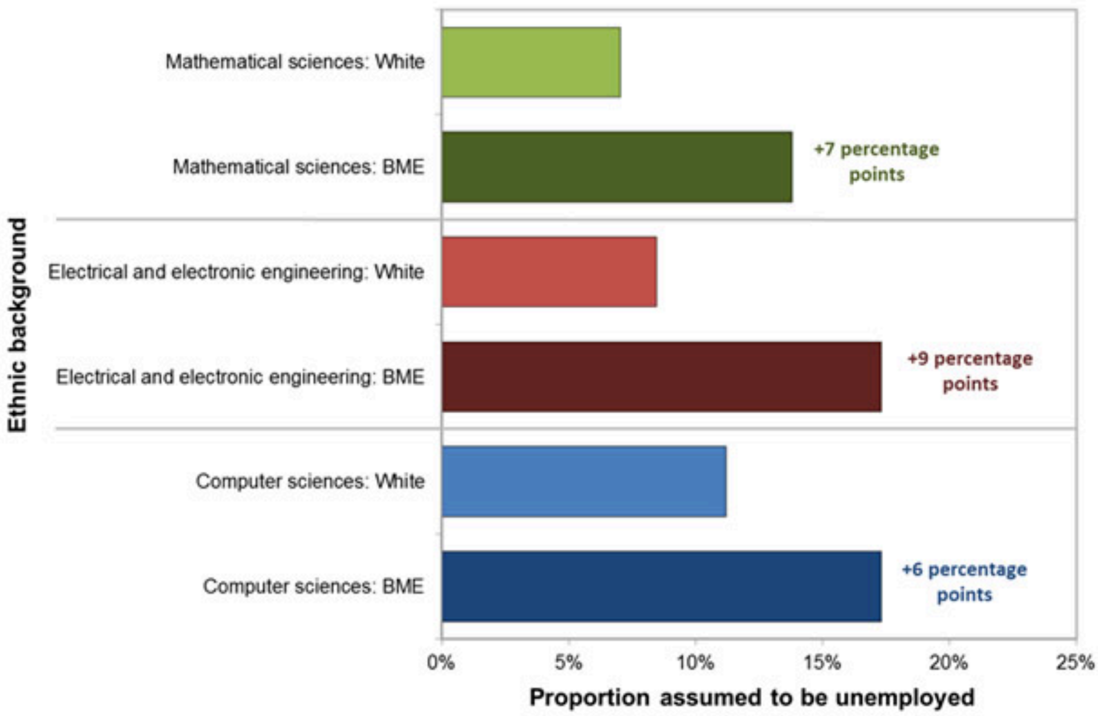


Figure 5.6: The percentage differential between (White) and (BME) assumed unemployed following graduation in Computer sciences, Electrical & Electronic Engineering and in Mathematical Sciences 2011-14

Note: The data is drawn from full-time first degree qualifiers whose ethnic background was known and who provided a valid re-sponse to the Destination of Leavers from Higher Education (DLHE) survey. Based on Qualifiers in academic years 2011-12, 2012-13 and 2013-14.

Source: Shadbolt, HEFCE: Destination of Leavers, Graph 4, Unemployment among computer science graduates, 08 July 2015:1

Many questions present themselves when considering the data relating to *Computer Sciences*. From a relatively high starting point in the time-series data with first-year full-time intake numbers at 35,000, the downward trend to 2008 (co-incident with the beginning of the global financial crisis), shows a weak recovery before the almost inevitable dip at 2013, and again a slight recovery to 2015 at around 25,000 (Figure 5.4 a). With the *Computer Sciences* listed by the job-search website *Adzuna* as among the highest paid categories of 2015, the first question is, was the drop in intake numbers reflected in the high salaries suggested by *Adzuna*, as might be expected in a demand-led market? And secondly have the relatively high salary levels been instrumental in the partial recovery of *Computer Sciences*, or were there other factors to consider?

Finally, it should be asked under what circumstance or circumstances did the downward trend occur, in a subject that has become not only a science in its own right, but a fundamental support to all the STEM subjects, and more generically, in daily life? The *House of Lords, Science and Technology Select Committee* in dealing with *Higher Education for Science, Technology and Mathematics* were able to offer a partial explanation. This was seen through the evidence given to the committee by stakeholders who suggested that tightening UK immigration rules for international students was perceived by many as 'unwelcoming'. As part of the government's move to control migration numbers the changes giving particular concern were those which were perceived to entail a lengthy and complex process of applying for a UK visa, increases in tuition fees and in the higher banked deposits required of students for their support over the duration of their course. Also seen as harsh was a new six-month limit to seek post-study graduate level employment (Science and Technology Select Committee 4th Session, 2013-14).

Coincident with the immigration changes was the notable decline in the number of overseas students from several countries including India. While some of the issues around international students are dealt with later in this chapter, a noted decline in the numbers of non-EU students, particularly from India, and from Pakistan and Bangladesh, appeared to have a significance for the intake numbers for *Computer Sciences.* Professor Colin Roirdan, as Vice-Chancellor of Cardiff University, for example offered his understanding of the international student situation to the Committee:

> *'What has shifted is where they are coming from. Like everybody else, we have seen reductions in students coming from India, but also from Pakistan and Bangladesh. I notice looking at the overall figures for the sector, specifically HESAs total entrants by subject from non-EU countries, which I am sure you have had, that computer science, for example has been quite badly hit. I have no way of proving that, but I would not be surprised if that was linked to the drop in the numbers of students from India, because we tend to get quite large proportions from those countries. It might be interesting to look at whether one could relate subjects to certain countries and see whether there is a correlation there.'*
>
> Source: Riordan, Oral and Written Evidence, Session No.3, House of Lords

Science and Technology Select Committee, International STEM students, QQ 32-41, 4 March 2014).

Although, as Professor Allison observed when giving evidence to the House of Lords Select Committee for International STEM students (4th March 2014), the loss at Loughborough University in student numbers from India was offset by higher numbers from China. Chinese students were however more likely to study business and economics than the STEM subjects. This suggests that simply increasing the overall numbers of international students may not necessarily help to boost domestic growth and maintain intake numbers of the STEM subjects particularly in *Computer Sciences and Engineering and Technology.*

This still leaves the question as to why *Computer Sciences* no longer appears to appeal to undergraduate students despite salary levels higher than those for *Mathematical* and *Physical sciences,* (Adzuna, 2015a, *Top five graduate degrees by annual pay*).

This was the question that prompted the Royal Society in 2010 along with the Royal Academy of Engineering, to appoint an advisory group to investigate the "dwindling intake" to Computer Sciences (Royal Society, 14, January 2014). The group was led by Steve Furber, Professor of Computing Engineering at the University of Manchester, and one of the designers behind the education-focused BBC Microcomputer System. The group's report, *Shut Down or Restart*? published in 2012, judged that that the way computer courses were currently designed and delivered at school as "highly unsatisfactory". This left pupils "not inspired by what they are taught" and gaining "nothing beyond basic digital literacy skills" (Furber, 2012, p. 5).

Michael Gove, then Minister for Education for the coalition government, reminding his audience at the 2012 BETT Show (the UK's annual showcase of education technology), of the "profound transformation" technology had already brought to education, announced his plan to consult on waiving the existing ICT curriculum as "too off-putting, too demotivating and too dull" in favour of allowing schools to make full use of the "amazing resources that already exist on the web". While the teaching of ICT would still be a compulsory school subject and the existing study programme would remain on the web as a point of reference, business and universities would be free to devise new courses, curricula and exams (Gove, 2012, *BETT speech, published 13th January* p. 7).

Although intake numbers for *Computer Sciences* had begun a slow upward trend from 2008 to a gentle peak in 2010, there was no immediate indication of a revival following Gove's policy change. Instead the numbers which had dipped notably at the 2013 data point, had recovered by 2014 and continued gently upward to the end of the data set, but still 29 percent lower than those recorded at the start in 2002-2003 as shown in Figure 5.4(a). It became clear however that concern for computer teaching in the classroom and the relatively low intake of HE numbers were part of a larger problem. If computer science skills were in high demand why was a consistently high level of unemployment for graduates recorded over the last decade, and why did many of those who were employed accept low-paid or non-graduate employment? (Figure 5.7).

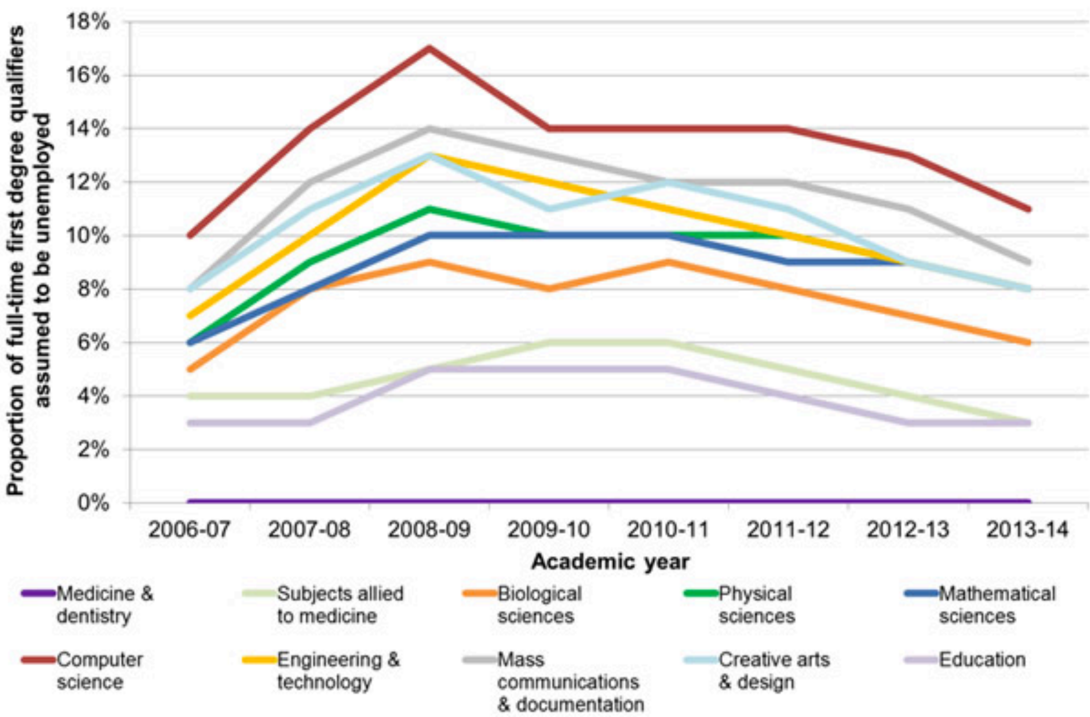


Figure 5.7: HEFCE's proportion of full-time degree qualifiers 2006-07 to 2013-14 assumed to be unemployed

Note from the HEFCE article relating to the above graph: Full Time-first degree qualifiers who provided a valid response to the Destination of Leavers from Higher Education (DLHE) survey Based on Qualifiers in academic years 2011-12, 2012-13 and 2013-14. Institutional grouping is defined by the average tariff score of an institutions young (under21) UK-domiciled undergraduate entrants holding level 3 qualifications which are subject to the UCAS Tariff

Source: HEFCE: Destination of leavers Graph 2, Unemployment among computer science graduates 08 July 2015:1

Professor Sir Nigel Shadbolt, head of the Web and Internet Science Group within the School of Electronic and Computer Science from Southampton University, was commissioned by the government to review the unemployment situation. In a preliminary examination of the data ahead of a full review report due in 2016, he wrote of the "distinctive profile of students" who studied *Computer Sciences*. It included a greater proportion of men to women, students from black or minority ethnic backgrounds (BME), and students with lower previous levels of attainment (Shadbolt, N., 2015, no pagination). The significance of the Shabolt's profiling account is seen in Figure 5.6 below where BME computer graduates are shown as six percentage points more likely to be unemployed than their white cohorts.

Figure 5.6 which spans the period 2011-2014, qualifies the findings with the statement 'Proportion assumed to be unemployed'. Although this suggested a degree of doubt about the findings, Zwysen and Longhi, four years later, after their own investigation into graduate unemployment, found a similar situation in that ethnic minority graduates were likely to earn less and were less likely to be employed compared to white British graduates (Shadbolt, N., 2015, no pagination).

5.4.9 Engineering and Technology

Prima facie, concern about an enduring UK shortfall in *Engineering and Technology* numbers appears to be confirmed by the data in Figures 5.4 (a) and 5.5(b). From around the end of the academic year 2002-2003, from a starting point of 27,000, first year full-time undergraduate intake numbers for *Engineering and Technology*, showed little growth for the next four years. The year 2008 however marked the beginning of a distinct rise which was maintained for the following three years reaching a high point of around 36,000 in 2010 despite the first indicators of the financial crisis appearing around 2007. Again a levelling in numbers over the next two year period followed by the familiar dip at 2013 when many universities increased their undergraduate fees to the maximum permitted £9,000 per year Figure 5.4. Again, like many of the JACS defined STEM subjects considered in this chapter, *Engineering and Technology* numbers recovered the following year and continued upward with numbers reached 2012 levels at around 34,000 by the end of the time-series data-set Figure 5.4.

Although there was a 7,000 gain in the full-time undergraduate numbers, when considering the measurement of intake numbers for *Engineering and Technology* over a twelve year period, growth was slow and at times stagnant. The results were little better for the first year part-time intake numbers at around 8,750 at the start of the time-series, as shown in Figure 5.5 (a) and (b). The numbers described an erratic pathway through the data-set, a rise, a levelling, a rise to 12, 000, followed by a drop and a recovery to 11,000, before finally falling below the starting point to their lowest over the time-series data at under 8,000.

These figures would seem to support concern about a persistent shortfall in numbers by a number of industry and engineering organisations. The Institute of Engineering and Technology for example headlined the chapter summaries of their *Skills and Demand in Industry 2015* report as “Recruitment trends and skills shortages”; “Filling the gaps-the role of education” and “Expanding and investing in the workforce”. The non-profit making organisation, Engineering UK which lobbies on behalf of the engineering community, estimated in their *State of Engineering Key Facts 2016* report, a projected need for 182,000 individuals *each year* (my italics) with engineering skills. The Institute of Mechanical Engineers (IME), however in quoting the same Engineering UK’s *State of Engineering 2016 report*, produced a figure of needing 69,000 *more* (my italics) engineers every year in Britain in addition to those already produced to meet industry requirements. The IME offered no specific time scales for the proposed increases (Institution of Mechanical Engineers, 2016).

The difference in the conflicting figures quoted in the above paragraph may be accounted for by the adverb ‘more’ when applied to the figure of 69,000 skilled workers. In this example, that could be taken to mean the difference between the projected annual overall future need of 182,000 quoted by Engineering UK’s *Key Facts* cited above, and the number understood to be currently produced. This example illustrates that the way figures are presented can lead to perpetuated assumptions and to misinterpretation, not withstanding the inexactitude of projection as a means of assessing future need. There are other concerns too about determining the level of recruitment to *Engineering and Technology* that moves beyond counting HESA statistics.

The question as to who might be considered an engineer was raised in 1998, by Glover, Tracey and Currie. In their opinion, “The title ‘engineer’ needed to be restricted to graduates to stop engineers being confused with technicians” (Glover et al., 1998, p. 207). The question is evidently longstanding and persistent. In 2010, Dick Olver chairman of the defence company British Aerospace Engineering (BAE), also argued that the term ‘engineer’ was misused when applied to those with limited technical qualifications: “Britain suffers from a language problem in that the word ‘engineer’ is applied to a lot of different people who do a range of jobs”. The solution as Olver saw it was that “Professional Engineers need to take ownership of the brand and keep it for themselves”. His comments were directed towards gas fitters, plumbers and others using the title (Gribben, R., 2010).

Olver’s argument was that misuse of the term ‘engineer’ was harming recruitment to the profession. At the time of Olver's comments in 2010 more than 16,500 professional engineers were employed by BAE Systems (Gribben, R., 2010). Olver may have read the recruitment situation with some accuracy, but failed to offer a convincing explanation for the recruitment patterns, the rises, the drops, and the stagnation seen in the levelling of numbers, over several years as seen in Figures 5.4 and 5.5.

The question of choice for potential engineers amongst the many current pathways to engineering and technology adds a further area of complexity. For students seeking the course best suited to their abilities and interests, for employers seeking staff with apt and recognisable qualifications for the job, and for those attempting to calculate the supply numbers for *Engineering and Technology*, a recent government initiative for post-16 technical education offers a more streamlined and straightforward approach.

The initiative, the government's Post-16 Skills Plan was published in July 2016 and hailed by the Royal Academy of Engineering (RAE) as "...the most significant transformation of post-16 education since A levels were introduced 70 years ago".The report chaired by Lord Sainsbury, was in response to the recommendations made into technical education. The Sainsbury inquiry found that those seeking a technical education were obliged to select their pathway from over 20,000 courses offered by 160 different organisations. Those deciding on an engineering course had to make their choices from 501 different courses (RAE, 2016, p. 1). The Sainsbury recommendations, published at the time of the government's response, suggested that not only was there a confusing multitude of courses on offer, but the qualifications gained were not understood or valued by employers and likely to be of poor quality and unfavourably compared to those acquired academically. At the time of the Sainsbury inquiry there were 13,000 possible qualifications young people could acquire (Sainsbury, D., 2016, p. 6).

Against such a plethora of technical and engineering routes and qualifications, several issues are highlighted. Firstly that the huge variety of pathways to employment may help to explain the inconsistent graduate recruitment patterns over the years for those treading the academic route as seen in Figures 5.4 and 5.5, and secondly, the difficulty of seeking and examining reliable and available data about the many current alternative routes to *Engineering and Technological* qualifications. Keith Lewes the managing director of the engineering recruitment company Matchtech seeking to explain why more young people do not enter the profession suggested in *The Engineer* that students were unable to understand the range of opportunities available within the profession (Harris, S., 2014, p. 3).

A further consideration in terms of recruitment numbers is the UK's international students. This was looked at in some detail for the *Computer Sciences* above taking particular note of the recent dearth in the UK of students from India where the evidence presented to the House of Lords Select Committee for International STEM students suggested that in addition to the *Computer Sciences* they were also likely to choose other STEM subjects such as *Engineering and Technology*. The RAE presenting their evidence suggested that a proportional figure of 24 percent of non-EU students had contributed to the engineering intake in 2014 (Science and Technology Select Committee, 2014, p. 342).

It is also noted that unemployment in electronic and electrical engineering appeared to follow the trend identified in Computer Science above, that graduates who are black or have an ethnic minority background (BME) are more likely to be unemployed than their white cohorts (Zwysen & Longhi, 2016, p. 1). As already mentioned in the analysis of Computer Sciences recruitment numbers, only counting intake numbers will clearly have implications for calculating the supply of UK engineering graduates.

5.4.10 HESA STEM part-time undergraduate data

The part-time undergraduate numbers are considered alongside their full time counterparts in the examination above. The numbers are slight compared to the full-time STEM intake particularly when converted to their full-time equivalent (FTE) where two part-time students are taken to be the equivalent of full-time student. Nevertheless they are an important addition to the overall supply of STEM skills, but usefully analysing recruitment patterns is likely to be challenging. The variables involved in part-time study recruitment while sharing the subject specific limitations and constraints of the full-time recruitment, present additional variables which will influence recruitment. They are likely to include a range of socio-economic factors affecting the study choices of individuals which though important are beyond the scope of this thesis to consider.

There are however some general data to be drawn from Figure 5.5 which plots the part-time undergraduate numbers. With the exception *Biology and Mathematical Sciences* and perhaps unexpectedly, *Agriculture and Related Subjects*, all other STEM subjects have suffered a decline in the part-time STEM intake across the time-series data set. Of these the most dramatic decline was seen in the *Computer Sciences* where intake numbers of over 14,000 thousand were recorded in 2003. By 2015 they had dropped to 4,000 representing a decrease of around 70 percent, dramatically exceeding the decline seen in the full time figures. Notable also, along with *Mathematics*, *Biological Sciences* and *Subjects Allied* *to Medicine*, was the 2013 dip in intake numbers. With the exception of the *Biological Sciences*, *Mathematics* and *Agriculture and Related Subjects* all other subjects finish at a lower number by 2015 than at the start of the data set in 2003. However in general terms roughly between 2006 and 2012 intake numbers showed a short-time gain. One possible explanation was the loss of UK jobs through the global financial crisis from around 2007, which may have encouraged a return to education.

The second stage of the undergraduate data collection, the statistics of the qualifications awarded, is presented in the next section.

5.4.11 Qualifications: First degree

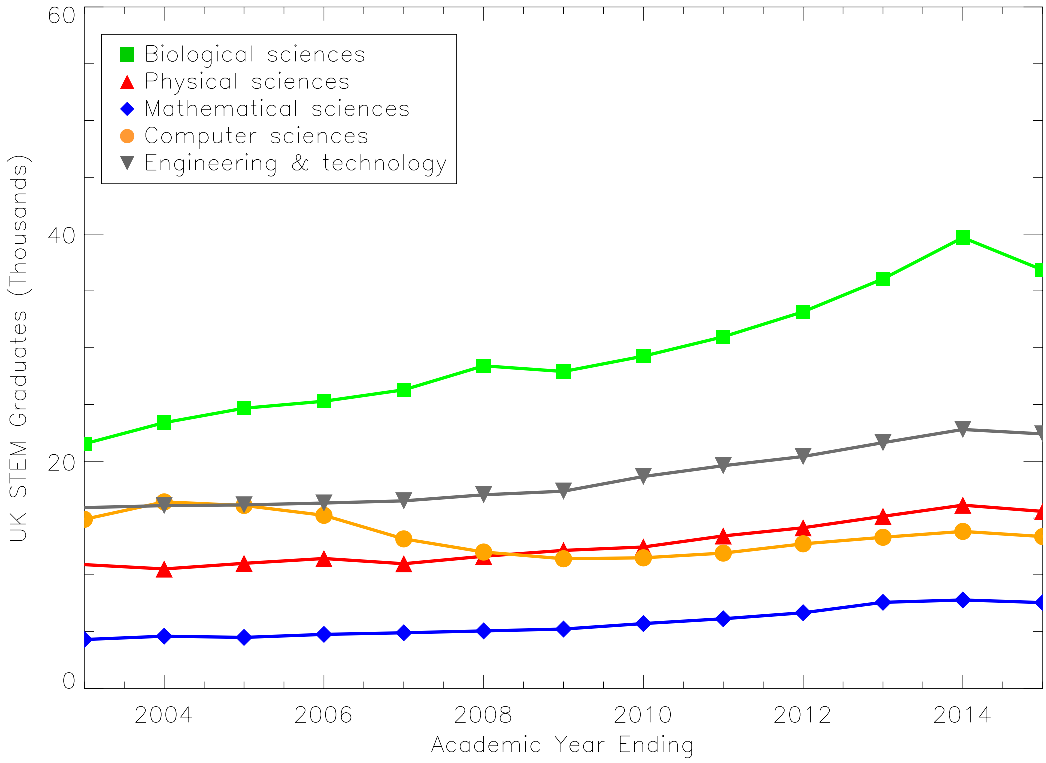
The ten STEM subjects are again divided into two groups of five and shown in paired data plots (Figure 5.8) The full and part-time results are combined in these two plots (FTE).

Although all five subjects shown in Figure 5.8 (a) finish the time-series data in a downward turn, overall the number of qualifications awarded show an increase over the research period. The exception is *Computer Sciences* where early growth in the qualifications awarded in 2003-4 and 2004-5 was offset by a later decline. Although there was some minimal recovery the earlier swell in numbers was not recovered by the end of the data-set.

The result was largely in line with the growth in intake figures (Figure 5.4) assuming a lag time of three years. The data peak across all subjects, particularly notable for the *Biological Sciences*, at 2013-14 shown in Figure 5.8 (a) would appear to reflect a rush for undergraduate university places ahead of the fee rise in the year 2012-13. The attrition rates for the time-series data set were not examined in this analysis.

For *Medicine and Dentistry*, a lag time between four and six years spent at university can be anticipated for medical students, and five years at university for dental students. With numbers strongly controlled for *Medicine and Dentistry*, flatlining qualification results would be expected where there is little attrition over the course duration. This is reflected in the data, see Figure 5.8 (b).

There are also a number of constraints affecting intake numbers for *Agriculture and Related Subjects* which act to keep intake numbers and qualifications down (see Section 5.4.6), where plotted results appear as all but flatlining, any increase in the numbers of students obtaining qualifications will be in the hundreds rather than thousands. Regarding *Subjects Allied to Medicine*, despite year-to-year variations in both full-time and part-time undergraduate intake the qualification graph indicates a surprisingly, almost linear rise. Most professions incorporated into the category *Allied to Medicine* usually spend three years at university taking their first degree. It would be expected that the results would reflect recruitment patterns with a three year lag period. HESA however, incorporates full-time and part-time results together; see the graduate results in Figure 5.8. The results therefore are not seen to reflect the undergraduate full and part-time intake patterns shown in Figure 5.4 and 5.5.



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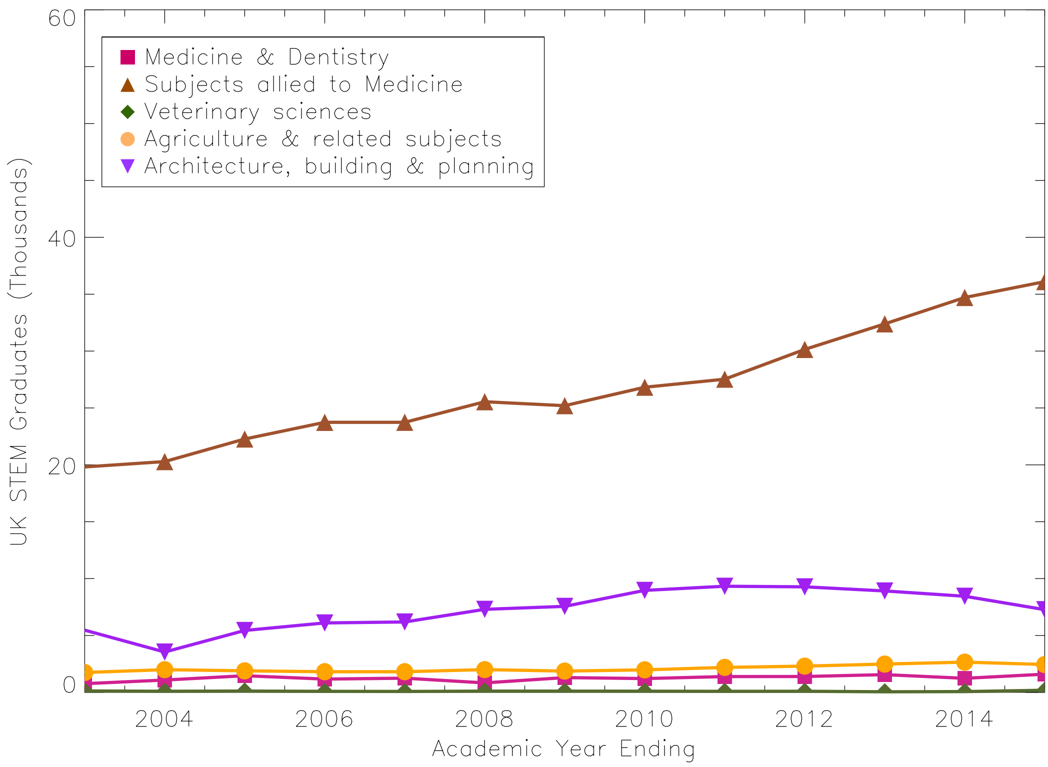


(b)

Figure 5.8: (a) and (b) UK STEM Graduate Results: The First Degree results include First, Upper 2nd and Lower 2nd degrees. Note however Medical degrees (b) are not graded. All results show Full time Equivalent (FTE)

Data source: HESA tables listed in Appendix A

5.5 Destination of first degree leavers

The destination of leavers is the final stage of the three-part undergraduate data collection process. Table 5.3 illustrates the destinations of STEM first degree graduate leavers six months after graduation averaged over a nine-year period from 2006 to 2014. Table 5.3 gives an overall insight into graduate employment and study status.

Table 5.3: Destination of STEM first degree subject specific leavers six months after graduation: results averaged over 2003 to 2015

Data Source: Higher Education Careers Services (HECSU) *What do graduates do?* for the years 2006 (the earliest year available from this publication) and annually until 2015 when the figures for 2014 were published. This particular data source was selected for its disaggregation of the STEM subjects.
Note: The plot was compiled by combining the annual percentage for each STEM subject listed and averaging the results over the nine years of the data-set.
* Unemployed, including those due to start work.

	In UK employment	*Unemployed	In overseas employment	In further study	Working & study	other
Biology	44.6%	9.3%	1.8%	25.1%	6.9%	12.3%
Chemistry	42.2%	7.8%	1.4%	34.1%	5.8%	8.7%
Physics	35.9%	9.5%	1.5%	35.6%	7.6%	9.9%
Computing	62.6%	13.0%	1.2%	8.6%	4.4%	10.2%
Mathematics	45.0%	8.3%	1.5%	23.5%	11.9%	9.8%
Civil Engineering	65.9%	7.3%	2.4%	9.8%	7.3%	7.3%
Electrical & Electronic Eng.	62.1%	10.6%	1.6%	11.2%	5.4%	9.1%

Table 5.3 is not able to indicate clearly whether those in employment are employed in their study subject. But a reasonable assumption is that the subject classification relates to the graduation subject. As such it gives an overall insight into subject specific STEM graduates employment and study status.

The subject group enjoying the highest levels of employment (in this data set) were the *Civil Engineering* at 65.9 percent while at 7.3 percent they also had the lowest level of unemployment. The employment pattern for *Physics* was reversed, with the lowest employment rate in Table 5.3 at 35.9 percent balanced by the second highest level of unemployment. *Computing* showed the second highest level of employment, but conversely was also found to be the highest unemployed group. This indicated that the group's involvement in other activities such as working overseas, in further study, working and study, and the unspecific 'other' would be low. According to Table 5.3, this proved to be so. Particularly notable for the *Computing* was the low levels of engagement in further study, and in combining work and study.

This low level of engagment for *Computer Sciences* (called *Computing* in the table) with further HE study was not wholly supported by the HESA data shown in Figures 5.10 (a) and 5.11 (a). Although both full and part-time numbers were in decline by the end of the time-series data, overall the numbers opting for further study appeared reasonably substantial relative to the other STEM subjects. For example, full time *Computer Sciences* postgraduate numbers stood at 7,000 with part-time numbers at 1,750. In comparison the intake numbers for full time *Physical* and *Mathematical Sciences* were around 8,750, and 2,750 respectively. For the Postgraduate part-time *Physical* and *Mathematical Sciences* intake numbers were under 500, and around 1,300 respectively, which for the *Mathematical Sciences*, was somewhat less than for *Computer Sciences*: Figures 5.10 (a) and 5.11 (a).

Table 5.3 also highlights the relatively small number of graduates from STEM subjects who have sought overseas work over the last nine years within six months of their graduation. While *Civil engineers* are seen as those most likely to work overseas due to the global locus of their profession, Table 5.3 shows a very small percentage of STEM graduates seek work overseas. This implies those who remain in the UK are available for graduate level work in the UK. Similarly with those STEM graduates who choose not to further their education after graduation, they too are assumed to be potentially available for graduate-level work in the UK and are counted as part of the STEM supply numbers, (see Table 5.3).

Of those choosing to pursue their academic careers, Table 5.3 shows that the *Biologists, Chemists*, and those engaged in *Physics* and *Mathematics* are among the most likely to engage with further study, although as seen for *Mathematics*, the numbers are not necessarily high.

Finally, Table 5.3 also shows the percentage numbers of those STEM Graduates who were unemployed six months after graduation. The figures are noteworthy when considered against widespread claims of a shortfall in STEM graduates. It is also somewhat surprising to see, according to Table 5.3, *Computer scientists, Mathematics* and *Physics* students, and *Electrical and Electronic Engineers* in particular, despite popular and widespread concern about their poor growth numbers over the preceding years, are also among the highest of those listed as unemployed.

While statistics are able to highlight inconsistencies in data, further qualitative research may be able help to answer the question of why, when STEM skills are understood to be in short supply against labour market demand, significant levels of unemployment in these fields are also apparent. The next section overviews the postgraduate intake and qualifications.

5.6 Examining HESA STEM Postgraduate data

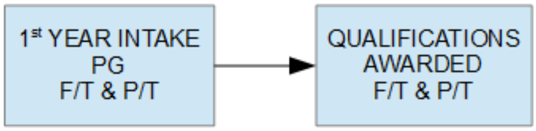


Figure 5.9: A diagrammatic model of the census points along the PG STEM supply chain at which data was collected. Source: Own interpretation of the data collection approach.

The postgraduate STEM intake numbers, with two exceptions, *Veterinary Sciences*, and *Computer Sciences*, all show a rising trend over the time-series data. In some cases the increases are substantial. While undergraduate *Medicine and Dentistry* levels flatline across the time-series, the postgraduate numbers show a 100 percent increase from a starting intake figure of around 2,600 to the end of the the data set. The increase is a reminder that students who start a medical course as a second degree are responsible for their own tuition fees at this level, and that subsequently, intake numbers are not constrained by the same limits as the medical undergraduates. A further indicator that the medical and dentistry students are fee paying is seen in the 2013 dip in intake numbers and the steeper increase prior to 2013 as students apparently rushed to beat the fee increase: Figure 5.10 (b).

Subjects *Allied to Medicine* have also substantially increased their numbers by an impressive 154 percent with the numbers levelling at 10,000 at the 2015 data point. *Biological Sciences* and *Mathematical Sciences* also show significant increases in their numbers by 106 percent and 71percent respectively at postgraduate levels, while the *Physical Sciences* have shown a rise in intake numbers of 42 percent. *Engineering and Technology*, a STEM subject long seen as one of perpetually inadequate numbers to meet demand, particularly a projected future demand, shows a rise over the time-series data of 6,000 prospective engineering graduates. Notably *Engineering and Technology*, starting at around 12,000 finished strongly representing a 54 percent increase in intake numbers.

Most notable about the full-time postgraduate STEM intake figures shown for the two graphs: Figures 5.10 and 5.11, with the exception of the *Veterinary Sciences*, are the four to five year positive curve shaped increases which is evident at the 2008 data point and truncated at the 2013 dip in numbers. *Computer Science* intake figures are shown falling both before and after the curve increase, but in all other cases the curve interrupts an upward trend. While the 2013 dip which is correlated with the increase in university tuition fees appears to be ubiquitous in most of the STEM subjects analysed in this chapter, this is not sufficient to explain the curved shape increase which represents an overall increase in postgraduate intake numbers.

A feasible explanation for this discrete 'curved' increase from 2008 is that it reflects UK job losses which ran into the hundreds of thousands at that time as a result of the global financial crisis (Dunkly, 2008). Where jobs are scarce further education may be seen as the best way to optimise employment chances when the situation stabilises and recovers. The 'curved' increase is a common phenomenon seen in all subjects in Figure 5.10 (a) and (b).

The context of the *Computer science* intake numbers for postgraduate STEM students for the *Computer Sciences* has shown a greater volatility than seen in the undergraduate numbers. Starting at around 9,500 in 2003, the downward trend for the full-time postgraduates was sharply reversed after 2008 to a four year rising curve which peeked in 2010 to just under 11,000 before falling to the 2013 data point, ubiquitous now in most of the STEM subject analysis and commonly correlated to the rise in tuition fees. But in this case the intake numbers were already falling. Although the rise in tuition fees was a probable agent affecting intake numbers at the 2013 point, it is not sufficient to explain why the numbers were already falling.

For the *Engineers* and *Technology* postgraduates the slight recovery after 2013 was followed quickly by a further decline which saw numbers drop to the 2013 level by the end of the data set. Postgraduate *Mathematical Sciences* and the *Physical Sciences* students however both show a slow but positive upward trend in their recruitment numbers particularly for the *Physical Sciences*, with both *Mathematical* and *Physical Sciences* barely registering the 2013 dip Figure 5.10 (a). All other subjects affected by the 2013 dip recovered intake numbers by the following year.

The popularity of the *Subjects Allied to Medicine* appeared undiminished at the PG level for the first year full-time intake numbers. The downturn in the upward trend seen at 2012 however is likely to reflect student concern about changes to funding which took effect for NHS degree courses starting after the 1st September 2012. For eligible students tuition fees were free (and still are for now) even at the postgraduate level (Gov.UK, 2016) which helps to explain the growth in this sector.

Medicine and Dentistry numbers for full-time postgraduates however showed what initially appeared to be a surprisingly steady growth over the time-series data set particularly when considered against the stability of the undergraduate numbers for this subject. Starting at around 2,750, by the end of the 2015 data set numbers had reached around 5,200. Although both undergraduate and postgraduate numbers were collected over the same period, assuming a period of six years for the primary medical study required for a first medical degree, and accounting for the lag time, the post-graduate figures might be expected to reflect those of the undergraduates. Apart from the very slight dip in both sets of intake figures at the 2008 data point in line with the timing of the global financial crisis, there was no clear correlation seen between undergraduate and postgraduate figures.

One explanation is that many of the postgraduates were studying *Medicine and Dentistry* as a second degree subject where they were expected to make a major financial contribution to their medical training (Malcolm, 2013). This explanation means that first year intake *Medical and Dentistry* students would be paying their own fees, a situation likely to account for the drop in postgraduate in-take numbers for *Medicine and Dentistry* at the 2013 data point (Figure 10).

Agriculture and Related Subjects showed some slight upward movement overall in the full-time postgraduate recruitment figures. Though the growth is seen as no more than in double figures at the end of the time-series data set, it does show a continuing interest in the subject, but whether the growth in supply is significant in terms of benefitting the sector's productivity is difficult to judge. In 2013 a review by DEFRA about the future of farming acknowledged that the number of new entrants graduates and postgraduates, skilled and unskilled farm workers were needed "now and in the future". This is a sector which intended (in 2013) to be proactive in widely promoting the interest of the sector and increasing the supply of agriculture students (DEFRA, 2013). While those who may aspire to farm ownership face a number of challenges and constraints which include the increasing role for technology in farming, the rising cost of farmland, and the scarcity of council farms to rent for those unable to inherit, the increase in recruitment may indicate an increase in employment opportunities in the agricultural sector.

The *Veterinary Sciences* at Postgraduate level however were still seen bumping along the base of the graph. Places are likely to remain strictly controlled. Reasons given were a lack of clinical training opportunities and to prevent a downward pressure on salaries (BVA, 2013, p. 3).

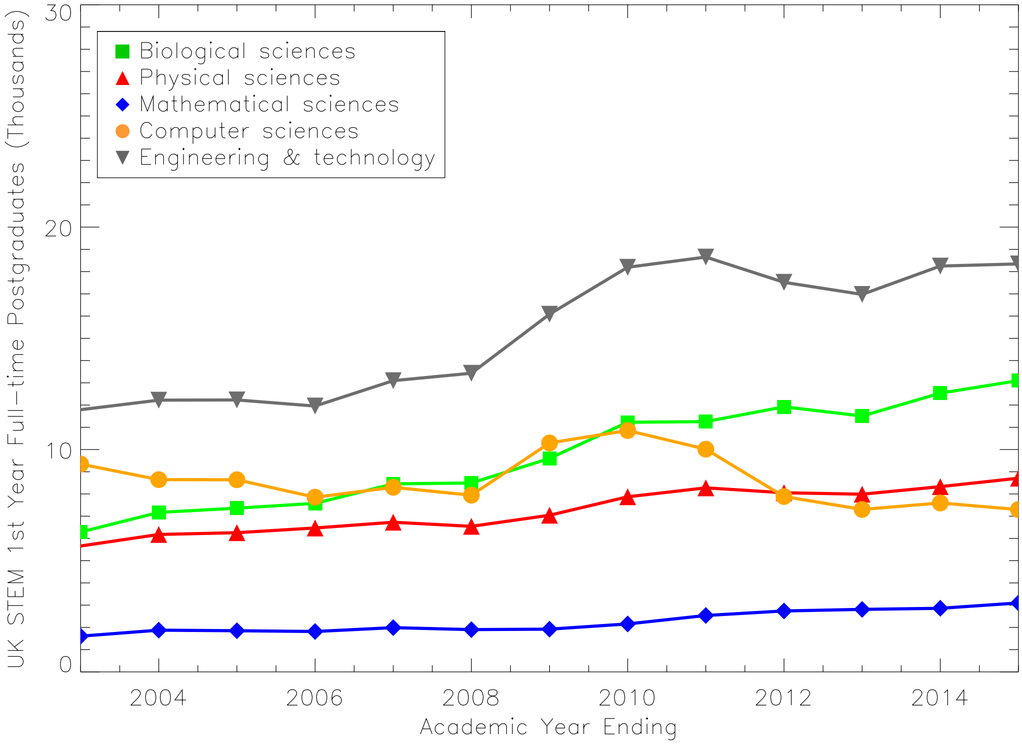
5.6.1 HESA STEM part-time postgraduate data

Against an increase of full time students for the *Mathematical Sciences*, the part-time intake for this subject shows a downward trend over the time-series data. *Engineering and Technology* makes a strong but volatile showing with an overall increase between start and end points, while the *Biological Sciences*, equally volatile and starting from the same point, show a greater increase in intake numbers, see Figure 5.11 (a).

Part-time postgraduates recruits for *Subjects Allied to Medicine* show a strong upward curve with some deviation from an equally strong start at around 12,000 recruits. It is a reminder that the NHS is likely to be paying students postgraduate fees at this time. *Medicine and Dentistry* shows a slight rising trend from the start of the time-series data although a dip at 2014 suggests the beginning of a downturn into 2015. *Agriculture* was also seen as showing an upward movement from 2008 onward. *Mathematical Sciences* and particularly *Computer Sciences* both exhibit a downward trend from a relatively strong start: Figure 5.11 (b).

As seen in the full-time postgraduate data the 'curved' increase is also evident in the part-time numbers from 2008 to 2011-12 (Figure 5.11). This suggests a similar explanation. That is, first degree graduates seeking employment in their study subject, at a time when job loses in the UK followed the global financial crisis, the scarcity of jobs in their field may have encouraged a return to postgraduate education. As part-time students it could be assumed they are combining casual employment with study.

The 2013 dip in recruitment numbers, seen in the intake data examined in this chapter, is not evident in the part-time postgraduate data, with the exception of *Computer Sciences*. At this time there is no obvious explanation for this anomaly.



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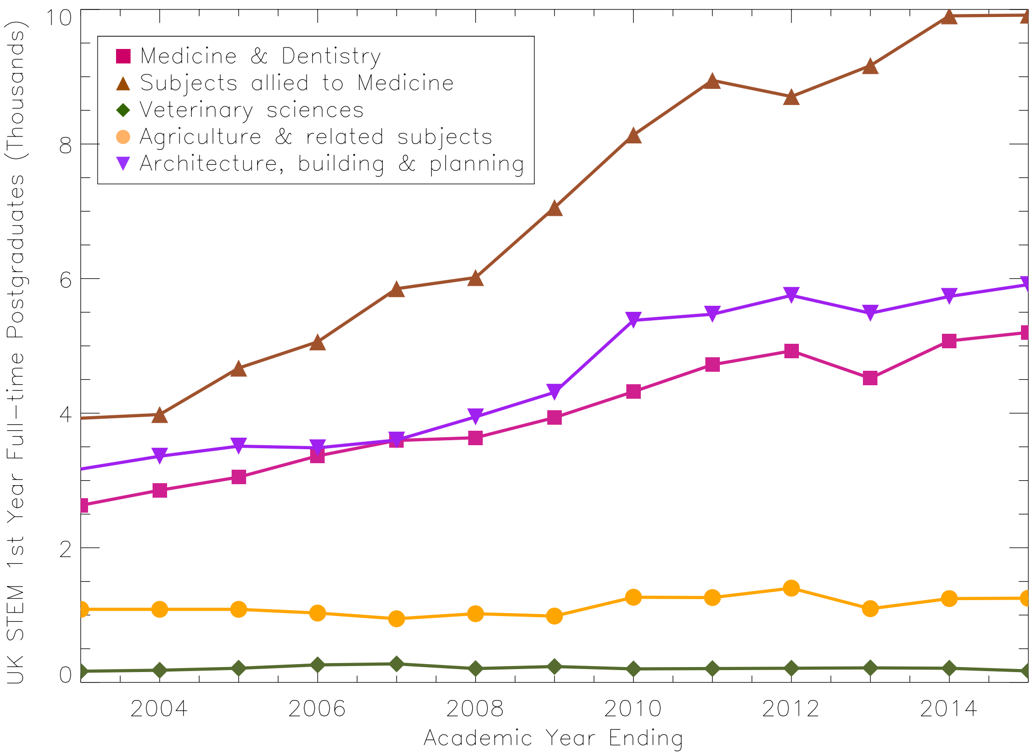
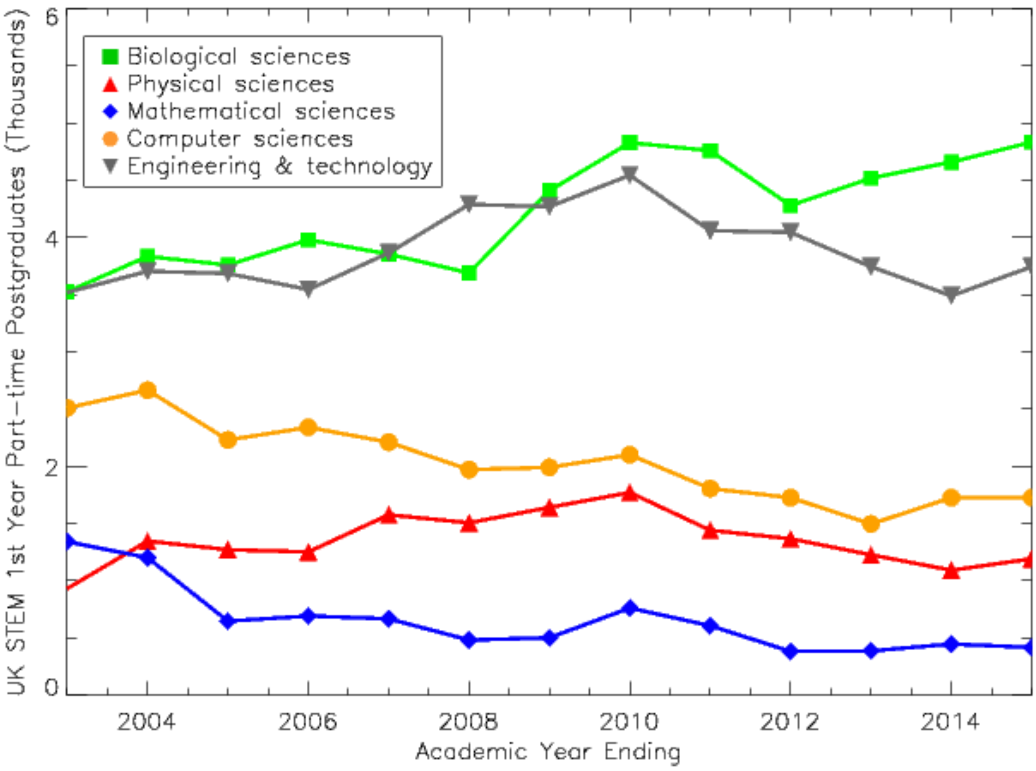


(b)

Figure 5.10: (a) and (b) UK STEM 1st Year Full-time Postgraduates

Data source: HESA tables listed in Appendix A



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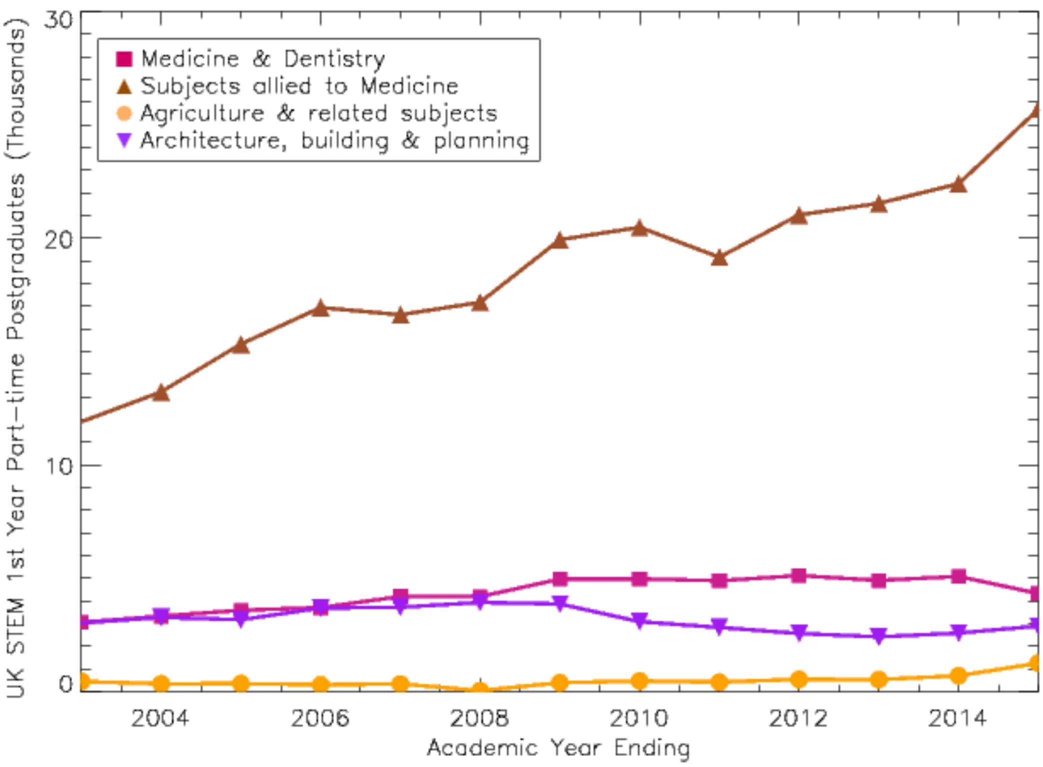

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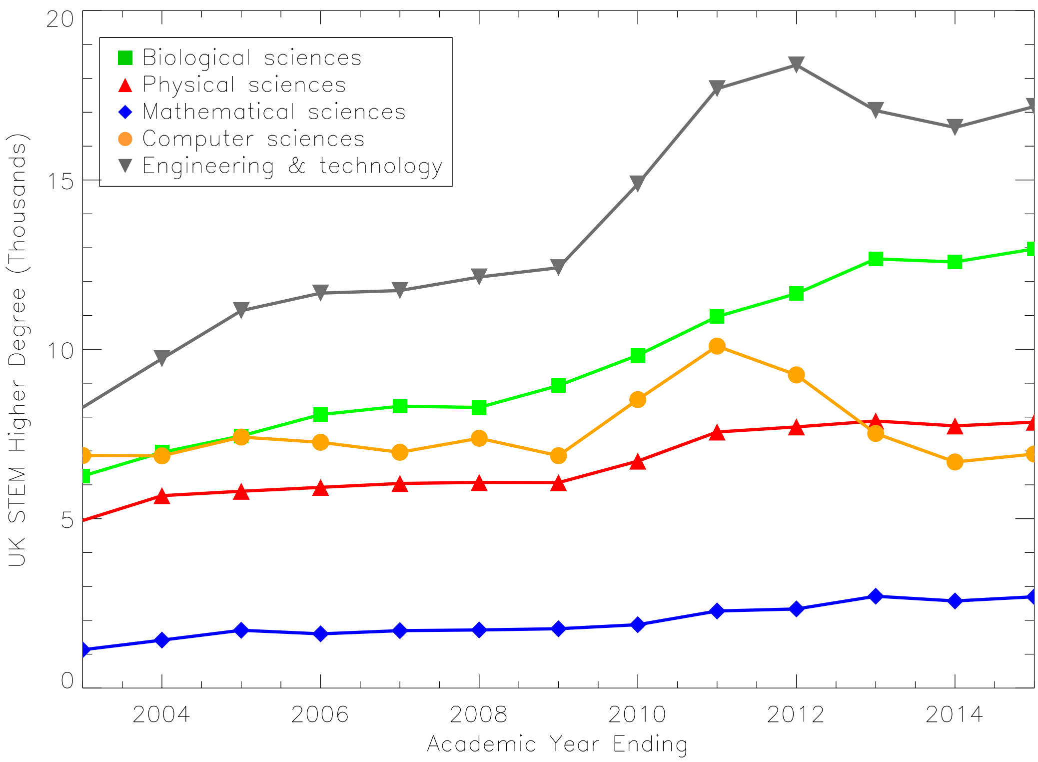
Figure 5.11: (a) and (b) UK STEM 1st Year Part-time Postgraduates

Data source: HESA tables listed in Appendix A



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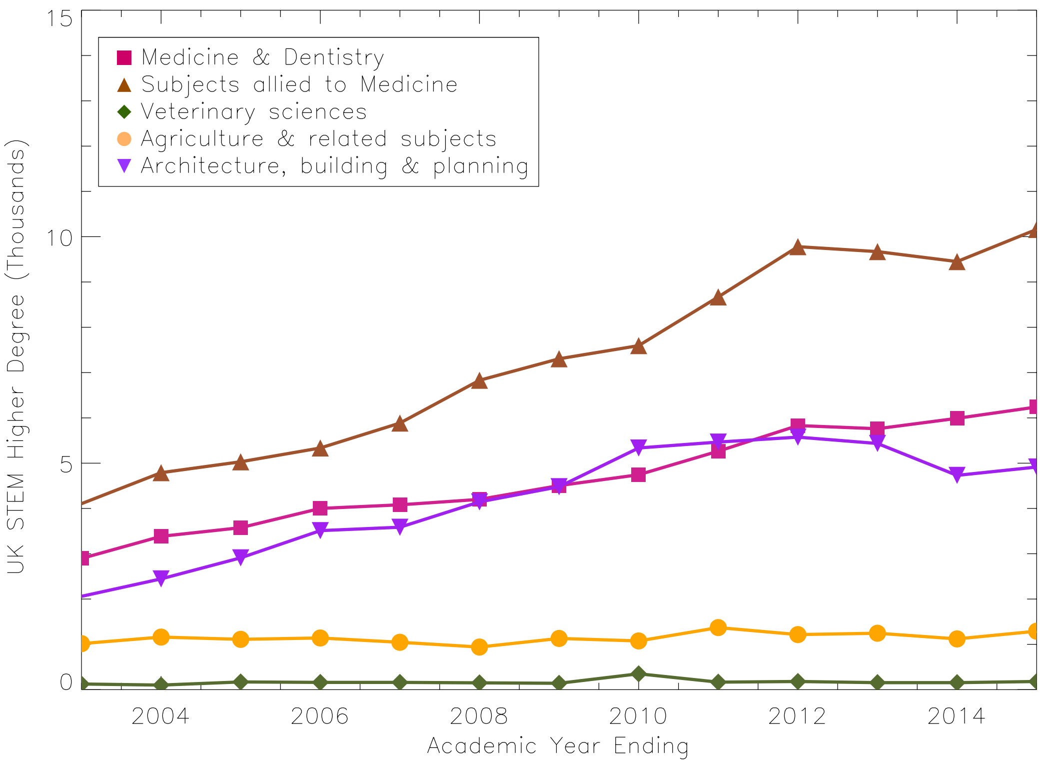

(b)

Figure 5.12: (a) and (b) UK STEM Higher Degree. Doctorate and other Higher degrees, excluding postgraduate certificates etc. Graph shows Full time Equivalent (FTE) from 2006 to 2014

Data source: HESA tables listed in Appendix A

5.6.2 Postgraduate results

STEM graduation numbers in general showed a clear rise across the majority of subjects over the data time-series. Particularly notable in the postgraduate results is the 107 percent rise in qualifications awarded in *Engineering and Technology*. This represents a difference of 8,900 between the number of postgraduate degrees awarded in 2003 to 2015. Also notable is the increase in awards for *Physical* and *Mathematical Sciences* of 56 and 180 percent respectively (Figure 5.12).

5.6.3 STEM intake figures for all subjects other than *Medicine and Dentistry* and *Subjects Allied to Medicine*

In 2013 the UK coalition government announced the intention to remove the cap on overall university intake numbers in a move towards a more demand-driven higher education system (Hillman, 2014, p. 1). Government control however on the specific subjects *Medicine and Dentistry*, and *Subjects Allied to Medicine* (which includes nursing numbers) as discussed earlier was not relinquished. Figures 5.4 (b) and 5.5 (b) showed numbers for Medicine and Dentistry although consistent had all but flat-lined over the period of the time-series data-set. This was assumed to reflect the tight control of annual intake numbers of medical and dentistry students rather than a narrowly consistent student interest. Also subject to government control but showing a very different intake pattern were the numbers for *Subjects Allied to Medicine*: Figures 5.4 (b) and 5.5 (b) which traced a very erratic growth and decline pattern over the period under observation. One suggestion for this is that workforce planning by the NHS and Department of Health under government guidance promoted recruitment drives that were regularly succeeded by constraint in recruitment.

Since growth in these two categories appeared to be significantly influenced by workforce planning and government budgetary considerations, removing them from the HESA collected data is included in this examination to offer a clearer picture of the overall growth of the other STEM categories examined in this chapter (see Figure 5.13).

As shown in Figure 5.13 without the categories *Medicine and Dentistry* and *Subjects Allied to Medicine*, the numbers for all other STEM subjects showed a more distinct growth curve over the time-series period starting at around 190,000 and finishing just short of 250,000. The dip in growth at 2013 was also more pronounced in this attenuated figure as expected as fee paying graduates responded to the higher tuition charges. Figure 5.13 shows numbers falling at this point to below 2009 levels. Recovery was typically swift

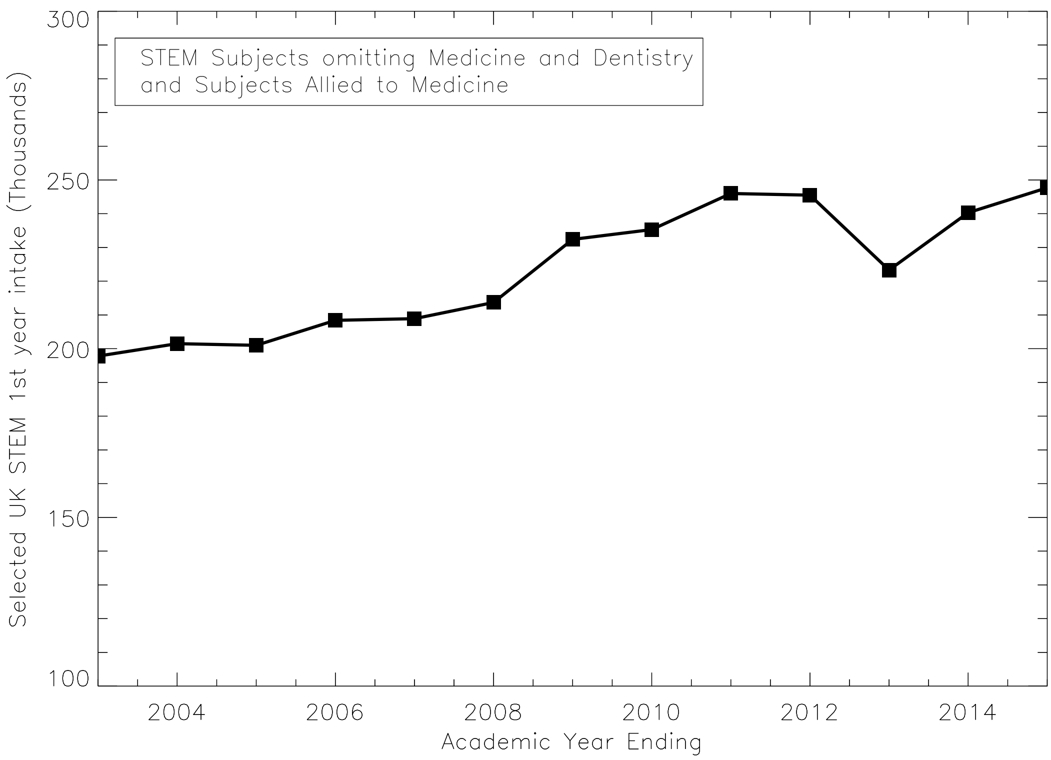

Figure 5.13: First Year Intake figures for UG and PG STEM both Full and Part time (FTE), UG and PG for the academic years ending 2003- 2015 excluding Medicine and Dentistry and Subjects Allied to Medicine

Data source: Amalgamation of HESA tables listed in Appendix A

and the remaining aggregated STEM numbers appeared to be set for further growth by the end of the data set (Figure 5.13).

5.7 The contribution of international students to the supply of STEM graduates in the UK

5.7.1 Introduction

Although some aspects of STEM international student intake have been considered earlier in this chapter to help to explain recruitment patterns in *Computer Sciences* and in *Engineering and Technology*, the further contribution of overseas students to UK higher education, and the tension that exists between their potential to augment UK STEM skills, and the concern their numbers present to the government's immigration policy, is further discussed in this section.

The importance of attracting students from overseas is essentially twofold. The first is the less tangible contribution of international students to UK university life. This encompasses the academic, intellectual and cultural vibrancy of the university and the enrichment of the experience to students. Secondly, and more measurable, are the financial benefits intentional students bring to UK universities. This covers issues such as the direct payment of substantial tuition fees which also help to support courses for domestic students, particularly the taught Masters (Lords Select Committee, 2014a). In addition, the Financial Times newspaper reported that in London alone, in 2015, international student spending was calculated to make a net contribution to the UK economy of 2.3bn annually while supporting 70,000 jobs in the capital (Warrell, 2015). Understandably, attracting international students has become a highly competitive endeavour where any indication of a lack of growth or decline is likely to be viewed with concern.

5.7.2 The evidence for the decline in international student numbers

Figure 5.14 replicated below, appeared as evidence of a decline in international student recruitment in the 2013-14 Report of the House of Lords Select Committee for international STEM students.

Figure 5.14 shows international STEM students entering UK higher education for the period 2002/03-2012/13. It shows a decade of gradual but consistent growth in the numbers of non-EU international STEM graduate and postgraduate student entrants studying in the UK, reaching a peak of 60,000 at 2010/11. Thereafter, the growth trend reversed falling to around 54,000 by 2012/13. Focusing on government reforms to the UK immigration policy, the Lords considered the possibility that the changes may have been instrumental in the diminishing recruitment numbers. An inquiry was set up calling for

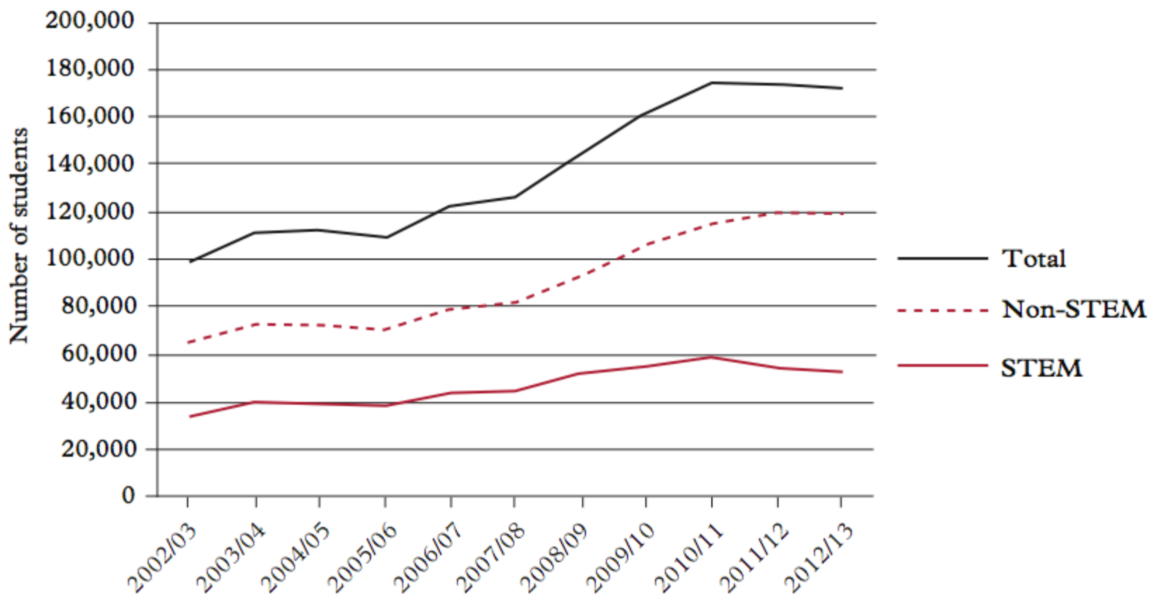

Figure 5.14: Number of international STEM and non-STEM entrants to UK Higher Education Institutions from non-EU countries (undergraduate and postgraduate

Source: HESA-data provided by BIS cited in the *House of Lords Science and Technology Select Committee* report of 11th April 2014 *Inquiry into the supply of International STEM students to the UK 2014*

evidence from a number of wide ranging stakeholders. They included the representatives of UK universities and institutions, government departments, MPs, and student unions, HEFCE, UK research committees and councils, and professional associations, and the British Council.

5.7.3 The Lords urge the government to reconsider the immigration policies affecting international students

Evidence given over the course of the inquiry strongly suggested to the Lords that despite the government's claims that the UK welcomed genuine international students, the stringent measures used to curb immigration numbers were a contributory factor in the decline of international student numbers. Those understood to particularly affect HE students included the complexity of obtaining a UK visa and the newly reduced post-graduation time limit in which to seek graduate level employment.

In 2014, Lord Krebbs, chair of the Lords Select Committee, said of the situation:

> *'When we really need to send the message that international STEM students will get a warm welcome in the UK, they've been getting the cold shoulder and*

> *heading elsewhere. We've seen in the last few years how international students numbers have fallen dramatically in particular from India. We're missing out on the talent, the economic and cultural contribution that international students bring when they come here to study, and our competitors are reaping the rewards'.*

Continuing, he added:

> *'We are calling on the Government to overhaul its immigration policies - in particular it needs to do away with the new rules on working after study. Allowing just a few months for a student to find work after graduation is more or less tantamount to telling students they'd be better off going to study elsewhere. Lord Krebs, Select Committee for Science and Technology'* (Krebs, 2014).

The British CounciI was included in the list of those who gave evidence to the House of Lords enquiry. Originally named the British Committee for Relations with Other Countries, the organisation was set-up in 1934 by the government of the day as a reaction to a growing concern about British interests abroad at a time of extreme political ideology in many European countries and one in which the British Committee held an intermediary role to promote, 'a wider knowledge of the United Kingdom and the English language abroad, and closer cultural relations between the UK and other countries'. Today, one of the Council's stated aims is to encourage international students to study in the UK, and for British students to experience life abroad (British Council, 2016).

Against that aim, and with concern about diminishing numbers of international students, the British Council conducted a survey to seek an understanding of the factors that influenced their choice of a study destination. Where the opportunity to develop language skills was also a criteria for choosing a study destination the UK has a natural and obvious advantage. However other English speaking countries, the USA, Canada and Australia for example are also able to provide a similar added benefit and consequently present a strong competitive force to the UK in attracting new international students to HE. The survey sample was therefore drawn from HE students studying at the time in the UK, in the USA, Canada and Australia.

Before examining the survey results it is noted that the original British Council survey was, to the best of my knowledge, not freely available through the usual online sources, nor from Sussex University Library. The hyperlink attached to the British Council press release did not give access to the survey for those not registered with the Council and students were barred from registering for online access. The survey findings were therefore alternatively sourced from the British Council press release of 2nd November 2015, and from a Times Higher Education (THE) article *Reputation of UK higher education main factor attracting international STEM students* summarised by Bothwell (2015).

The survey sample size of 1,348 was made up of 200 students from Canada, 200 from Australia, 400 from the USA with the majority (548) from the UK (British Council, 2015). Whether these numbers were weighted to minimise bias is not known. Moreover bias appears likely where students express a preference for their chosen destination while actually studying in that country and with no opportunity to test the alternative choices. With these caveats in mind the results give an indication of the factors that international students considered when making their choices.

The target population was a mix of current undergraduates (45 percent) and post-graduates (55 percent) (British Council, 2015).

5.7.4 British Council Survey Findings

The survey found that a majority of international STEM undergraduate students (51 percent of sample population) on STEM courses chose the UK as a study destination "overwhelmingly" for its reputation for high-quality education when compared to the response rates for Canada, (22 percent), Australia (21 percent) and the US (15 percent) (British Council, 2015).

The UK was also rated relatively highly against the three other countries, with 29 percent agreeing that a qualification from the UK offered excellent career prospects in their chosen discipline. This response suggested that the qualification was likely to be viewed as a cachet for the wider international labour market rather than necessarily seeking employment in the UK.

A further comparative strength of the UK chosen by 19 percent of the sample was its position at the forefront of research and innovation. The US was rated by just 11 percent, with Australia and Canada around 10 percent. Unsurprisingly, one of the UK highest ratings was in offering overseas students the opportunity to improve their English skills.

The findings were not all positive for the UK. Overall, the UK ranked lowest in seven of the fifteen issues raised in the survey. This was the greatest number of negative responses of the four countries. Rated as the most concerning for international students was the difficulty of applying for a UK visa, while finding employment in the UK during and after graduate studies was rated second lowest at 16 percent, slightly above the US (14 percent) and Canada at 17 percent, while 21 percent agreed that Australia was most popular for post-study employment opportunities. This supported the particular concerns of international students Lord Krebs outlined above.

Although 42 percent of postgraduate overseas students studying in the UK responded that the UK was the best destination for career opportunities, this was the lowest level of agreement compared to Canada at 61 percent, the USA at 71 percent and Australia at 72 percent. Overall the relatively low response rates of students to the various questions posed suggested that none of the respondents were greatly confident about any of the four countries ability to support the issues raised.

This account from the British Council accords with the Lords inquiry findings outlined earlier. Nevertheless, the government's response to the Lords was to reiterate their policy objectives; the reforms were intended to address the abuse of the higher education system while steps had been put in place to continue to attract talented international students where they were sponsored by reputable institutions, had a sufficient command of English to cope with study in the UK, and were possessed of adequate funding to support themselves through their studies. The government reminded the Lords that within this criteria there was no limit to numbers, and no barriers to studying in the UK. The government acknowledged an awareness however of a number of "myths and inaccuracies" about the UK's international recruitment process, and in this the government looked to a partnership with the HE sector to rectify (HM Government, 2016, Undated, accessed 2016).

As at 2016 international students are still considered and counted as migrants. However, in extending the data set for international students (Figure 5.14), despite the government's determination to persist with the immigration policy reforms, a slight increase in intake numbers of around 0.5 between 2013-14 to 2014-15 was noted (HESA: Table F - Percentage of HE students by subject area, mode of study, sex and domicile), despite the government's determination to persist with the immigration policy reforms.

5.7.5 Absolute and relative gain over time

Table 5.4 shows change in HE intake STEM figures over time. The numbers include all STEM graduate supply data, that is undergraduate, post graduate, full-time and part-time students between 2003, the start of the time-series data set, and its finish in 2015. The change is shown in both absolute and relative terms.

With just one notable exception, STEM subject intake is shown to have increased over the 13 years of the data set. The exception is the dramatic downward change in

Table 5.4: Absolute and relative change 2003-2015 for all STEM graduates including undergraduate, postgraduate full and part-time. (Note that Architecture is not included in the analysis) Data source: Amalgamation of HESA tables listed in Appendix A

	2003-04	2014-15	Change	Relative change
Medicine & Dentistry	12550	17074	4524	36.1%
Allied to Medicine	89802	98992	9190	10.2%
Biological sciences	44612	77572	32960	73.9%
Veterinary sciences	1090	1347	257	23.6%
Agriculture	5542	7972	2430	43.8%
Physical sciences	24240	32847	8607	35.5%
Mathematical sciences	9125	14282	5157	56.5%
Computer sciences	55810	35024	-16786	-32.4%
Eng. and Technology	46227	60202	13975	30.2%

intake numbers for the *Computer Sciences*. One reason the change appears as 'dramatic' is the high intake numbers seen at the beginning of the data set. Around 55,810 first year undergraduates were recorded as studying the *Computer Sciences* in 2003. By 2015 that number had dropped to 35024 (-32.4 percent). Several possible explanations for the loss in intake numbers have already been offered in this chapter. They include loss of students from India, the content and delivery of Information and Communication Technology (ICT) lessons at school, and the possible bias against black graduates and those with an ethnic minority background regarding employment opportunities.

Some of the other results in Table 5.4 also call for a fuller explanation. *Medicine and Dentistry*, for example, show 36.1 percent rise in numbers despite the flatlined profile for the both full time and the part-time undergraduate intake numbers seen in Figures 5.4 and 5.5. The flatlining was seen to be due to the tight control over medical students numbers exerted by the government. However those who choose to enter medicine as a second degree subject are obliged to pay for their course. Since the government has little financial interest in medical training at the postgraduate level, the constraints on numbers are relaxed, and it is in the postgraduate numbers (Figure 5.10 b) with their strong upward growth that the source of the increase in intake numbers for *Medicine and Dentistry* is found.

Biological Sciences are still very strongly represented in the table increasing intake numbers both at the undergraduate, postgraduate level and for full and part-time student intake by 32,960 (73.9 percent). The *Physical Sciences*, which include physics and chemistry, have also gained an additional 8,607 (35.5 percent) intake numbers to its disciplines over the duration of the research. Although from Table 5.4 it is not possible to distinguish the individual growth patterns of the ten disciplines incorporated into the category, the growth is likely to be linked with the new popularity of physics as an HE study subject. This too has been the subject of an earlier discussion in this chapter about the possible mechanisms, such as the media's role in driving science and physics interest.

First year, full time undergraduate and post-graduate numbers for the *Mathematical Sciences* have also risen slowly but consistently over the data set by 5,157 (56.5 percent). Since the *Mathematical Sciences* incorporates just four disciplines within the macro heading, this represents a strong growth in student interest. While again Table 5.4 does not identify the individual growth patterns of the four disciplines contained under the macro heading *Mathematical Sciences*, the growth of mathematics itself as one of the most popular 'facilitating' A level subjects for entry to top universities from around 2014, is likely to be a key mechanism in accounting for the elevated HE recruitment levels.

A surprising result, considering the widespread concern over numbers, *Engineering and Technology* show a 13,975 (30.2 percent) gain in intake numbers over the last thirteen years. This is second only to the huge growth recorded for the *Biological Sciences* at 32,960 (73.9 percent). *Veterinary Sciences* show a small increase of 257 (23.6 percent) students, but in looking at the full time intake figures for both undergraduates and postgraduates (Figures 5.4 and 5.10), the rise is undetectable in the plotted data. This low figure, where any annual increase in intake is seen in the tens rather than the hundreds, appears consistent the professions concern about rising numbers overwhelming the available resources of specialist teaching staff and clinical placements discussed earlier in the chapter.

Examining the relative differences between the start and finish data points over time can be misleading particularly if the absolute values involved are low. This can be see in the *Veterinary Sciences* results where the increase of 23.6 percent may appear impressive until noting that the difference between the 2003 intake and that of 2015 is only 257 students, whereas an increase of 9190 students to *Subjects Allied to Medicine* showed only as a 10.2 percent (9,190) increase with the larger numbers for this group.

5.7.6 Querying the supply data

High quality data retrieved from HESA has been used throughout this chapter to estimate the supply levels of UK STEM skilled graduates. Despite the wealth of information about student participation in higher education the challenge to identify a coherent time-series data set over the research period in question was largely in negotiating the complexities caused by changes in classification and table headings at various stages in the collection period. Moreover, there were concerns about missing or inaccurate data returns from some learning establishments. Also notable in this chapter about the supply of STEM skills, is a certain inconsistency in the way supply figures were presented. My decision to use the first-year intake figures to estimate STEM graduate numbers in preference to student enrolment numbers was based on HESA's comment that students are able to enrol on more than one course. Enrolment numbers used as a proxy for estimating labour market supply would naturally have been skewed if this approach was used. A further example of inconsistency and the possible consequences for estimating supply was not necessarily in the accuracy of the data, per se, but in the way data was collected and presented. The supply data for the incoming international students (Figure 5.14) offered an example.

The Lords Select Committee inquiry into the UK immigration policy and the possible effect on international student numbers coming into the UK made use of a HESA sourced graph (Figure 5.14). This showed annual entrant intake figures for the decade 2002-03 to 2012-13. It showed a decade of gradual but consistent growth in the numbers of non-EU STEM undergraduate and postgraduate entrants studying. Numbers reached a peak of around 57,500 at 2010-11. Thereafter growth was reversed falling to around 47,000 by 2012.

Table 5.5: The number of Students studying STEM subject areas by level of study and domicile 2013-2014

Source: Abridged from an un-numbered table entitled Background figures in the British Council survey report UK Education top attraction for international STEM students, published 2 November 2015. The British Council cites the data source as from 2013/14, HESA Student Record.

Domicile	Postgraduate	Undergraduate	Total
UK	139,170	706,055	845,220
Other EU	19,880	32,200	52,080
Non-EU	53,870	56,470	110,340
Total	212,920	794,725	1,007,640

The following year according to an untitled Table 5.5, produced by the British Council, the number of non-EU students graduate and postgraduate, studying STEM in the UK stood at 110,340. This suggested prima facie, an influx of over 60,000 more non-EU STEM graduate and postgraduate students were studying in the UK between the end of one academic year and the start of the next when considered against Figure 5.14.

The numbers quoted in the table however cannot be verified against HESA records under the source given. The author Tim Sowula, the Senior Press Officer is no longer with the British Council moreover the link given in the press release is broken. Whether the numbers given in the table represent data collected across all cohorts for the academic year, as opposed to first year entrants as in Figure 5.14 is one possible explanation for the apparent disparity. No indication is given within the table that this was the case. The British Council is a well respected organisation with considerable influence in government circles and as such was called to give evidence to the Lords International Students Select Committee (Lords Select Committee, 2014b, p. 21). This example illustrates the ease in which unfounded statistics without a means of verification are still able to become disseminated.

5.8 Summary

A number of key findings emerged from the data. Firstly and overall, there was a consistent rise in the first years intake number of undergraduate and postgraduate STEM students including those studying part-time. *Engineering and Technology*, long a concern in some circles for its perceived insufficiency in numbers, was found to be a more popular subject in terms of intake numbers than might have been anticipated, by showing a relevant increase of 30.2 percent and an absolute gain overall of 13,975. It appears that despite criticism, or because of criticism, about a confusion of pathways to a career in engineering, the academic route has been a popular choice for an increasing number of potential engineers and technologists. Also demonstrating an increased popularity among first year undergraduates and postgraduates are the Physical, and the Mathematical sciences. The two subjects are still seen as low in absolute numbers when compared to the other STEM subjects, but have shown a relative and absolute increase of 8,607 (35.5 percent) and 5,157 (56.5 percent) respectively.

Secondly, and in terms of a new concern was the decline seen over the decade, and more, over the last thirteen years of the *Computer Sciences.* Against a very strong start in 2002-03 when intake numbers were among the highest of the STEM subjects, the following years had shown a persistent general downward trend. Although occasional pockets of increased intake had surfaced from time to time, the House of Lords Select Committee Inquiry singled out the overall poor performance of the Computer Sciences, for particular concern. Noting its particular importance as a new science in its own right, and its increasingly supportive role in the other sciences, the Select Committee's concern for *Computer Science*, with along the other STEM subjects, focused on the possible impact of the government's changes to the UK immigration policy. Introduced to reduce abuse of the immigration system through the international student route, it was believed by the Lords to have had a particular affect on the overseas students, the genuine, and those deemed less so.

In examining the potential of international students to augment the supply of domestic STEM skills, it also emerged that the level of intake to particular science was in part dependent upon the 'sending' countries. Thus it was seen that students from India were more likely to study the STEM subjects, in particular the *Computer Sciences* and *Engineering and Technology*, while those from China favoured *Business and Management*. While a decline in absolute numbers from one sending country (India, for example) had so far been offset by gains from another (China), the change in sending countries was likely to affect the intake numbers of particular subjects. In this, the decline of the *Computer Sciences* was held as an example.

A further finding concerning Computer Sciences was seen in the low levels of employment of graduate students with a black and minority ethnic background, and the lower pay levels, compared to white graduates, for those who are employed in their field. This is a concern that may shift the bottleneck seen in the academic pathways and other pathways for the STEM subjects, to the transition between HE and employment.

After analysing recruitment patterns, an understanding emerged that intake numbers to *Medicine and Dentistry*, and *Subjects Allied to Medicine*, where the NHS assume responsibility for university tuition and continuing professional training costs, were strongly constrained by limited budgetary resources.

Also to emerge from the data while analysing the recruitment patterns, was the correlation between a noticeable dip in recruitment levels at the 2013 data point and the substantial increase in university fees which took effect at this time. In some cases the 'dip' was preceded by an increase in recruitment numbers, suggesting attempts by students to enrol ahead of the rise. Similarly seen was a 'curved' increase particularly noticeable in the postgraduate intake figures over the 2008 data point over the 2011-12 period. This was found to correspond to the years following the global financial crisis. At this time of high job losses in the UK, the assumption was that those first degree graduates unable to find employment in their subject discipline specific areas had chosen to resume their education at a higher level to optimise they future chance of employment.

When estimating the supply of STEM graduates to the UK labour market a concern for a possible loss of numbers to overseas employers was unfounded by the Destination of Leavers data for the first six months after graduation. Only the *Civil Engineers* showed a percentage of over 2 percent of their members were working overseas at the six-month timing of the destination survey, with the second highest, *Biology,* with 1.8 percent working overseas within six months of graduating. Unemployment figures for graduates counted within the same period, contained a degree of ambiguity in that they included an unspecified number of graduates claiming they were due to start work. Not withstanding this, the figures given for STEM skilled graduates six months after graduation are not inconsiderable suggesting either employers are not queuing up to recruit, or the graduates are not seen as recruitable.

In further examining the Destination of Leavers data, some paradoxical findings emerge from the results. In particular figures for the *Computer Sciences* show the second highest level of employment, as well the highest level of unemployment by almost three percentage points. *Electronic and Electrical Engineering* show a similar result. Listed as the third highest employed group, they are also the second highest unemployed. These are both subject areas understood to be in short supply.

5.9 Conclusions

Summarising the research question:

- Is there a contemporary crisis in recruitment to Science and Technology in the UK?

One response might be to point out, that the STEM subject numbers have been recorded as constantly rising over the time-series data set, a period of 13 years. This however does not take into account the level of labour market demand for those with graduate STEM skills as a resource popularly perceived as being in a persistently short supply. Nor does it account for the relatively high figures given for unemployment levels for graduates in STEM subjects. This suggests, among other possibilities, that the skills possessed by some graduates, particularly those showing the highest levels of unemployment, are incompatible with employers needs.

The next chapter, which deals with the difficult question of attempting to measure a level of demand for the STEM skills, will also attempt to understand some of the reasons behind the paradoxical situations described above.

Chapter 6

Evidence of demand for scientists and engineers in the UK 2002-2015

6.1 Are STEM Skills currently in short supply?

This empirical chapter examines the available evidence for a possible imbalance between the supply and the demand in the labour market for higher education STEM Skills through two specific proxy indicators, the graduate vacancy rates, and the graduate starting salary levels. Both indicators are examined for their current positions and from the recent past to determine the trend overtime.

To set the question of labour market demand in some context, the methodology of a sample number of approaches and reports estimating a level of demand are overviewed within a similar time period as the supply data research, from 2004 to 2014. With the rationale for the literary selection described in the methodology chapter, a preliminary examination of the demand literature showed that the dominant narrative in the field in the question of demand was seen in the series, the *Working Futures Reports*. The reports are produced either biennially or over a three-year period with the aim of estimating demand levels sector-by-sector over a period, currently, from 2002 to the year 2024 (Wilson et al., 2006).

The content of the reports relied upon a partnership between the Warwick Institute for Employment Research (IER), with Cambridge Econometrics (CE) and with the UK Commission for Employment and Skills (UKCES). The lead author was Rob Wilson of IER. UKCES itself was described as a social partnership, led by Commissioners from large and small employers, trade unions and the voluntary sector (Wilson & Homenidou, 2012). Along with projected demand levels, growth, decline and change in occupational employment have been estimated up to the year 2024 decade-by-decade.

The first of the *Working Futures* reports, *New Projections of Occupational Employment by Sector and Region, 2002-2012*, was published in January 2004. Its intention was to inform those bodies interested in skilled employment policy. Included among them were the Sector Skills Councils (SSC), The Sector Skills Development Agency (SSDA), the Regional Development Agencies (RDA), the Learning Skills Council (LSC) and the Council for Industry and Higher Education (CIHE) and others. The purpose of the report was not only concerned with the policy issues relating to demand, an additional aim, according to the authors, was to provide a basic understanding of the labour market and in its utility in producing goods and services. In this way labour was seen as a "derived demand" critically dependent on the goods and services market, and the technology used in their production (Wilson et al., 2014, p. 10).

Such factors were to form part of the wider contextual fabric of the analysis, where the data projections were based on an economic model known as the "multi-sectoral, regional macroeconomic model" (MDM) (Wilson et al., 2004, p. 1). Incorporating a range of contextual social, economic and employment data from number of sources, including the 2001 Census of Population and the UK National Accounts, and the Labour Force Surveys and the Annual Business Inquiry (ABI), in terms of the demand for STEM graduates the model was able to offer, according to the author: "...some useful insights into possible developments and contribute to a better understanding of the overall demand/supply relationship for STEM personnel, currently and over the coming decade " (Wilson, 2009, p. 10).

From the first *Working Futures* report using the CE model, the series has informed a number of influential organisations and publications. They include the *Leitch Report* (2006), and many of those commissioned by the UK Commission for Employment and Skills (UKCES), the Council for Industry and Higher Education (CIHE), the Department for Innovation Universities and Skills (DIUS), the Engineering Technology Board (ETB), the Department of Trade and Industry (DTI) and others. Not surprisingly, the research has become the dominant voice among those organisations planning future workforce needs and in those seeking to inform policy design both in education (particularly higher education) and in employment practices.

The effect of the near ubiquity the *Working Futures* reports as a readily and widely accepted data source used to inform a number of official UK documents has inevitably narrowed the range of independent approaches made to estimate levels of UK labour market demand, as those organisation listed in this paragraph testify. In terms of the future demand for labour however, the early projections of *Working Futures* allow a unique opportunity to test the accuracy of the projections against actual employment data. With the first three *Working Futures* reports overviewed below, with other literature, the projections for the decade 2004 to 2014 was chosen as the most suitable as a test sample since the period falls neatly within the data limits set for the thesis and as comparable data over those dates were available.

Before examining the reports however the question of classifying occupations must first be considered. Notable in some of the literature reviewed is the replacement of the academically recognised acronym STEM and the JACS coding system already used in this thesis to identify and differentiate between the sciences throughout the education system. Although commentators such as Wilson (2009), and Bosworth (2006) and others still refer to STEM occupations where they directly addressed the question of STEM labour demand, other data sources are likely to classify economic activity and occupations under alternative headings.

When referring to the issue of STEM employment, for example, the subject disciplines, science, technology, engineering, and mathematics occupational vacancies are likely to be grouped under the macro heading of ‘professional and technical’ and further refined into specific occupations within a discipline, such as a maths and physics teacher, electronic engineer, organic chemist, microbiology technician, and so on. While a description of the employment role is an obvious approach in advertising job vacancies, it is just one of several means of classification currently used to describe subject disciplines previously considered in this study under the STEM acronym. James Harris, for the Office for National Statistics (ONS), for example, acknowledges the lack of a standard classification for what he broadly refers to as Science and Technology (S&T) data and the difficulty this presents to those interested in S&T statistics to inform policy and planning decisions (2015, p. 1). Harris suggests two approaches to clarify comparison studies.

The first is the UK Standard Industrial Classification of Economic Activity (UK SIC), which Harris described as classifying economic activities across a five-level hierarchical framework. The second is the Standard Occupation Classifications (SOC) designed to classify occupations. It is also described by Harris as a hierarchical method nested within four tiers. Both classifications are included in business statistics, household surveys, the Census, and in National Accounts (Harris, 2015, p. 1,2). Both SIC and SOC categories are in use in many official reports. But, as will be seen, this approach also presents difficulty in the ONS practice to recode their classification groups every decade to accommodate changes in the type and nature of employment, and particularly for this thesis, when the recoding occurs during the time period generally under question, that is 2003-2015.

Harris also points out, in adding to concerns about data consistency, that where a standard classification is missing for S&T and its subcategories, such as Life Sciences and Digital Technology, other varying definitions have been introduced and used by some analysts. Harris does not offer a sample of the possible alternatives, but he acknowledges that the lack of standardisation hinders comparison across sources to assess evidence (Harris, 2015, p. 2).

While Harris's suggestion however to limit methods of classification to the Standard Industry Classification (SIC) and the Standard Occupation Classification (SOC), may be useful for future studies, the periodic recoding of classifying industry and occupations is not presently helpful in seeking consistency across archived UK data and statistics, nor in data on the transition between education and employment. Where such changes affect the way the Office for National Statistics (ONS) classify their collection of occupational employment data affecting the integrity of the data over time, this is not the only hazard to *Working Futures* projections, and other literature, as the following overview shows.

6.2 An overview of a sample of the Demand literature

Each *Working Futures report* consists of up to six volumes including annexes. Common to all reports are the Main, Technical and the Evidence report. The *Working Futures reports* all use the Standard Occupational Classification SOC2000, as discussed above, which incorporates science and technology professionals, engineers and information and communication technology professions under the major sub groups of Managers and senior officials, Professional occupations, Associate, Professional and Technical occupations, as highly skilled occupations.

The first of the reports for 2002-2012 utilising the MDM model projected these occupations for growth along with Personal service occupations, and Sales and customer service occupations. This implies they were assumed to have the growth potential to increase the demand for labour. Administrative, clerical and secretarial labour markets however were projected to lose jobs to technology, along with the Skilled Trades (some of which were seen by the authors to be most closely associated with the engineering industry). Also projected to decline were jobs for the Machine and Transport Operatives, and the

Elementary Occupations [1] along with skilled construction and building trade occupations. Significant job losses with the largest reductions in numbers of all groups over the following ten years, were seen in the projections for the Elementary occupations (Wilson et al., 2004, p. xvii, 36, 62).

The second and third iterations of the *Working Futures Report* series by Wilson, Homenidou and Dickerson, dated January 2006 for the period 2004-2014, and December 2008 for the period 2007-2017, followed a similar methodological approach in utilising a multi-sectoral regional macroeconomic model (RMDM) updated by Cambridge Econometrics (CE), to aid analysis in projecting the future employment needs and, by implication, the projected level of demand (Wilson et al., 2006, p. 3). The approach, as in the first report, detailed employment prospects by sector and occupation as well for the regions and countries of the UK. The SOC 2000 classified Managers and senior officials, those in Professional occupations and Associated professional and technical occupations (and therefore the sciences), and they were again projected as most likely to show increases in employment over the forthcoming decade. Sales and customer service occupations and Personal service occupations were also projected to benefit from employment growth, albeit to a lesser extent (Wilson et al., 2006, p. xvi).

Projections of job losses for Administrative, clerical and secretarial occupations, and of Skilled trade occupations, Transport and machine operatives and again those in the Elementary occupations showed a similarity with the first *Working Futures Report*. Projected for the greatest decline were again, the Elementary occupations (Wilson et al., 2006, p. 3).

With subsequent reports serving to update previous reports, all three showed similar results in suggesting occupations most likely to be in growth and those in decline over their respective forthcoming decades (*Working Futures*, 2003, 2006, 2008). One major difference in the third report's projections for 2007-2017, suggested an accelerated growth rate over the period for those with higher skills, such as managers, some professional and many associated professional occupations, the protective service occupations (and for the sciences classified under SOC 2000) (Wilson et al., 2008, p. xviii). Similarly the pace of decline was projected to increase more rapidly in the clerical and secretarial occupations, the skilled manual and electrical trades, and in other skilled trades. Conversely, the Elementary trades were thought more likely to see their rate of job-loss slow down as new employment

[1] Tasks performed by workers in elementary occupations usually include: selling goods in streets and public places, cleaners, care takers, delivery, messengers, door keepers, meter readers, garbage collectors, street sweepers and similar basic skills occupations. Source: International Labour Organisation, Major Group 9.

opportunities were expected to be generated by the space sector (Wilson et al., 2008, p. xviii). To Holmes and Mayhew of the independent British 'think tank', the Resolution Foundation, Wilson et al's., future workforce projections described a phenomenon which had become known among economists as the "hour-glass economy" (Holmes & Mayhew, 2012, p. 3).

Also considered in the *Working Futures Reports* was the question of 'replacement demand' [2] to deal with employee losses through retirement, career change, mortality and so on. Despite the concern over projected job losses, the numbers needed to replace existing staff were likely to be "... about eight times larger than the net changes projected between 2004 and 2014." (Wilson et al., 2006, p. xvi). Positive expansion [3] therefore, according to the Wilson group's conclusions, were thought to create new opportunities across all occupations even those in decline, "... particularly so for new entrants to the job market." (Wilson et al., 2006, p. xvi).

The extent to which the levels and directions of change, to which the Wilson, Homenidou and Dickerson predictions for the growth and decline of occupations noted in the *Working Futures Report* for 2004-2014, were met is discussed below in some depth, notwithstanding the following caution articulated by the Wilson group, a version of which is seen to be offered in various forms all the *Working Futures Reports*:

> *'Users of the results are cautioned that they should not be seen as precise predictions but rather indicative of general trends and tendencies. This applies with particular force to the more detailed disaggregations.'*
>
> Source: Wilson, Homenidou and Dickerson,Working Futures Reports: 2002-2012; 2004-2014; Wilson, Homenidou and Gambin, Working Futures Report, 2007-2017.

In 2006, the Department of Education and Skills (DfES) published the findings of their research on the *Supply and Demand for Science, Technology, Engineering and Mathematics Skills in the UK Economy* (DES, 2016). Referring to, and building on, a previous economics paper by the Department of Trade and Industry (DTI, 2006), as well as a number of other studies, including the *Working Futures 2004-14* report by Wilson et al, and referenced above (2006), for the employment projections. The report aimed to present

[2] Replacement demand refers to the total number of people in an occupation who will need to be replaced as workers leave the labour force (Working Futures: New Projections of Occupational Employment 2002-2012:6)

[3] The total net requirement for jobs is expansion demand plus replacement demand, where expansion demand represents net job growth (Working Futures: New Projections of Occupational Employment 2002-2012:6)

an analysis of the prevailing and projected trends in the supply and demand for STEM-qualified people. In this report the DfES approach to the question of labour demand was made largely in terms of the level of earning (returns):

> *'The demand for STEM skills can be measured by the benefits that accrue to those who possess them. The returns to STEM skills relative to lesser qualifications, estimated lifetime earnings profiles and unemployment rates of STEM graduates will all give an idea of how in demand scientists and engineers are. Employment projections will give some idea as to how the demand for STEM skills will appear in 10 years time.'*
>
> Source: (DfES) Supply and Demand for Science, Technology, Engineering and Mathematics Skills in the UK Economy (Research Report No 775, 2006).
>
> Note: The research report advises that the views expressed in this DfES publication are those of the authors' and do not necessarily reflect those of the DfES. It is noted however, that the authors' names were not given in this publication.

Following this approach, the DfES report suggested high returns (earnings) for those with graduate skills in medicine and in subjects like mathematics, engineering and computing compared to the lesser earnings for the biological and the physical sciences, and to the earnings of those holding two more A levels (DfES, 2006, p. 10). The findings were presented with the proviso that there were likely to be "…unobservable differences…" associated with subject choice that might also be related to earnings. No indication was offered as to what those unobservable differences might be.

Presented also as evidence of a demand for graduates in medicine, physics, chemistry and engineering, was a table (shown in Fig. 6.1) of Additional Discounted Net Lifetime Earnings sourced from *The Economic Benefit of Higher Education Qualifications* produced by Pricewaterhouse Coopers for the Royal Society of Chemistry and the Institute of Physics. The table shows engineering, chemistry and physics ranked third, fourth and fifth respectively out of twelve subject areas, including medicine and biology, where law and management were ranked first and second (PricewaterhouseCoopers, 2005). Neither the data, nor the data table were however dated.

It is also important to note that while the DfES report was dated 2006, it utilised data collected between 1993-2002 to show an increase in the returns to medicine and engineering from 19 percent in 1993 to 26 per cent in 2002. On that basis, the report suggested: "…demand might be exceeding the supply of engineering graduates, perhaps

	Public and Private Investment in Higher Education					
	Individual			Exchequer		
	Direct and Indirect Costs	Additional Discounted Net Lifetime Earnings	Rate of return	Subsidy	Additional Discounted Lifetime Taxation*	Rate of Return
Law	-£24,026	£246,367	17.2%	-£15,624	£171,712	19.3%
Management	-£24,026	£152,947	16.9%	-£15,624	£107,405	19.7%
Engineering	-£32,809	£219,971	15.5%	-£30,742	£155,104	13.1%
Chemistry	-£28,037	£186,307	15.0%	-£26,705	£132,305	12.1%
Physics	-£26,661	£188,249	14.9%	-£25,156	£133,852	13.0%
European Languages	-£32,809	£163,466	14.0%	-£21,167	£117,769	16.6%
Soc. Sciences (ex Law and Psych)	-£24,026	£154,135	13.5%	-£15,624	£109,219	16.2%
Medicine (ex Dentistry)	-£53,165	£346,156	11.6%	-£78,126	£255,045	7.8%
Biological Sciences	-£24,026	£109,845	10.2%	-£22,762	£82,135	9.5%
Psychology	-£24,026	£100,479	10.1%	-£18,682	£74,079	10.9%
Linguistics/English/Celtic Studies	-£24,026	£92,797	9.7%	-£15,624	£68,330	12.1%
History	-£24,026	£89,630	8.8%	-£15,624	£65,471	10.4%
All Degrees (currently)	-£26,208	£128,771	12.1%	-£21,218	£92,781	12.1%
All Degrees (following current student finance reforms)	-£22,974	£125,315	13.2%	-£24,556	£95,388	11.0%

Figure 6.1: Total costs and revenues associated with obtaining alternative degree level qualifications

Data source: Table 5, The economic benefits of higher education qualifications, PricewaterhouseCoopers LLP, January 2005

partially driven by the decreasing supply of graduates with engineering skills" (DfES, 2006).

While this may or may not have held true in 2006, the assumption of increased demand based on outdated statistics appears to be misplaced in the DfES report, particularly where the same report showed in Figure A20, that in 1999 engineering graduates were 150 percent more likely following graduation to have been unemployed for six months or longer than those with medical degrees and those with degrees associated with medicine (DfES, 2006, p. 12, 31).

The DfES study suggested that a change in supply might arise naturally as students became more aware of the earnings differential and employment opportunities offered by some STEM subjects, and in responding to those market signals (2006, p. 17). The question of employee (and employer) preferences for one type of work over others was an area considered by Alfred Marshall, after his early identification in 1890 of a number of 'peculiarities' observed in individuals considering employment. Later reiterated by Bosworth et al., (1996) in a study of labour economics, among the peculiarities understood to influence job choices and decisions were the expression of preference in the type and location of employment. The DfES's notion that earnings would be the sole, or even a major, determining factor in career choice decisions is therefore problematic, when examining students' individual preferences for particular subjects; and not least, the skills and aptitude needed to pursue them successfully.

By 2009, Wilson, with the Warwick Institute for Employment Research (IER) and working closely with organisations such as the Council for Industry and Higher Education (CIHE), the Department for Innovation, Universities and Skills (DIUS) and the Engineering Technology Board (ETB), focused more specifically on the question of the demand for STEM graduates. His report, *The Demand for STEM Graduates,* had two main objectives. The first, to develop some benchmark projections of the employment of people with graduate level qualifications in STEM. The second, which involved the use of Labour Force Survey (LFS) data to extend the *Working Futures* reports about the qualification levels held by those in employment to use the results to provide:

> *'... a better understanding of supply-demand issues for STEM personnel. While the prime focus is on demand, it is evident that the effects of demand and supply factors are difficult to isolate, as illustrated in the shift-share analysis conducted as part of the project.'*
>
> Source: Wilson, The Demand for STEM Graduates: Some Benchmark Projections, 2009:6 Summary

Wilson's shift-share [4] analysis used the LFS 2007 distribution data across employment sectors of the STEM graduate and postgraduate supply. The analysis was extended by the previous work on qualifications levels held by those in employment updated for *Working Futures* 2007-17 (Wilson et al., 2008). Whereas manufacturing was once a major employer of STEM graduates and postgraduates, Wilson's findings suggested that they were then represented in just over three in ten jobs across all sectors, with the ratio increased to over five in ten in the non-marketed services.[5] With the question of demand for those with STEM qualifications, Wilson resorted to the trends, identified through his earlier work

[4]Shift share is a standard regional analysis method that attempts to determine how much of regional job growth can be attributed to national trends and how much is due to unique regional factors. Shift share helps answer why employment is growing or declining in a regional industry, cluster, or occupation. 5 Dec 2011 Rob Sentz EMSI (Sentz, R., 2011)

[5]market services cover those services provided to the community as a whole free of charge, or to

with the *Working Futures* series, to extrapolate the observed LFS historical patterns and considered against the detailed multi-sectoral occupational projections of future workforce demand (Wilson, 2009, p. 7, 11). With employment trends for most STEM categories understood to be rising over previous years, Wilson suggested that growth in STEM employment could be expected to be significantly faster than average, for those highly qualified in most STEM subjects raising the demand for skilled workers, while those with no or few qualifications were likely to face a declining labour market (Wilson, 2009, p. 11).

Again, a caveat was offered, in respect of the accuracy of the data, to the effect that the 'benchmarks' highlighted in the report should be considered as indicative of future trends, depending as they did, on what might happen if past trends and behavioural patterns were to continue. One difficulty was given as a limited sample size within the LFS data, and which Wilson described as:

> *'... quite sparse in places (especially at the most detailed level of aggregation by sector and occupation).'*
>
> Source: Wilson (2009, p. 6)

And in referring to the benchmark projections:

> *'As such they should not be seen as inevitable but rather as likely outcomes if these assumptions hold true.'*
>
> Source: Wilson (2009, p. 7)

Whereas manufacturing had over many years been a major employer of STEM graduates and post graduates, in 2007 their share of the graduate market was just 2 percent of the total manufacturing workforce. Wilson's analysis however suggested that the change over time in the employment patterns seen in manufacturing was similar for all industries in terms of employing a smaller share of highly qualified (NQF) individuals. But while the prospects in manufacturing sector were seen as poorer than for all other industries and services, somewhat contradictory, the rate at which STEM graduates and postgraduates were being employed in manufacturing is, according to Wilson, rising faster than elsewhere (Wilson, 2009, p. 7).

The largest share of individuals with STEM qualifications was reported to be employed in Non-marketed services. This was unsurprising since that sector includes the medical

individual consumers either free of charge or at a fee which is well below 50 per cent of production costs, Source: OECD (2011) professions. Also growing at a high rate in terms of the share of people with graduate skills was Business and other services along with "significant" numbers of those with graduate skills employed in Distribution and transport including hotels and restaurants). Although "significant" graduate numbers were then employed in engineering (particularly first degree graduates), the utilities, construction and transport, their share of the total number of graduates and postgraduates employed were seen to be falling (Wilson, 2009, p. 7).

Overall, STEM graduates and postgraduates were strongly represented,

> *"... in managerial, professional and associated professional occupations, although quite significant numbers are employed in lower level occupations".*
> Source: Wilson (2009, p. 7)

Further, the Wilson *Demand for STEM* report suggested that in 2007 of the almost a million individuals of the working age population holding a STEM qualification at the National Qualifications Framework (NQF) level 5, along with just over 2.5 million people holding STEM qualifications at NQF level 4, the "vast majority" were found to be economically active and in employment with only "very few numbers unemployed" (Wilson, 2009, p. 8). In comparison Wilson also reported that a much higher number of the workforce with qualifications lower than a NQF level 4 were found to be economically inactive and/or unemployed in 2007. Moreover those qualified in STEM subjects were seen by Wilson to be marginally more likely to be economically active and in employment than graduates in other disciplines. These findings suggested to Wilson, that future growth in employment for those qualified at the highest level (for STEM as in other subject areas) would be expected to be fastest, while those with few or no qualifications would be expected to be in a declining demand 2009, p. 8.

Wilson's conclusions, although in this instance referring specifically to those graduating in the STEM subjects, reflected the projections to a lesser or greater degree, made for those highly qualified in all HE subjects, in the first three reports of the *Working Futures* series (ie. 2002-2012, 2004-2014 and 2007-2017). It is important however to remember the conditional conclusion Wilson et al. offered in the *Working Futures* report for 2004-2014 that replacement demand for that period was likely to be about eight times larger than the net changes projected for the 2004-2014 period. *The Demand for STEM* does not appear to suggest a quantitative value for replacement demand (as in the 2004-2014 *Working Futures*) but Wilson acknowledges that there will be a considerable future requirement for higher level STEM skills not only due to expansion growth but to replacement demand

(Wilson et al., 2006, p. xvi). Accommodating the largely unquantifiable number for replacement demand, which will necessarily include mortality and retirement rates as well as job changes, to meet market needs will naturally influence the demand flow to a prior unknowable extent.

The demand literature discussed so far has considered the question of the labour demand from a perspective that has included, either directly or indirectly, the analytical research of Wilson et al., from Warwick's Institution of Employment Research (IER) and the *Working Futures* reports. The Wilson group, in approaching the question of the demand for labour, have exploited the detailed multi-sectoral macroeconomic model developed by Cambridge Econometrics (CE), which incorporated a wide range of economic variables in a comprehensive examination of past and present economic and socioeconomic events. For *The Demand for STEM* (Wilson, 2009), report, an additional dimension was introduced: the historical developments in patterns of employment for those qualified at the first degree and postgraduate levels.

Despite the scope and evident sophistication of the MDM and the advanced RMDM model, the data constraints running through the *Working Futures* series and the STEM Demand report were frequently highlighted by Wilson, and by Wilson et al. (2004, 2006, 2008, 2009), and so on through out the later dates of the series. Among the examples given for the *Demand for STEM* report was the allocation of NQF levels which Wilson considered less than straightforward. He reported,

> *"The mapping is complicated by the need to recognise that in some cases only a proportion of individuals have achieved the threshold levels to move them up from one NQF level to the next (depending upon the grades achieved, etc.)".*

There was more concern reported about the number of missing cases in LFS survey data about qualifications with a "Don't know" response from some respondents about the qualifications they held.

These cases could be analysed in a number of ways, according to Wilson, each of which likely to produce a different outcome. There were other examples seen by Wilson in *The Demand for STEM Graduates* as hampering outcomes. They included the use of different population numbers which excluded all workers above retirement age, and a focus at times by LFS data solely on those with the highest qualifications rather than across the NQF qualification spectrum (Wilson, 2009, p. 48). Moreover, although government departments were allowed uncensored access to Labour Force Survey (LFS) data, not all data were made publicly available for reasons of confidentiality particularly when they involved small sample sizes. Adding to Wilson's concern in obtaining reliable LFS data were the different versions available at only one time any of which could contain different data (Wilson, 2009, p. 48). Wilson concluded, "Without very detailed documentation on how data were extracted and estimates made it often not possible to exactly relocate results produced previously" (2009, p. 48).

Some attempts to foresee a future demand took a slightly different approach. The major factors under consideration in the account of Robert Garlick, Head of Global Equity Products for Citi Bank focused on technological instead of socioeconomic and historical events. Rather than consulting an economic model, Garlick gathered some wider opinions about technological developments and implications from an "informed public" poll carried out in a 2015 survey by the Edelman Trust Barometer (Edelman, R., 2015). The survey authors saw the question of trust as an important factor in facilitating market acceptance of new business innovations. Of the survey population of 27,000 (General Public) plus 6,000 (Informed Public) which were claimed to have been drawn from twenty-seven countries world-wide, the findings of respondents suggested that 51 percent had agreed that in 2015 the pace of development and change in business "today" was "too fast" with 70 percent citing technology as the driver (Edelman, R., 2015).

Citibank's own survey (no date given) suggested that 96 percent of institutional clients believed that automation would be likely to accelerate over the coming five years. Adding to Garlick's concern was Frey and Osborne's 2013 paper about the susceptibility of jobs to computerisation. This suggested that 47 percent of jobs in the USA would be vulnerable to computerisation. Looking further afield to data produced by the World Bank and the Organisation for Economic Cooperation and Development (OECD), an estimation of an average figure of 57 percent rising to 69 and 77 percent respectively was offered for the proportion of jobs in India and China at risk from computerisation. A figure was not given for the UK.

What do the findings of these surveys and estimates imply in terms of workplace future demand? Garlick took the prospective of job losses and the findings of the Edelman Trust Survey to imply that new job opportunities would be those requiring highly skilled workers (Garlick, 2016, p. 7). Where targets for business growth continue to be a driver of innovation and where advances in technology both advances and supports innovation, a future demand for a workforce with the necessary high level skills to generate, develop and exploit innovation is a reasonable assumption. Such approaches however say little in terms of quantifying the levels likely to be required.

Other approaches to the issues around future employment demand include a variety of opinions as to a range of possible future scenarios based upon the emergence of new industries, business models and behaviours as a result of disruptive innovations (PWC, 2014).

As in the *Working Futures* reports, *The Future of Work, Jobs and Skills in 2030* was also a UKCES report. Although Wilson's research played a part, the report looked at the question of demand in employment "...based on expert input from a number of key groups including business, trade unions, and academia as well as a detailed and comprehensive view of the literature". As in the PWC account above, the general approach of this exercise also produced a three scenario projection of likely possibilities, and the possible impact on jobs by advances in areas such as robotics, artificial intelligence, big data and intense global competition. From this, a list of skills likely to be in demand was produced. Data analysis, data handling, high-level software abilities and computer programming, cyber security and ITC skills in general, were seen as essential characteristics of the workers of the future, along with interpersonal, psychological and educational skills. Where more routine jobs were likely to be automated, those individuals with innovative and creative abilities were forecast to be needed, implying rising future demand, as suggested throughout the overview, for a highly skilled workforce (Glover & Beck, 2014, p. 88-91). In this respect, the predicted outcome in terms of the anticipated increased demand for skills was not dissimilar to other approaches.

What appeared to be missing, however, were quantitative estimates of levels of demand for those skills. Was the economic model employed by the *Working Futures* reports able to offer an additional account not only of the skills but the numbers likely to be needed? While attempting to replicate the econometric model approach used by Wilson et al. is clearly beyond the scope of this thesis, it is possible to make a comparison of the data results produced for the *Working Futures* 2004-2014 report using a data-set of employment statistics compiled from ONS Employment by Occupation tables, although the ONS comparison data used also has limitations as explained below.

6.3 Testing the Working Futures Projections for 2004-2014

While Wilson emphasised his concerns about the consistency and robustness of various data from official sources, in attempting to test the level of accuracy in the 2004 -2014 projections, a similar caveat about the comparison data presented in Table 6.2 should be made. The SOC 2000 classification, which underpinned the occupation groups examined in *Working Futures* 2004 -2014, was re-coded in 2010, for the second revision SOC 2010 as part of an ONS ten-year revision cycle. This was to allow the ONS to take account of "...new areas of work and associated training and qualification requirements." (Elias & Birch, 2010, p. 2). The main classification changes brought about by SOC 2010 included:

- The introduction of a stricter definition of 'managers'
- The reallocation of most nursing occupations as degree holders from Major Group 3 to Major Group 2
- A reclassification of occupations associated with information technologies
- An alignment with the 2008 revision of the International Standard Classification of Occupations (ISCO08) to introduce a limited number of supervisory groups.

  Source: Elias & Birch (2010, p. 2-3), *The Revision of the Standard Occupational Classification 2000,* and based upon the Labour Force Survey composite file 2003-2007.

The SOC changes, as might be expected, created a discontinuity between data covering the period 2004-2014. However when employment figures were projected for Working Futures 2004-2014 and published in 2006, the occupational groups were necessarily identified under the SOC 2000 classifications. The result is seen in Figure 6.2:

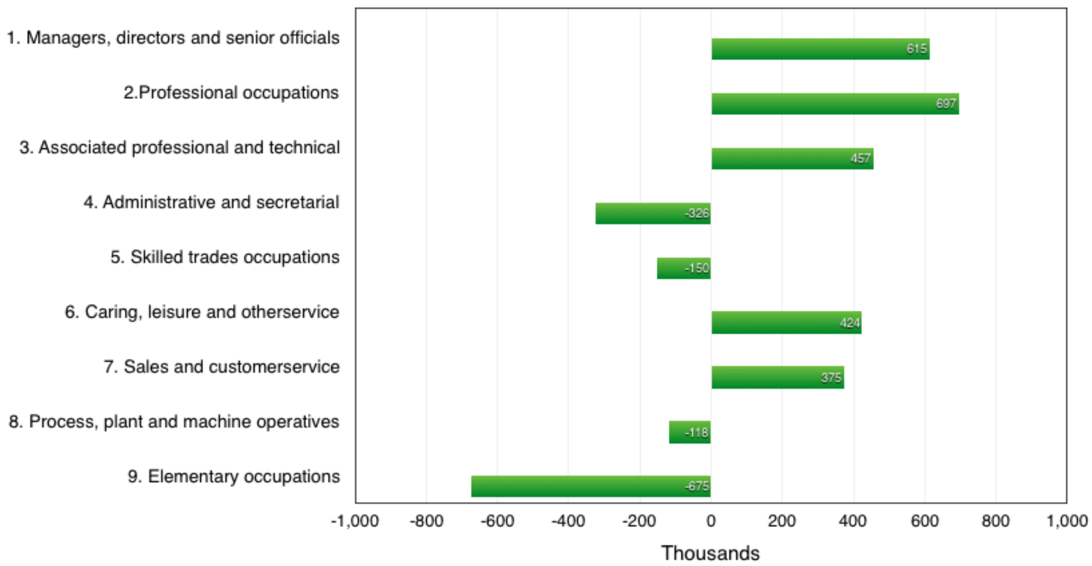

Figure 6.2: Projected Net change in employment from 2004 to 2014 in SOC2000 defined groups

Source: Working Futures 2004-2014 technical report, January 2006, Wilson et al.

The projections in Figure 6.2 indicate labour demand growing over the period in question for those in the top three of the listed occupational groups, and in the Caring, leisure and other service groups. Growth was also projected for the Sales and customer services although to a lesser degree. Jobs for the Skilled trades occupations and the Process plant and machine operators were also projected in a declining trend, as did jobs in Administration and secretarial. The Elementary occupations however were projected to experience a marked decline of almost 70,000, at a rate of 2.2 percent per annum when compared to the other groups listed in Figure 6.2 over the decade 2004-2014; workers in this group were mainly unskilled workers (Wilson et al., 2006, p. xvi,68). Figure 6.3 below compares the projected figures for the same period using data sourced from the ONS.

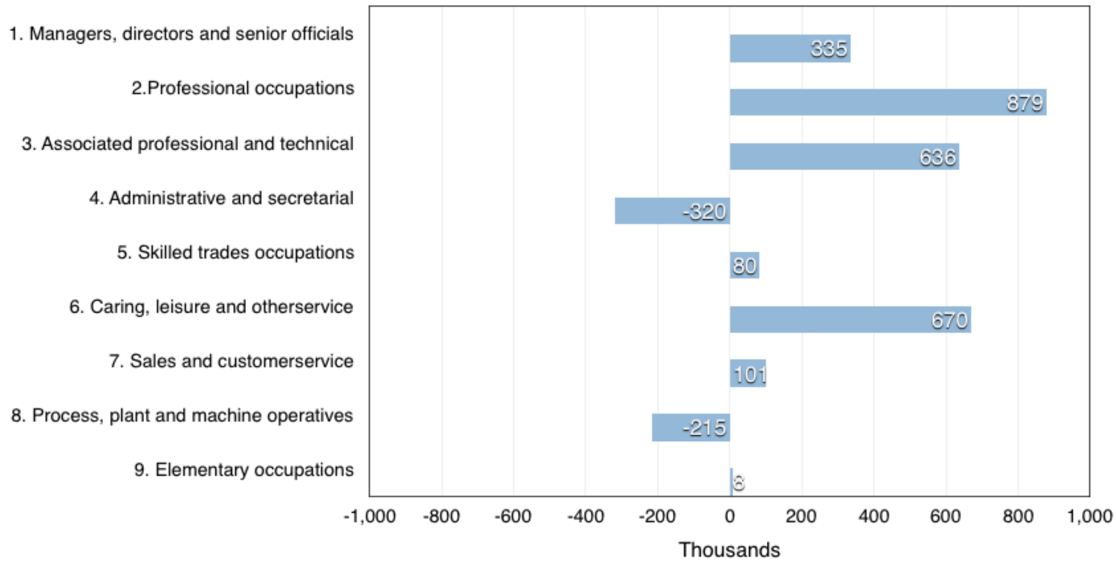

Figure 6.3: Net change in employment from 2004 to 2014 in SOC2010 defined groups
Source: ONS Employment by occupation. Tables EMP04, June 2004-June 2010 (SOC2000)* and June 2011-June 2014 (SOC2010). *see text for conversion to SOC2010 levels

Note 1 Figure 6.3 shows the occupational change over the years 2004 to 2014. Employment data is taken from the ONS EMP04 tables 2004 to 2014. The data for years, 2004 -2010 was classified under the Standard Occupational Classification, SOC2000, while 2011-2014 data followed the classifications given in SOC 2010.

Note 2. Numbers in groups 1, 2 & 3 for the years prior to 2011 (SOC 2000) have been adjusted to account for reclassification following 2010. The change primarily affected Managers in group 1 with some moving to group 2. Nurses were raised from group 3 to group 2 at the same time. This approach would have also accommodated the changes applied to the Information technologies in adding to group 2. The method of adjustment is explained in more detail below.

There are two aspects to note in examining the estimates shown in Figures 6.2 and 6.3 . The first is the forecast rates of change over time, and the second is the direction of change. There are also a number of possible explanations to account for the differences. They are considered later.

While both Figure 6.2 and Figure 6.3 show the same three groups heading the list of occupations - predicted to grow, there is a notable difference in the levels of change shown for the Managers, directors and senior officials between the two figures with 615,000 given for the projected numbers in Figure 6.2 and 335,000 for the ONS numbers in Figure 6.3.

The projected decline for the Administration and secretarial occupations however is closely matched between both Figures 6.2 and Figure 6.3, at -326,000 and -320,000 respectively, while the Skilled trade occupations were both predicted to experience positive growth at 80,000 in Figure 6.3, against their projected decline of -150,000. The ONS numbers used in Figure 6.3 indicates a smaller level of growth at 101,000 for the Sales and customer service occupations against the projected growth of 375,000. The largest difference however between the projected figures and those based upon the ONS 'employment by occupation' numbers is seen in the Elementary occupations. Figure 6.2 projects a considerable level of decline of -675,000 in the numbers, while Figure 6.3 shows the group just registering at 8,000 jobs, marking a significant difference in the direction and level of change between the two Figures. Wilson et al., observed:

> *'It is important to recognise that, without enormous resources, it is not possible to monitor and to quality ensure every one of these (Working Future) series. CE/IER have checked to ensure that the basics trends and structural features of the data are sound but it is impossible to check and validate every series, especially at the local level. The detailed projections therefore are provided on a caveat emptor basis. The aim is to provide a useful benchmark for consideration rather than a fully thought out, local level forecast for particular LEP areas.'* Source: Wilson, May-Gillings, Pirie and R. Beaven, *Working Futures*, Technical Report, 2014-2024, published, 2016.

The warning of Wilson et al, in terms of data validation was not the only difficulty the group faced in producing the projections for 2004-2014 in Figure 6.1 some of which have already been highlighted. Some of the discrepancies between the Projections and the ONS numbers might be explained at least in part by the changes made by the ONS in classifying occupations noted above. Whereas Wilson et al.'s, projections in Figure 6.1, reflected the distribution of occupational shares under the SOC2000 classification current at the time, the results shown in Figure 6.2 were compiled using ONS data classified under both SOC 2000 and the later SOC 2010 (which took effect from 2011) to cover the period of the projections for the period 2004-2014. The changes, which primarily affected affected groups 1, 2 and 3, saw some managerial roles in group 1 re-designated to group 2, while nurses were raised from group 3 to group 2, as were some supervisory roles for the Information technologies (Elias & Birch, 2010).

The changes led to Group 1 numbers being reduced by 35 percent, Group 2 numbers increasing by 46 percent and Group 3 numbers reducing by 7 percent. The level of statistical adjustments between the two SOC classifications was obtained by finding the percentage difference for the numbers given for each group in question between the 2004 ONS data (under SOC 2000), and the 2014 ONS data (under SOC2010). The percentage difference was then applied in retrospect to the data for the year 2004 to 2010 to bring the two data sets into closer alignment. Clearly in this approach a degree of uncertainty is likely. However 96 percent of the activities in the Elementary occupations group were described as remaining unchanged through the transition between the SOC2000 and SOC2010 classification (Elias & Birch, 2010, p. 17).

This means that the employment numbers for the Elementary occupation group could be used directly from the ONS data without the need for adjustment between the two Standard Occupation Classifications. Where the projection numbers for the Elementary occupations in Figure 6.2 represented the greatest difference when compared to the ONS numbers in Figure 6.3, it might therefore be fairly assumed that the ONS figures were the more likely of the two to be of greater accuracy than the projected results. What might explain the discrepancy in the projections for Elementary occupations against the ONS figures? It is possible that Wilson's econometric approach may have been premature in its projection with the anticipated decline slower in manifesting itself. Beyond the SOC changes, the major event in 2008/9 that followed the projections for 2004-2014 figures was the global financial crisis, which added a further dimension to the uncertainties associated with projection. Stephen Taylor, however, of the Chartered Institute of Personnel and Development (CIPD), writing in 2008 and presumably before the economic crisis materialised, had a different perspective which may help to explain the positive result seen in Figure 6.3 for Elementary occupations when he looked at developments in the labour market and the UK economy over recent years:

> *'First, because the economy has performed well and because of long-term demographic trends labour has become more scarce in general terms. Second, the*

nature of the work that we carry out is steadily becoming more specialist in nature. More jobs are advertised that require applicants to hold some kind of professional qualification or to have achieved a defined level of educational performance. At the same time there are fewer unskilled workers available. Not only does this create acute skills shortages in some areas, but it also makes the recruitment and training of new people more expensive. Thus we have a situation in which the loss of effective performers through voluntary resignation creates many more problems for organisation and is much more costly than when it was when most jobs require few skills and could be readily filled by a pool of unemployed people.'

Source: *People Resourcing*, Published by CIPD (Taylor, 2008, p. 41,42).

While it appears that Taylor had expressed his view prior to the emergence of the full effects of the recession, there may still be some truth in his reasoning that some organisations saw advantages in employing and training those without costly formal skills when seeking savings in salary costs throughout the lengthy economic consequences of the financial crisis. There is some support for Taylor's view of a demand for semi - and unskilled workers. A Bank of England report of August 2015, commenting upon UK recruitment difficulties, announced that "Recruitment agencies reported a difficulty in filling semi and unskilled positions and that a reliance on migrant workers was increasing in a range of areas."(No named author, Agents' Summary of Business Conditions, August 2015 (Bank of England).

If there was a growing market for UK semi - and unskilled labour in the light of a growing pressure to encourage workers to acquire a portfolio of skills, it would appear there are also implications for skills and employment policy with issues of pay and productivity in the UK, particularly when mid-level skilled workers, seen at the the centre of the so-called hourglass economy, are forecast to be facing job losses (The Economist, 2013, August 10th).

The inherent uncertainty in projecting future trends was acknowledged by the Wilson et al, group in a caution that the projections were intended as no more than an indication of the UK employment trends. Moreover, Wilson et al. had already issued a warning early in the *Working Futures* series about the robustness of the data used to compile the projections in describing the data as not only "...pushed to their limits...", but that "Many of the official data sets have not been designed to provide robust information at such a detailed level" (Wilson, Homenidou and Dickerson, 2003-4: Summary).

For those seeking to estimate the demand for STEM skills in employment, the lack of disaggregation between STEM and non-STEM occupations hampers clarity when seeking to reinterpret data relating to the transition between a science education pathway and science and technology skills in employment. Also hampering efforts to produce a cohesive account over time of the level of demand for science skills lies both in the way vacancies are advertised and in the way the employment statistics are collected and the mode and classification terminology of their presentation.

In 2009 Wilson focused specifically on the question of demand for STEM graduates using the same methodological approach of the *Working Futures* reports. *The Demand for STEM Graduates: Some Benchmark Projections* (2009), also made use of LFS data in projecting STEM demand for the period 2007-2017:

> *'The benchmark projections are generated using data from the Labour Force Survey (LFS). This extends previous work on the levels of qualifications held by those in employment, as published in Working Futures (linked and updated to Working Futures 2004-2014) It does this by incorporating an additional dimension, highlighting the subject of qualifications for those qualified at degree level and above. The analysis assesses recent historical developments in the patterns of employment by the subject/discipline of qualifications held, and considers how these patterns might change over the next decade.'*
>
> Source: Wilson (2009, p. 6)

However the shortfalls of the available data were evident when Wilson further commented that the LFS data utilised for the STEM study had caused concern, in that they were:

> *'...quite sparse in places (especially at the most detailed level of aggregation by sector and occupation). Various procedures were developed to deal with gaps in the data.'* Wilson (2009, p. 6).

Nevertheless the procedures applied in projecting a level of demand for STEM skills appears to have been sophisticated and complex. It included the earlier mentioned analysis of historical and industrial sector data, the focus particularly on NQF level 4 and 5 [6] STEM qualifications, and what Wilson described as "...other dimensions, for example economic activity (employed, unemployed. etc,), gender and age." Included too was a series of

[6] National Qualifications Framework (NQF) level 4=Certificate of HE and level 5=HNC and HND and other higher diplomas (NiDirect, 2017)

Excel Workbooks containing a quantity of detailed information to facilitate the projection of future patterns of STEM activity in the workplace. The workbooks contained a number of dimensions that could be both interpolated, to estimate unknown values between two known data points, and extrapolated by extending a known sequence of values beyond those already known (Wilson, 2009, p. 50). Included in Wilson's et al. statistical tools was a sophisticated approach known as the Restricted Additive Schwarz method (RAS), This was utilised by Wilson et al. to ensure a "consistency across the various dimensions of employment." (Wilson, 2009, p. 6).

Trinh and Viet Phong explain that the main function of the RAS, as the most widely known and commonly used automatic procedure in such cases, is as a iterative algorithm used to balance input-output, or supply and use tables where the columns and rows are successively forced to add up to the correct margin totals (Phong & Trinh, 2013, p. 134). By interrogating a range of analytical and statistical approaches using such an approach, and others, an indication of the assumptions about the future demand for STEM skills in the workplace was derived against the economic uncertainty following the 2008/2009 global financial crisis. The final calculations lead to the graduate benchmark projections presented in *The Demand for STEM Graduates*. Table 6.1 indicates the result of the process, for the decade 2007-2017:

There is some uncertainty about Table 6.1 both in terms of the data origin and in the terms used to identify the qualification levels. In the first instance, for example, it is not made clear, whether the 'base year level' starting in 2007 was based upon actual employment figures or was also a projection. Moreover, since the report title indicates a specific focus on the demand for STEM graduates and assuming that Wilson's reference to 'graduate' refers to first degree, postgraduate and doctoral graduates, it would be expected that National Qualifications Framework (NQF) levels 6, 7 and 8, respectively, (Gov.UK, 2017), would feature in the results. Although Wilson refers to graduates and postgraduates in some of the figures and tables included in the report, the highest level included is the NQF 5 (Wilson, 2009, p. 9). According to government guidelines NQF 5 represents the HND qualification, the Foundation degree, and other higher diplomas, awards and certificates (What qualification levels mean, (Gov.UK, 2017)).

As the results stand, the implication of the figures inTable 6.1 appears to be that those with higher skill levels (NQF3-5) can expect to find themselves in greater demand in a growing market for their skills, while those without formal qualifications or at the lower end of the skill spectrum (0-2) are likely to face a declining labour market. Again, as in

Table 6.1: The demand for STEM graduates: Implications for Qualifications
Source: The Demand for STEM Graduates, Table 3.1 (Wilson, 2009, p. 26)

NQF All Industries	Base year level 2007	Change 2007-2017	Projected level 2017	Total requirement 2007-2017
NQF 5	2,420,669	897,709	3,318,378	1,789,070
NQF 4	7,986,647	1,968,485	9,955,133	4,909,404
NQF 3	6,125,075,	179,841	6,304,917	2,435,274
NQF 2	6,085,987	-169,232	6,636,754	2,336,932
NQF 1	5,422,300	-112,897	5,309,403	1,883,753
NQF 0	2,473,769	-814,580	1,659,188	96,334
total	31,234,447	1,949,326	33,183,774	13,450,768

	%share	%share	%share	% of base year level
NQF 5	7.7	37.1	10.0	73.9
NQF 4	25.6	24.6	30.0	61.5
NQF 3	19.6	2.9	19.0	39.8
NQF 2	21.8	-2.5	20.0	34.3
NQF 1	17.4	-2.1	16.0	34.7
NQF 0	7.9	-32.9	5.0	3.9
total	100.0	6.2	100.0	43.1

the *Working Futures* reports, Wilson offered a warning, this time less about the fidelity of the data (although this is also well covered in the report, as already mentioned) and more about the uncertain economic climate:

> *'The projections are based on the Working Futures macroeconomic scenario which was developed in the first half of 2008 at a time of considerable economic uncertainty, with concerns about the impact on economic prospects of the "credit crunch" and rapidly rising commodity prices (especially oil and food). Despite these uncertainties, and the deepening recession in the short term, the medium and long-employment prospects for the UK remain quite Bullish* [7] *with substantial growth expected, driven by rising population'.*
> Source: The Demand for STEM, (Wilson, 2009, p. 8)

[7] Bullish is an economic term that describes a financial market whereby prices are rising or expected to rise. Source: Ininvestopedia.com/terms/b/bullmarket.asp

Two main approaches to estimating the demand for labour are identified in the overview above and both have focused on the future demand for skills. The first, and the most prolific in this sample, is based upon extrapolating data from econometric modelling, historical employment levels and qualification levels and patterns, along with a complex statistical approach to dealing with available, missing, overlapping and sometimes sparse and deficient data sources. The outcomes of such approaches are based on assumptions that past indicators of labour demand will persist into the future. While this approach comes with warnings as to the reliability of the projections where assumptions are made, the premise has given rise to a number of decade long projections as to which occupations (classified under the SOC 2010 coding), are likely to be in growth and with a demand for labour at the end of the decade. The projections also extend to the estimation of which occupations are likely to be in decline and therefore with declining opportunities for labour. The level of skills anticipated to be in demand are projected.

The second approach seen in the overview has been to suggest a range of possible future scenarios based on a number of estimated and alternative outcomes in which labour requirements are seen to depend on which scenario, if any, materialises by some pre-calculated future date. While the first approach is far more specific in terms of the future occupations and in quantifying employment levels involved, the second approach is more generalised.

The overall consensus emerging from the sample literature overviewed above however appears reasonably clear-cut, namely that those with higher skills levels are more likely to be in demand from employers, while those with mid-level skills are more likely to face job cuts. Unresolved in this account are the prospects of those at the lower end of the skills spectrum, or for those entirely lacking formal skills or qualifications.

The question however as to whether there is currently an imbalance between the supply and demand for STEM skills, is not answered by approaches such as those above, to estimate needs of the labour market. This question will be revisited later in the chapter in discussing possible explanations for the perceived mismatch between STEM supply and demand despite the obvious difficulty in establishing a level of demand.

The next section considers demand through estimates of the number of job vacancies.

6.4 The Approach using Proxy Indicators of Demand

While the general emphasis in studies of the demand for STEM skills tends towards projected figures based on past performance and events, as well as an acknowledged assumption of a continuity of socioeconomic conditions, this section attempts to estimate the present level of demand from the available proxy indicators.

Two proxy indicators of demand are used. The first is the number of STEM job vacancies compared to the number of annual graduate supply figures in particular fields. This approach utilises the data published by the online employment agency *Adzuna.* Founded in 2011 with the aim of amalgamating all online advertised job vacancies (including those understood as STEM occupations) by 2015 *Adzuna* had recorded almost 1.3 million UK vacancies for the month of November 2015 (Adzuna, 2015b, p. 1). Used to inform the government of the rate of economic growth, the data aggregated by *Adzuna* from a number of online sources, present a novel opportunity to track labour market movement.

While the change in classifying the science and technology skills of higher education with the classification of occupations in the labour market adds considerably to the challenge of comparing STEM graduate supply with the labour market demand, vacancy data have an advantage that it is possible to identify a shortfall in labour supply for specific occupations or range of related occupations. For example if the vacancy numbers for any one *month* exceed the *annual* UK supply of new graduates, then a considerable UK educated labour shortfall, compared to the level of demand can reasonably inferred. A *prima facie* oversupply however may be questionable. The 'surplus' may be employed within the overall category, but in different occupations to those used for advertised vacancies. Nursing is an example which would be included under the category Allied to Medicine see Table 6.2 below.

The second indicator is the level of STEM graduate starting salaries compared over time. That salary levels may be closely linked with supply and demand is, as a theoretical postulate, attributed initially to the Scottish philosopher and economist Adam Smith in the mid-18th century. It persists today as a fundamental assumption of neo-classical market economics and is often assumed to apply both to the market for goods and services, and to the selling and buying of labour (Bosworth et al., 1996, p. 3). The theory assumes that when supply is plentiful relative to demand, salary levels will drop. Conversely when demand is high relative to supply, salaries will rise. They are not however expected to rise indefinitely. Higher salaries may provoke a reduction in the demand for that type of labour, presenting an inverse correlation between salaries and employment levels (Economics Online, 2017). According to orthodox economic theory, high unemployment is likely reduce wages as the number of those seeking employment increase market supply with lower salary costs leading to an increase in demand (Economics Online, 2017). Theoretically, a degree of equilibrium will be reached at the point where workers are prepared to sell their labour at a price employers are prepared to pay.

Considering the level of salaries as indicators of the relationship between labour supply and demand however, relies on the assumption that salary levels are the prime driving force in those who sell their labour. Bosworth, Dawkins and Stromback, in their study of labour market economics, put forward a number of alternative factors or “major peculiarities” believed to influence the selling of labour. Based upon the codification by Alfred Marshall in 1890 of Adam Smith's *The Wealth of Nations* (1776), the peculiarities, according to Bosworth et.al, distinguish the labour market from other types of markets (Bosworth et al., 1996, p. 3). Acting as potential influences affecting career choice they include personal preferences as to both the type and location of work offered as well as psychological factors, which are discussed later in this chapter. Nevertheless in attempting to estimate a level of demand that does not rely upon a future statistical projections, which itself is dependent upon past performance and an envisaged future scenario, salary levels are sufficiently measurable to contribute to a critical discussion about their influence on the labour market. This may be particularly so for new graduates who, if lacking work experience, may not yet have formed strong opinions as to their working preferences. There may also be a greater willingness among new graduates to accept the ‘market rate’ and conditions of work where there is high competition for employment. The empirical examination begins with the vacancy data.

6.5 Employment vacancies versus graduate labour supply

The vacancy data presented in Table 6.2 are interpreted against a number a number of caveats. Firstly, the unit of comparison is not uniform, as noted above. Instead the *annual* graduate numbers are compared against Adzuna's *monthly* indexed vacancies. While this allows a useful finding in those areas with a graduate undersupply compared to the vacancy numbers, it cannot be assumed that those fields showing an *oversupply* necessarily represents a potential labour *surplus*. In Table 6.2 for example, the data shown under the STEM category, *Allied to Medicine*, lists vacancies for ‘Pharmacists etc’ against what appears to be a large oversupply of graduates. However the STEM category also includes the nursing profession as one in which vacancies are seen as hard-to-fill according to the government approved UK Shortage Occupations List (Gov, 2015).

With the requirement from 2013 for nursing applicants to have a university degree to be able to qualify as a registered nurse, the consultancy firm Christie & Co looking at

Table 6.2: Vacancies in November 2015 for all STEM occupations compared to 2015 graduate supply, including undergraduate, postgraduate full and part-time.

Data source: Table compiled from data collected by Adzuna. Note: Adzuna is a search engine that claims to list every employment vacancy (accessed 14th November 2016)

STEM Subjects*	Occupations*	Adsuna Vacancies listed	HESA Graduate No's 2015	Demand ratio
Medicine & Dentistry	Doctors, Dentists	14,573	17,074	1:1.2
Allied to Medicine	Pharmacists etc.	11,739	98,992	1:8.4
Biological sciences	Teachers, Biologists	4,055	17,074	1:4.2
Veterinary sciences	Vets	1,276	1,347	1:1
Agriculture	All aspects	3,258	5,542	1:1.7
Physical sciences	Teachers, Lecturers	42,005	32,847	1.27:1
Mathematical sciences	Teachers, Lecturers	9,323	14,282	1:1.5
Computer sciences	IT workers and programmers	79,682	35,024	2.27:1
Eng. and Technology	Civil, Electrical and Electronic Engineering	96,365	60,202	1.6:1

Note 1: Vacancies listed in Table 6.2 are indexed on a monthly basis, while HE graduate numbers represent the estimated total annual output from complied HESA data.

Note 2: *Occupations listed by Adzuna in column two have been identified and matched to the appropriate *STEM category in Column 1. This is to reconcile the different categorisation systems used by the eduction system and the employment agency.

changes in the nursing profession found demand for training had doubled between 2008 and 2015 while the number of places available had remained constant. "Demand for training is there," they reported, "...but austerity measures have resulted in 3,000 fewer graduates from UK universities" (Christie, 2015, p. 6).

The main pressure points on the nursing workforce, according Christie and Co's report on nursing numbers were government funding cuts, an ageing UK population with increasing care needs, a reduction of overseas nurses entering the UK against tighter immigration controls while more were leaving, and a forecast of a likely increase in the domestic retirement numbers where 37 percent of the nursing workforce were, in 2015, over the age of 50 (Christie, 2015, p. 3). The shortfall in nursing numbers, according to Christie and Co, in 2015 was a 7 percent vacancy rate in the NHS, and 9 per cent for adult social care. This apparently accounted for some 24,000 full time equivalent (FTE) vacancies over the two sectors of the health service (Christie, 2015, p. 11). Christie and Co's investigation put the figures for subjects Allied to Medicine as seen in Table 6.2 into some perspective. It would be unlikely for instance, that a UK oversupply of prospective nursing graduates, as the figures in Table 6.2 might suggest, would be overlooked by employers in such numbers before sponsoring workers from abroad. This implies that caution is needed in interpreting the figures in Table 6.2 particularly where an oversupply is indicated and when categories are broadly defined.

Table 6.2 is useful however in considering an undersupply in graduates against the Adzuna vacancy data. In three fields, the computer sciences, the physical sciences, and engineering and technology, there appears to be strong evidence of a shortfall of graduate labour against the vacancy rates, where the annual UK graduate output is below the monthly vacancy rate.

For the computer sciences a shortfall in graduate numbers compared to vacancy rates shown in Table 6.2 appears to be a reflection of the recruitment pattern for this discipline, as seen in Chapter 5 in the dramatic decline over time in computing graduate numbers between 2003 and 2015. From this a shortfall, when compared to the vacancy rate, appears to fit with the HESA supply evidence. With the emphasis on the potential graduate workforce, an undersupply in their numbers may represent a real deficit in the workforce. There are however alternate routes to computing (as there are in engineering and technical services) other than through a university education, which would increase the potential supply while remaining absent from the graduate count. If this were the case, and significant vacancies remained, the mismatch between supply and demand would consequently be greater. Where the annual engineering graduate figures as shown in Table 6.2 fall far short of the number of *Adzuna's* monthly vacancies despite graduate numbers showing a steady increase over the research period (Table 5.4), this scenario would support persistent industry concerns of a shortfall in engineering numbers (Opito, 2015b).

It is interesting to note that in just one area shown in Table 6.2, there appears to be a close match between graduate supply and demand in the data shown for the veterinary sciences. This result also fits with the recruitment pattern for the veterinary sciences where a tight control was seen to be kept on recruitment numbers to avoid what was seen as superfluous to needs (see Table 5.4 in the previous chapter on supply).

For the physical sciences, where vacancies have been recorded, Adzuna data refer to specific occupations in need, namely teachers and lecturers. Again this appears to be an example where the annual figures for the physical sciences in some specific occupations falls short of the monthly indexed vacancies inducing a substantial deficit in supply. Beyond the figures and conclusions derived from Table 6.2, however it becomes clear that data at a more refined level are necessary to reveal the real state of science graduate demand beyond the macro level STEM categorisation.

6.6 Vacancy rates

Where the job vacancy rate is rising, relative to a previous measure, economic theory suggests that salaries and demand for labour will rise too as employers seek to attract applicants. The *UK Job Market Report December 2015*, and the *Vacancies* report, also for December 2015 (Adzuna, 2015a), records vacancy rates on a year-on-year basis. For the year 2015 for example the number of *Adzuna* advertised vacancies in the UK in November 2015 rose by 31.1 percent year-on-year when a total of 1,244,2772 vacancies were indexed by Adzuna. Vacancy rates for jobs were recorded at 0.52 per vacancy down from 0.90 the previous November (Adzuna, 2015a).

While *Adzuna's* data provide current estimates of vacancies by types of occupations, there remains a lack of historical data. A longer term-approach, which supplements *Adzuna's* vacancy data is offered by the independent *High Fliers Research* company in its examination of the graduate market; their research provides both graduate job vacancies and graduate starting salary levels data over time. There are however constraints in those data. The units of analysis used vary, depending on the areas of economic activity of the employers who year-by-year responded to the surveys. The list of "top employers" [8] are chosen from a final year graduate students' poll in response to the question, "which employer offers the best opportunities for graduates". The "top employers" therefore are subject to change over time, and the sector and industry categories with them. Moreover, they may be unrepresentative of the wider category of firms that recruit STEM graduates. Such consequential inconsistencies in the data make it difficult to construct a robust and consistent time-series data set for the numbers of vacancies.

However, in Figure 6.4, *The Graduate Market* has produced a composite data-table of vacancy changes for a number of "top employer" activities (occupations) over the five year period, 2005 -2015. Before considering the findings, a difficulty evident from the chart is that the activity terms (occupations) are not sufficiently detailed to clearly identify those

[8] The "Top Employers" are a group of organisations referred to as *The Times Top One Hundred Employers 2014* in poll of 18,336 final year students in response to the question, " Which employer offers the best opportunities for graduates" (The Graduate Market, High Fliers Research, 2014).

likely to be most representative of STEM intensive industries. While many of the listed aggregated categories were likely to include some STEM skilled workers, a judgement was made as to what categories were most likely to be the STEM intensive industries. This was achieved by noting the way employment and educational agencies advertised vacancies and education courses for those industries. Against this guidance the vacancy levels over time for three industries, IT and Telecommunications (Independent Jobs, 2017), Engineering and Industrial (STEM Graduates, 2017), and the Oil and Energy industry (Opito, 2015a) were examined.

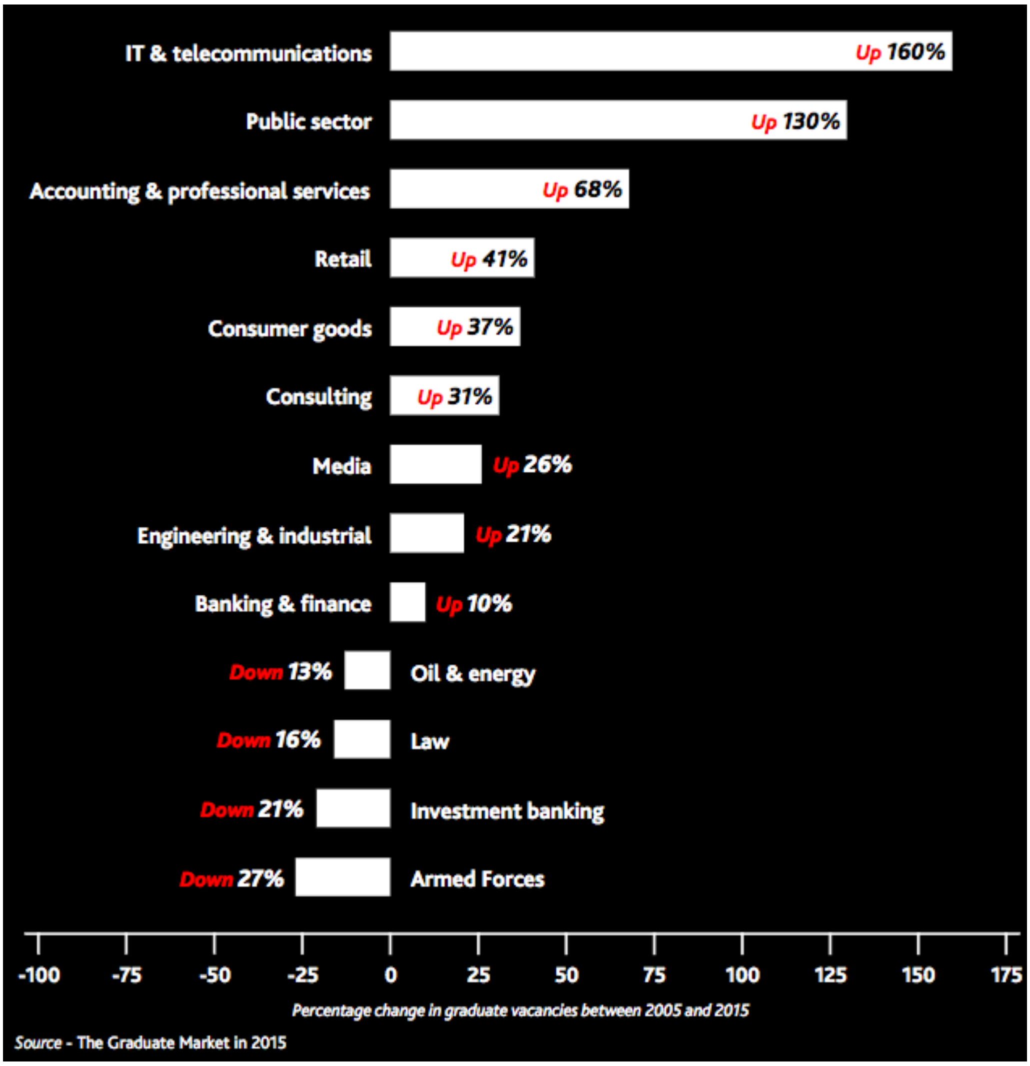

Figure 6.4: How Graduate Vacancies Changed 2005 to 2015, by Sector or Industry
Source: The Graduate Market, Table 2.11, High Fliers Research, 2015 p.17

From Figure 6.4, IT and Telecommunications vacancies can be seen to have risen over time by a very considerable 160 percent indicating a striking rise in an unmet demand for technological skills over the five years the data were collected. Whether this is due to a recent expansion in the industry or an ongoing mismatch between supply and demand over the years is not possible to determine from the data. But one likely explanation of an increased demand for telecommunication services is the roll-out of the 4G network across the nation and Ofcom's instruction (as the UK's communications regulator) that British Telecom (BT) reduce installation times for businesses "…from 48 to 40 working days…" (The Guardian, 2016a). Whilst this may help to explain a shortfall in STEM skilled workers it does not mean the shortage is any less real or urgent.

Engineering and Industrial as a category also showed an increase the vacancy rate by a more modest but still notable 21 percent over five years, suggesting the demand for Engineers was also rising over that time. With IT and Telecommunications, these were the only two STEM intensive occupations in Figure 6.4 with an increasing vacancy rate. The third and final STEM occupation included in the Graduate Market list was the Oil and Energy industry. A declining vacancy rate of 13 percent over the five year period suggested a closer balance both the supply and the demand for the science and engineering skills used in the oil and energy business represented in Figure 6.4 had been achieved of the three STEM occupations examined.

It must be remembered however, that the list of activities in Figure 6.4 was taken from The Times 'Top Employer' list as voted for by HE final year students. As such the selection of employer activities listed in Figure 6.4 would not necessarily represent the general distribution of STEM disciplines throughout the rest of the industry in terms of salary and vacancy levels and the type of occupational activities

Salary levels as a second proxy indicator to estimate the levels of demand are examined in the next section and may offer a further insight into the issues raised in this section about vacancy numbers.

6.7 Salary levels

Figure 6.5 uses the same industry activity categories from the Graduate Market High Fliers research report for 2015 as illustrated in Figure 6.4 to provide estimates of the starting salary levels for IT and Telecommunications, Engineering and Industrial, and the Oil and Energy industry. Understood as STEM-intensive, their graduate starting salaries are compared with two Non-STEM professional activities, Accounting and Professional Services and the Law profession which, like most STEM occupations, impose an entry requirement of at least a first degree, or equivalent.

Most notable in Figure 6.5 are the salary levels for IT and Telecommunications which

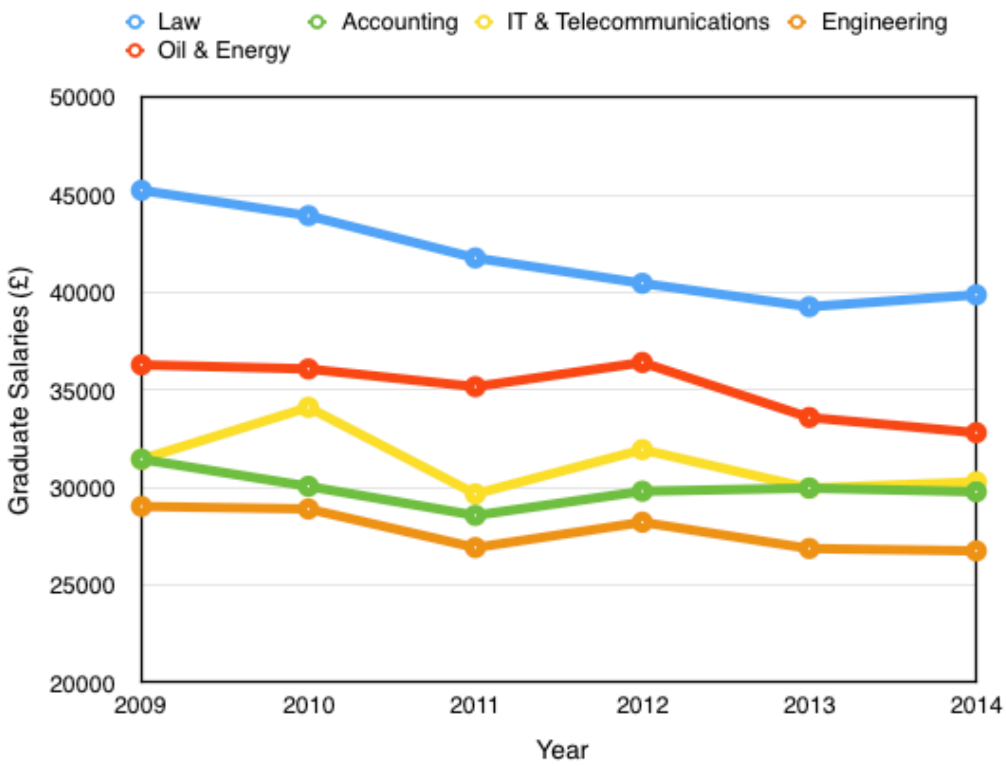

Figure 6.5: Graduate starting salaries for selected STEM and Non STEM activities 2009-2014

Source: Salary figures are plotted from the annual The Graduate Market, High Fliers Research Limited reports, Starting Salaries for Graduates, for the years 2009, 2010, 2011, 2012, 2013 and 2014.

Note: the figures have been adjusted year-by-year for inflation using the Bank of England inflation calculator, and rounded to the nearest 100. Although Figure 6.5 data terminates in 2014 the salary data levels are adjusted to the 2015 inflation rate to allow an equal comparison with the data in Table 6.5.

show an oscillating pattern with a two year wavelength. This pattern gave graduate starting salaries for that industry as £31,500 in 2009, rising sharply to a peak at around £34,000 in 2010 before dropping to its lowest point in 2011 at under £30,000. A second high at £32,000 was reached before finishing at the start of 2014 at just above £30,000 mark.

Engineering and Industry offered the lowest starting salary of the five activities in Figure 6.5, at £29,000 in 2009. A clear downward trend is evident over the period and despite a slight recovery at 2012, the industry barely recovers its 2009 level before continuing a steady decline to 2014 with salary levels at £26,800.

Of the three STEM-dependent industries examined in Figure 6.5, Oil and Energy appear to offer the highest starting salary for graduates at £36,300 in 2012, although the industry also showed the greatest change in STEM graduate starting salary levels by

2014, declining to £32,800 in 2014. Nevertheless the salary levels were still recorded as the highest of the three STEM occupations in this survey. It is interesting also to note that the vacancy rate for the Oil and Energy business was seen as the lowest of the three STEM occupations examined in Figure 6.4 with a 13 percent declining rate, suggesting a link prima facie between salary and vacancy levels.

The two non-STEM activities however showed a similar downward trend. In 2009 Accounting and Professional Services were offering graduates starting salaries of £31,500. By 2014 they had dropped to around £29,800, while new Law graduates students could expect to earn around £45,200 a year in 2009. Five years later salary levels for new Law graduates had declined to £39,900.

Table 6.3: Percentage change in STEM and Non-STEM graduate salary levels 2009-2014
Salaries corrected for inflation to 2015 and rounded to the nearest hundred.

Occupation	2009	2014	Change
Law	45,200	39,900	-11.7%
Oil and Energy	36,300	32,800	-9.6%
Accounting	31,500	29,800	-5.4%
IT and Telecommunications	31,500	30,300	-3.8%
Engineering	29,000	26,800	-7.5%

Source: Salary figures are plotted from the annual The Graduate Market High Fliers Research Limited reports, Starting Salaries for Graduates, for the years 2009 and 2014.
Note: The figures have been adjusted year-by-year for inflation using the Bank of England inflation calculator, and rounded to the nearest 100. Although Figure 6.5 data terminates in 2014 the salary data levels are adjusted to the 2015 inflation rate to allow an equal comparison with the data in Table 6.5

Since both the STEM and non-STEM categories suffered a clear downward trend in salary levels over the period 2009 to 2014, an external cause is indicated. The most obvious was the financial crisis of 2008/2009 and the recession that followed. If that were the case, the findings suggest that the economy was not in full recovery by the 2014 data point. Common across all occupations in Figure 6.5 is a particular drop in salaries noted in 2011 and, with the exception of Law, the salary level rise at the 2012 data point. While the bankruptcy rate (as an indicator of a difficult financial climate for business), had begun to fall following a peak in 2009, this was clearly a time of continuing financial uncertainty for industry and business. During the time of the data collection, 2009-2014, annual price inflation levels over that the period 2009 to 2013 had exceeded the government's target rate of 2 percent. Indeed, in 2011 inflation had more than doubled the government's 2 percent target limit according to the figures in Table 6.4.

Table 6.4: Average Inflation (CPI*) levels in Great Britain (Scotland, England & Wales) by year. Source: www.Inflation.eu *CPI: Consumer Price Index

	2009	2010	2011	2012	2013	2014
Average Inflation Rate	2.17%	3.29%	4.48%	2.83%	2.53%	1.47%

In the case of IT and Telecommunications, as already mentioned, there is the likelihood that the salary pattern for the sectors shown in Figure 6.5 at the 2010 and the 2012 data points may be connected to the countrywide installation of the high-speed data lines for business services. Following Ofcom's demand to speed the process as essential to the competitiveness of the UK (The Guardian, 2016b), there may have been a need for the telecommunications industry to offer higher salaries in the short term to attract additional workers to meet increased demand peaks. An overall increase in demand was indicated by the vacancy levels recorded in Figure 6.4 above.

While new graduates in those industries examined can be seen to have suffered in terms of reducing salary levels through the period 2009 to 2014, Figure 6.5 shows the graduate starting salary for the category Engineering and Industry lagging well behind those for IT and Telecommunications, and most particularly, the Oil and Energy industry which also recruits engineers (E & T Jobs , 2015). On this basis, and with the understanding that the level of labour market demand may be positively related to salary levels, the findings indicate there may have been a close balance between the supply of engineering graduates and levels of employers' demands, furthermore the supply numbers were slightly in excess of those for demand. The comparatively lower vacancy figures also noted in Figure 6.4 support this conclusion.

The next table looks at the salary levels across the major STEM disciplines.

Table 6.5 shows the changes in starting salary levels across the major STEM disciplines. The 2015 salary figures show a marked decline when compared to the inflation-adjusted figures for 2010. The greatest changes are shown for Medicine, with salaries declining at 6 percent, and for the Nursing profession at a loss of 12 percent over that interval.

Table 6.5: STEM Graduate Starting Salaries and the change, 2010 -2015 in the UK.
*Data adjusted for inflation averaged at 3.0% a year (using the Bank of England inflation calculator)
Data source: The Complete University Guide (accessed 15th November 2016)

STEM Subject	2010 original	2010 inflated*	2015 original	Change original	Change adjusted*
Medicine	£28,996	£33,502	£28,191	-3%	-16%
Nursing	£22,357	£25,858	£22,840	2%	-12%
Biological Sciences	£19,260	£22,277	£20,624	6%	-7%
Veterinary Medicine	£25,242	£29,195	£26,872	6%	-8%
Agriculture	£18,015	£20,836	£20,696	14%	-1%
Physics	£23,540	£27,226	£25,047	6%	-8%
Mathematics	£24,120	£27,898	£25,840	7%	-7%
Computer Science	£22,184	£25,658	£25,203	13%	-2%
Engineering	£23,000	£26,602	£26,146	13%	-2%

Since training and salaries in this occupational area are funded by the government, it is plausible that these figures reflect a time of national economic restraint during the recessionary period following the 2008/9 global financial crisis, rather a lack of demand for medical services.

While financial concerns are likely to have played a part in depressing STEM salary levels, there are implications in Table 6.5 for the question of demand for some STEM skills over others. HE enrolment numbers for medical and nursing students were strictly controlled, and those who successfully completed their medical, dentistry or nursing training, irrespective of salary levels, were less likely to face unemployment six months after graduation when compared to other graduates (de Vries, 2014, p. 33).

Leaving medicine and nursing aside, some broad implications can be inferred. Firstly, by considering the differences in 2015 STEM salary levels between the sectors, and by the percentage changes in salaries over the five year period 2010 to 2015, it is possible to infer changing general patterns of demands for sector-specific STEM skills, though is the data are not sufficiently detailed to enable specific levels of demand for particular sub-sectors.

While Veterinary Medicine headed the salary list in Table 6.5 at almost £27, 000, it endured overall an eight percent drop in salary levels over the previous five years. However the question of demand is somewhat moot for this occupation where the numbers enrolled in veterinary studies are also tightly controlled by its professional body. This ensures that graduates were also less likely to remain unemployed when compared to other non-medicine disciplines (de Vries, 2014, p. 33).

Mathematics and Physics graduates, though their starting salary levels were also relatively high at £25,840 and £25,047 respectively, faced a salary change over the time period 2010-2015 of -7 percent to -8 percent respectively. This suggested that demand for their skills in their own right was not seen as a growth trend. Mathematics and physics skills however underpin all other science and engineering disciplines and the salaries listed here do not take into account the earnings that might be available to practitioners if employed in other sciences and even in areas outside the sciences, such as the financial services. This does indicate however that the market value of newly graduated STEM skills may depend upon the field in which they are employed; the same could be said of Engineering.

By 2015, Engineering was shown in Table 6.5 with the second highest graduate starting salary at £26,146 of those listed. With only a two percent decline in salary levels over the previous five years, the combination of relatively high starting salary and low change rate over time implied that the demand for engineers was likely to have been growing. In terms of starting salaries however, the Oil and Energy industry also as an employer of engineering skills, according to the Offshore Industry Training Organisation (Opito, 2015b), offered a starting salary in 2014 of £32, 800, albeit the level had declined in real terms over the previous five years by 9.6 percent (Table 6.3). Over that interval, crude oil prices also declined. (InflationData, 2017)

The lowest rate of change at minus one percent, was also seen for one of the lowest salary levels in the list, that of £20,696 for Agriculture. The lowest starting salary however, was that of the Biological Sciences. At just £20,624, the sector salary levels also suffered a decline of 7 percent in salary levels over the five year period. While all salary levels are seen to have suffered cutbacks in their graduate starting salaries those, with the lowest levels of decline in over the five years can be reasonably assumed to indicate a level of stable or increased demand in the labour market for their specific skills.

Somewhat surprisingly, the salary level for Computer Science in 2010 was given in Table 6.5 as around £1000 less than that for Engineering, despite the reported concerns about a 'digital skills crisis' which was claimed to threaten the UK's productivity and economic competitiveness (see for example, (House of Commons, 2016, p. 3)). Computer Science was the only STEM subject to have suffered a shortfall, (and a considerable shortfall recorded at 32.4 percent) in HE enrolment numbers over the period 2003 to

2015, (Chapter 5, Table 5.4). It appeared reasonable therefore to assume that salary levels would reflect a need to attract potential computer graduates when considering the apparent importance attributed to the subject to the UK economy. However, although Computer Science salaries were ranked no higher than number fourteen in the Salaries list, real salary levels had been cut by only two per cent over the previous five years (Table 6.5).

In considering salary levels and the percentage change in their real value over the five year period, 2010 to 2015, it appears that while new graduates in the Biological Sciences were becoming less in demand in the labour market, demand for Engineering skills was increasing along with those for Computer Science. On this basis despite the evident increase in enrolment numbers between 2003 to 2015 for Mathematics and Physics degrees (up by 56.5 percent and 35.5 percent respectively, (Chapter 5, Table 5.4), the decline of seven and six percent respectively in real terms for *salary* levels over the years 2010 to 2015, suggests the demand for those skills was not a growing demand.

While all salary levels in Table 6.5 are seen to have suffered reductions in their graduate starting salaries, those with the lowest levels of decline over the five years can be reasonably assumed to indicate a level of stable or increased demand in the labour market for their specific skills. Although the figures differ slightly across the different tables, these findings are supported by Table 6.6 below which lists the twenty-five highest starting salaries across all graduate occupations in 2015.

When considering the demand for STEM skills, it is notable from Table 6.6 that fourteen STEM occupations were included in the list of the top twenty-five highest graduate salaries in 2015 out of a total of seventy general graduate occupations in the full list produced by *The Complete University Guide* for that year (*What do Graduates Earn and How has this changed?* (The Complete University Guide, 2017). Of the fourteen STEM subjects listed, six were in engineering. One interesting feature of this list is the partial disaggregation of the listed occupational group for engineering into a number of subgroups. This provides estimates of the salary differences within the various engineering fields. With salary levels assumed as proxy indicators of the relative scarcity of skilled personnel, they imply differences in the levels of demand for several fields of engineering. The starting salary for example for Civil Engineering was some £5,000 less than that for Chemical Engineering, which was ranked second in the list with a salary of £28,603, although the salary differences between the top five occupations listed in Table 6.6 were minimal.

Table 6.6: Top Twenty-five Graduates starting salaries and the level of change 2010 to 2015

Source: Abridged from The Complete University Guide, *How much Do Graduates Earn and how has this Changed?* 20/02/17. Data based on Destination of Leavers from Higher Education (DLHE), 2014 - 2015 graduate/professional jobs level jobs only, where professional refers to a job or occupation which jurally requires a degree.

Note: Data are incomplete for Complimentary Medicine and Aural & Oral Science. Data adjusted for inflation at 1.15% based upon the Bank of England Inflation Calculator.

	Occupation	2010 inflated	2015 original	Change original	Change adjusted
1	Dentistry	34,837	30,432	0%	-13%
2	Chemical Engineering	31,274	28,603	5%	-9%
3	Complimentary medicine	no data	28,259	no data	no data
4	Medicine	33,502	28,257	-3%	-16%
5	Economics	29,580	28,157	9%	-5%
6	General Engineering	30,523	27,157	2%	-11%
7	Veterinary medicine	29,195	26,872	6%	-8%
8	Mechanical engineering	28,435	26,361	7%	-7%
9	Building	24,949	26,286	21%	Gain 5%
10	Electrical & electronic engineering	26,602	26,146	13%	-2%
11	Mathematics	27,898	25,840	7%	-7%
12	Aero nautical & manufacturing Eng.	26,758	25,588	10%	-4%
13	Civil engineer	27,217	25,550	8%	-6%
14	Computer science	25,658	25,203	13%	-2%
15	Physics & astronomy	29,227	25,047	6%	-8%
16	Geology	28,481	24,818	0%	-13%
17	Social work	27,942	24,761	2%	-11%
18	Librarianship & IT	23,596	24,576	20%	Gain 4%
19	Land & property management	22,422	24,505	26%	Gain 9%
20	Philosophy	24,260	24,377	16%	0%
21	Russian & East European languages	27,562	23,973	0%	-13%
22	Business & Management	24,528	23,592	12%	-2%
23	East & South Asian studies	22,170	22,723	23%	Gain 7%
24	Aural & Oral science	no data	23,658	no data	no data
25	Politics	24,819	23,603	9%	-5%

The findings from this examination of labour market demand have suggested that the lowest demand for the listed STEM skills, between 2010 and 2015, was for Biology graduates. It was noted however unlike the engineering group no effort has been made in Table 6.6 to delineate biology into specific areas, which can include for example experimental, mathematical, human, evolutionary and computational biology. Seeing the differences for the disaggregated subgroups of the engineering profession, and it is reasonable to suggest that a similar approach to biology may also highlight similar differences in salary levels and, in turn, infer a difference in labour market demand.

With Mathematics seen in Table 6.6 commanding mid-level starting salaries, new maths graduates were clearly valued in the labour market over the years 2010 to 2015. But cuts of 7 percent in real salary levels for Mathematics graduates, positioned in Table 6.6 salary-wise between Electronic and electrical engineering, and Aeronautical engineering, with reductions of just 2 and 4 percent respectively, compare less favourably. This would imply the demand for Mathematics graduates was not then growing strongly. Physics salaries, as with Mathematics, were above the £25,000 level, suggesting a similar level of demand, but since salary levels fell by 8 percent from 2010 to 2015, also suggests that there was no growth in the demand for Physics graduates by 2015.

Salaries for Computer Science graduates, ranked at number fifteen in the list of the twenty-five top graduate starting salaries, were also in the £25,000 mid-salary range. They too experienced a two percent drop over time in the real value of their salaries. The implication is, to the extent that salaries are indicative of demand, that Computer Science graduates were valuable to the labour market in 2015, but that they too did not experience growing demand, having suffered a 2 percent loss over five years in the real value of their salaries, despite a heavy dependence by business and society on digital skills (see, for example, the House of Commons, Select Committee, 2016, p. 7). In all, fourteen STEM occupation of the twenty-five occupations listed in Table 6.6 show STEM as a set of well-rewarded professions.. However all fourteen also showed a percentage loss in the value of their real salary levels, which ranged from two percent to sixteen percent over the five years of the data 2010 to 2015.

Supportive evidence indicating that demand for some of the best rewarded STEM professions did not grow in 2015 can be seen in Table 6.6. Compared to the statistics for the demand of the listed STEM occupation are those for:

The Building industry, ranked number 9 in the top twenty-five graduate salaries list in Table 6.6

Librarianship and IT at number 18,

Land and Property Management at number 19, and

East and South Asian Studies at number 23.

Not only had these four occupations been included in the top twenty-five salary list, each of them had seen increased salary levels over the period 2010 to 2015, in real terms by five, four, nine and seven percent respectively. They were occupations in growing demand over the period 2010-15. Moreover, all four included in the list are noted as "... graduate/professional jobs level jobs which generally requires a degree" (*How much Do Graduates Earn and how has this Changed?* The Complete University Guide (2017)).

Although the differential in salary levels, and in the rate of change in specific occupational salaries over time, may help to indicate those STEM occupations for which the demand for particular skills were higher or lower than other occupations, it is important to note that data examined in this chapter were drawn from a time period of exceptional financial uncertainty, following the global financial crisis of 2009. Those considerations suggest that unanticipated and extended events can change labour market demand both in the short and in the medium term. This implies that long term forecasting may be even less reliable that might otherwise be supposed.

6.8 The supply and demand mismatch perception

In contrast to persistent suggestions of an imbalance between the supply of STEM graduates and the labour market demand, this chapter has looked at a range of approaches which have endeavoured to estimate the trends in the demand for STEM skilled workers over the period 2010 to 2015.

The critical question of the demand for STEM graduates, quite apart from the obvious difficulty of projecting future workplace requirements, is somewhat ambiguous when attempting to estimate current demand. The STEM field is defined by the Standard Occupational Classification coding through a hierarchy of four levels.

The broad major disciplines are broken down into a set of major sub-groups to reflect increasing specialisation within subject areas. The difficulty in determining where a shortfall currently exists in the sub-groups can have ethical, economic and policy implications. An oversupply of potential STEM labour is likely to leave those graduates frustrated and disillusioned at what might be taken as an expensive and wasted education when there are too few jobs available in their chosen STEM field, or where the earnings are relatively low.

An undersupply on the other hand is likely to affect industry productivity and innovation, and the UK's global economic competitiveness (House of Lords, 2012). Forecasting future levels of labour market demand cannot and should not be made independently of wider industrial strategic policies.

When considering demand at the sub-group level, the Engineering profession offers an indication of the extent of diversity that exists under the generality of major group headings. Engineers currently classified under Group 2 for example in the Standard Occupational Classification (SOC) codes, can be identified as civil, mechanical, electrical, electronic, design and development, production and process engineers, as well as professional engineers working under the New Engineering Contract (N.E.C.; The Institute of Civil Engineers). The broad category also appears to include Chemical Engineering, a subject shown in Table 6.6 as second largest in the top earnings list for 2015.

Given that the labour market for graduates with STEM skills can be expected to co-evolve with technological changes, governmental industrial and innovation policies and corporate strategies, there is likely to be an advantage to both graduates and to employers if STEM graduates acquire broad and flexible skills across a range of sub-fields in their chosen discipline, and even across disciplines. That would however require changes to curricula for STEM degrees, which may in turn imply that the A-level GCE systems may also need to change.

In the context where perceptions of an ongoing and future crisis in terms of an undersupply of science and engineering graduates, it is relevant to ask how reliable are salary levels as indicators of the prevailing level of demand for STEM graduates? Orthodox economic theory suggests, all else being equal, that when the supply is plentiful in relation to demand the price of the commodity declines; when supply is short prices rise, which raises the question of whether the STEM graduate labour markets follow a similar pattern?

Bosworth's et al approach to labour market economics emphasised significant distinctions in the way the two labour and commodities markets behave in identifying a number of 'peculiarities' of labour markets in general, which they argued are exemplified in STEM graduate labour markets. Bosworth's et al constructed their analysis based on the earlier work of Alfred Marshall (1890), to argue that the market for skilled labour differed from general commodities markets. Interestingly, not one issue in their list was solely concerned with levels of earnings.

Bosworth et al's list of peculiarities included:

1. 'The worker sells his work, but retains capital in himself' (Marshall, 1890).

2. Each seller of labour possesses subjective preferences about the use to which that labour is put, the location of employment and working conditions.

3. Employers may possess subjective preferences about who they wish to employ.

4. The decisions to supply labour and consume goods are strongly interdependent.

5. The labour supply decisions of persons within the same household are strongly interdependent.

6. The suppliers of labour often form interdependent labour unions, and take collective action in pursuit of their goals (buyers of labour services can also band together).

7. Psychological factors can have an important influence on the relationship between employers and employees. Concepts such as trust, loyalty, fairness and motivation are very important.

Source, Bosworth, Dawkins & Stromback, The Economics of the Labour Market, 1996, p. 3,4.

Bosworth and colleagues' list suggests that decisions about selling of labour is influenced by a range of issues other than just salary levels. It is important to note however that Bosworth et al's, list was compiled before universities began charging students for their HE education. Salary levels in this case might assume a larger consideration today in those able to pursue them. This may have increased the influence of salaries on level of supply of STEM graduates and of their employment choices, but not on the overall aggregate level of demand.

The subjective preferences of employers also listed by Bosworth et al., as a peculiarity of the labour market is unlikely to affect overall levels of demand. If exercising a preference however restricts the choice of potential employee to a narrow portion of the labour market supply it may lead to some supply areas under exploited and others strained to meet demand. Employer gender preferences were noted in a 2014 report by UK lawyers, Slater and Gordon, which identified levels of workplace discrimination. A survey of 500 managers found that one-third of the respondents would rather employ a male in his 20s or 30s, than a women of similar age, to avoid the potential cost of funding maternity leave. The report also suggested that: "... 40 percent of the managers surveyed had admitted that they were generally wary of hiring a women of childbearing age." A similar number were said to have admitted they were also wary of hiring woman who already had a child, or in hiring a mother in a senior role (*Slater and Gordon Highlights Maternity Discrimination,* S and G in the News (2014)). The report does not qualify how many, if any, of the sample base were managers of STEM graduates, but if similar approaches were also to be found in the STEM industry, demand for male workers was likely to be substantially higher.

While financial considerations can often be seen as drivers of human behaviour, Bosworth et al. recognised in their list of 'peculiarities' that prospective employers were also known to practice a non-pecuniary discriminatory approach based on social class, gender or race. This is supported by an empirical study that found employers tend to recruit individuals who shared similar backgrounds, education, likes and interests, a phenomenon that Lauren A. Rivera, when researching US recruitment practices, of elite professional service firms, referred to as 'cultural matching'. Rivera writing in the American Sociological Review, summed this as "Employers sought candidates who were not only competent but also culturally similar to themselves.", and where, "Concerns about shared culture were highly salient to employers and often outweighed concerns about productivity." (Rivera, 2012, p. 999), To what extent this phenomenon may help to explain the paradox of STEM graduates who remain unemployed six months after graduation against the persistent claim of a shortfall in STEM skills is a topic that remains to be researched. What is known however from Shadbolt's description of the "distinctive profile" in 2015 for those students studying Computer Science, is that the cohort included a greater proportion of male students over females, students from black and minority ethnic (BME) backgrounds, and students with previous lower levels of achievement Shadbolt, 2015). Shadbolt also reported that black and ethnic minority Computer Science students were six percentage points less likely to be employed than similarly qualified white graduates (see Chapter 5), (Shadbolt, 8th July 2015: unpaginated web article published in advance of the full report in 2016, *Unemployment among computer science graduates - what does the data say*). This differential was, however, less than that for graduate subjects like electronic and electrical engineering or the mathematical sciences (Shadbolt, N., 2015). This strongly indicates that the demand for STEM graduates, as Rivera had found in her (2012) "cultural matching" research, is uneven, and heavily dependent on factors other than formal qualifications.

Whatever the cause, there remain repeated assertions of a mismatch between employer needs and what graduates can offer.

The Annual Skills Survey of the Institute of Engineering and Technology (IET) for 2014, interviewed 400 employers from UK engineering and IT companies. When asked about their recruitment plans, 40 percent said they had trouble recruiting engineering graduates, while 70 percent did not expect to be able to recruit over the next four to five years. They suggested the problem was due to a lack of suitably qualified candidates, while half the respondents cited difficulties in recruiting those with specific skills (Bloomfield, 2015, p. 1).

Georgina Bloomfield, of the employer marketing Company *ThirtyThree*, with consultant Marcus Body from the same organisation, looked at the problem from a different perspective in considering aspects of graduate recruitment. The first was the quality of graduate courses. Some universities are better, suggested Body, than others. A 2.2 degree from Imperial (College) in engineering for example: "…is going to be miles better than applicants with a first from most other universities." Nevertheless, according to Body, those who screen graduates for their first job interview, in-house or third party, "…know nothing about engineering, so they will use bonkers criteria from degree grade to spelling." to select candidates. (Body cited in Bloomfield (2015, p. 1,2)). Bloomfield picks up the argument,

> *'If this is the case, then it is no surprise when companies have trouble with recruiting a new generation of engineers and technicians. Could it be that companies are being far too fussy with their criteria? They cannot expect a graduate to be able to replace someone who's about to retire and has probably been in the job for over thirty years - like - for- like?'* (Bloomfield, 2015, p. 1).

The question of salary levels was raised in the 2014 Skills Survey of the Institute of Engineering and Technology (IET) where fewer than 20 percent of employers' respondents said they would offer more attractive salaries when recruiting over the next four to five years. To this, Body suggested that salaries should be doubled before declaring a shortfall in engineering graduate numbers (Body, cited in Bloomfield (2015, p. 1, 2)).

Geoff Mason, of the National Institute for Social and Economic Research, as long ago as 1999, questioned the long-running 'alleged' shortages of engineers and scientists in the UK against salary levels.

> *'If these occupations are in such short supply, why has this excess demand not put pressure on their salaries and thus eventually (all else being equal) helped to encourage more young people to study engineering and science subjects at university?'*
> Source:Mason, Department for Education and Employment, Research Brief 112, 1999, page 3 of 4.

The answer, according to Mason, was that while many companies accepted that salary levels contributed to the difficulty in recruitment, some operated an 'internal labour market' where it was seen necessary to preserve a stable salary differential between roles, and for in-house internal promotions to fill senior roles. If salary adjustments were made for new entrants it was likely to cause a 'knock-on' effect on graduate salaries elsewhere in the firm. Such employers were therefore reluctant to raise salary levels for new entrants for fear of disturbing existing salary structures (Mason, 1999, p. 3, 4). Where similar internal labour markets are operating in companies today, that justification for not responding to external market pressures to increase salary levels may still operate.

One further issue is examined to help to understand the persistent call for an increase in STEM numbers, despite a lack of conclusive evidence of a mismatch between supply and demand. According to Bosworth et al, there is a clear picture, of substantial regional differences in the availability of STEM graduates in the commuter patterns seen across England as a result of commuting in 2013:

- London had a net gain of 87,000 Core* STEM workers
- South East had a net loss of 50,000 Core STEM workers
- East of England had a net loss of 20,000 Core STEM workers
- East Midlands had a net loss of 22.00 Core STEM workers

Source: Bosworth et al. (2013, p. 6, 7).
Note* Core STEM workers are described as the Biological sciences, Agricultural sciences, Physical and Mathematical sciences and Computing, Engineering, Technology and Architecture, but not including Medicine.

Those figures suggest that London strongly attracts those with STEM skills, which has a negative effect on regional STEM labour markets in other parts of the UK. The exceptions were in pharmaceutical companies located close to Oxford and Cambridge. Excepted too were engineering companies whose head offices tend to be outside London (Bosworth et al., 2013, p. 6, 7). Those industries based outside London may enjoy less expensive rents and rates, but will struggle to find the skills they need without offering competitive employment packages. This unequal distribution of STEM skills in England may well contribute to the perception of a STEM graduate shortfall, whatever assurances may be offered as to the relationship between aggregate supply and demand.

6.9 Summing up the Trends in Demand

6.9.1 Vacancy rates as indicators of demand

A mixed picture is presented when attempting to estimate a level of demand when vacancy rates and salary levels for new STEM graduates are utilised as proxy indicators. In first considering vacancy rates and the demand for STEM skills, there is indication of demand for some STEM subjects and an oversupply in others.

For two subjects, *Engineering and technology,* and *Computer Science*, a substantial shortfall was indicated for the level of graduate supply when compared with the number of vacancies. Table 6.2 for example shows that monthly vacancy rate for November 2015 at over 96,000 with the *annual* (2015) supply of first and postgraduate degrees for *Civil, Electrical and Electronic Engineering* graduates at just over 60,000 highlighting what appeared to be a very substantial shortfall in supply against demand. A shortfall was also seen for *Computer Sciences.* With listed monthly vacancies at almost 80,000 there was just over 35,000 graduates produced for the *whole* of the year 2015. It is important to note however that in both of these disciplines, there are alternative routes to employment in the industry that do not necessarily call for a university degree. Adding this unknown number to the workforce supply will obviously affect the overall balance between supply and demand.

The third evident shortfall in supply when compared to the vacancy rate is seen in the *Physical Sciences.* Table 6.2 shows the number of *monthly* vacancies standing at 42,000, while the annual supply for the year 2015 was 10,000 short of that figure. It is noted that the listed vacancies were for teachers and lecturers. Whereas the graduate workforce numbers for *Engineering and technology*, and *Computer Science* were likely to be boosted by alternatively qualified workers, teaching roles in schools and universities require practitioners to hold at least a first degree and a teaching qualification. This implies the supply of graduates for the Physical Sciences is unlikely to be augmented other than by overseas sources, supporting the argument for a shortfall in the UK supply.

There is also an indication in Table 6.2 of an oversupply of graduates in some disciplines. For example, the subject category *Allied to Medicine* appears, *prima facie*, to be heavily oversupplied with the number of graduates produced in the academic year 2015 outweighing the number of vacancies for November that year by about 87, 000. However if the monthly vacancy rate is typical of each monthly rate and calculated as such over twelve months the graduate supply figure is clearly inadequate to meet the overall vacancy demand. Moreover, as the major group *Subjects Allied to Medicine* also included nursing profession as a sub-group, with nurses included on the government's list of occupational shortages, far from an oversupply, again a deficit in graduate numbers become evident.

From these examples it becomes clear that although this particular method of comparing monthly vacancy rates with annual graduate production figures can indicate an undersupply, without knowing the monthly vacancy take-up rate and how much of an overspill there from is month to month it cannot comment on an oversupply.

Remaining with the question of vacancy rates as a proxy indicator of demand further evidence of shortfalls in supply are evident in Figure 6.4 which looks at the growth or decline in the number of vacancies over the period 2005 to 2015. From this it can be seen that two STEM activities have been in growth. The first and most substantial is that of *IT and telecommunications.* Over the ten year period the study by the *Graduate Market* in 2015 found the vacancy rate for this occupation had increased by 160 percent. It was possible that a rise of this magnitude was due to increased activity in the nationwide installation of the 3G broadband network. Growth was also seen, but to a lesser extent, in the increase of vacancy numbers by 21 percent for what the *Graduate Market* data categorised as *Engineering and Industrial.*

Figure 6.4 however also shows a declining vacant rate of 13 percent over the ten year period 2005 to 2015 for the category *Oil and Energy.* The decline suggests a closer equilibrium between supply and demand has been achieved over the period. Notable of the vacancy rates discussed for *Engineering and Industrial, IT and telecommunications* and *Oil and energy, Oil and energy* with the declining vacancy rate, also paid the highest graduate starting salary suggesting a consequent demand for a STEM skilled workforce, although the real value of the Oil and Energy salaries, seen to be in common with all the STEM occupations, had fallen over the preceding years according to Figure 6.4 indicating that the demand was stable rather than in growth.

6.9.2 Salary levels as indicators of demand

In examining salary levels as proxy indicators for the demand of new graduates a similarly mixed picture is presented.

Fourteen STEM occupations were included in the Top Twenty-five graduate starting salaries list for 2015 (Table 6.6). Six of the fourteen represented engineering, with Dentistry and Chemical engineering occupying the top two positions. From this it appeared that the demand for STEM skilled occupations in 2015 was relatively high. Nevertheless most of the occupations in the list, including those for STEM, had suffered a cut in the real value of their salaries when adjusted for inflation over the previous five years, meaning earnings for these occupations had declined over time. While the financial crisis of 2009 and the subsequent recession was able to partially explain the decline in earnings, it did not explain why the salaries for four occupations, Building, Librarianship and IT, Land and property management, and East and South Asian studies, were seen to have made a continual gain in growth throughout the period 2010 to 2015 by nine, seven, four and five percent, respectively. It is inferred that although the particular STEM subjects in the list were in demand relative to some other occupations, they were not a growing demand.

Starting salaries for the STEM subjects, IT and telecommunications, Oil and energy, and Engineering were compared with two non-STEM professional subjects, Law and Accountancy. Figure 6.5 shows the salary for Law graduates starting at just over £45,000, representing around £15,000 more than starting salaries for Engineering. Oil and energy earnings were the second highest at £36,000. IT and telecommunications, and Accountancy as STEM and non-STEM professions shared similar staring salaries, with engineering graduates as the lowest paid of all five categories in Figure 6.5 at around £29,000 in this data, despite a persistent concern about the shortage of engineering graduates, forecasts of a significant future shortfall, and with the continuous call to increase their numbers by '36 professional engineering institutions' (Royal Academy of Engineering, 2014, p. 3).

Moreover while both Law and Accountancy showed an upturn at the 2013 data point to finish at 2014 in a modest but upward trend. A slight upward trend towards 2014 was also just apparent for IT and telecommunications, but Oil and energy, and Engineering were seen on a downward trend from 2013 to the beginning of 2014 implying those particular STEM skills were less valued over the period 2009 to 2014 than Law, Accountancy and IT and telecommunications.

Chapter 7

Analysis of the LIYSF questionnaires

7.1 Introduction: Informal science

> *In many of the developed countries of the world, school science is seen to be in crisis. Pupils attitudes to school science declines progressively across the age range of secondary schooling and declining numbers are choosing to study science at higher levels and as a career. Responses to these developments have included proposals to reform the curriculum, pedagogy and the nature of pupil discussions in science lessons* (Reiss & Braund, 2006, p. 1373).

Pedagogy in school science is dominated, according to Osborne and Dillon, by a 'conduit metaphor'. This to imply that science knowledge is treated as a commodity that needs to be transmitted by the teacher who attempts to 'get it across' to the students. The students' in turn are seen to either 'get it' or not as the case may be. The means of such transmissions would generally involve students copying text from the blackboard and only rarely having the opportunity to use the 'language of science' in collaborative writing or discussion despite evidence, according to Osborne and Dillon, that such methods led to enhanced understanding in students (Osborne & Dillon, 2008, p. 9).

Hodson (1998), was critical too of the teaching and learning methods employed by teachers. In citing Nott and Wellington's concept of powerful 'hidden' messages and views that teachers might impart to their students *implicitly* (Hodson's emphasis) through their teaching language, approaches and materials about science and scientists. Hodson's own particular concern however focused on the curriculum *content* (my emphasis) of science lessons. This he saw as outdated and lacking relevance for students and detrimental in terms of a 'proper understanding of science and scientific enterprise ...' (Hodson, 1998, p.192). This is how he described school science education at the end of the twentieth century:

> *At present many students in science lessons are bored by the content they consider irrelevant to their needs, interest and aspirations. They are uninvolved by the kinds of teaching/learning methods we employ and they find the social and emotional climate of the classroom uninviting and even alienating. My concern ... is that where many of the messages about science that we build into the curriculum (either consciously or unconsciously) are still locked in the mind-set of the 1960s and early 70s* (Hodson, 1998, p.192).

Much of the recent criticism about the science curriculum and pedagogy lays the cause on the dual goals of school science education which requires schools to prepare a minority of students for career science while simultaneously ensuring all students achieve a state of science literacy. It is, according to Osborne & Dillon (2008, p.7) and Fensham (2008, p.1) a problematic role that has led to a Europe-wide fall in science interest in young people:

> *Asking the school science curriculum and teachers of science to achieve both of these gaols simultaneously places school science in tension where neither goal is served successfully* (Osborne & Dillon, 2008, p. 7).

> *Getting the balance right between the purposes of enthusing enough students to go on to scientific and technological careers and of giving all students an interest in and enough knowledge of S&T (science and technology) to appreciate the importance of science and technology in society, is perhaps the major S&T educational issue facing all counties today* (Fensham, 2008, p.1).

While formal science and the way it is taught is seen by some as failing to motivate many young people across Europe to study science at post-16, Stocklmayer, Rennie and Gilbert see informal science eduction with the potential to offer a rich and varied approach to STEM learning (2010, p.11). From museum visits, science and environmental centres, television documentaries and films, magazines and journals, summer schools and science fairs and other outreach events the sector does appear to be able to offer something for every science interest, but one criticism is offered: the difficulty to measure any personalised learning that takes place (Stocklmayer & Rennie, 2010, p.11). However there is some evidence that intrinsically motivated visits - events that are motivated by interest and arousal - and a chance to pursue science away from the classroom that integrates both leisure and school learning have a lasting effect with long term gains in learning resulting in an enhanced science education (Ryan & Deci (2000, p.1), Falk et al. (2007, p.456), Rennie (2007, p.89), Stocklmayer & Rennie (2010, p.2, 9), Harder (2010, p.1)).

As one of the number of more formally constructed initiatives that give young participants a taste of living and working with like-minded others, and an insight into relevant career opportunities for those with a science qualification, this chapter focuses upon the findings and analysis of pre- and post-event survey-based questionnaires seeking an insight into the effect of the LIYSF event of 2015 on the student participants in respect of their future study and career plans.

7.1.1 The London Youth Science Forum (LIYSF)

The London Youth Science Forum (LIYSF) is a science enrichment programme which offers its participants a two week residential experience in lectures and demonstrations from leading figures in the world of science. Included are visits to industrial sites, research centres, scientific institutions and organisations, and to world class laboratories and universities. There is also an option to visit the European Organisation for Nuclear Research. Situated in Geneva Switzerland known as CERN and operates one of the largest particle physics laboratories in the world.

LIYSF was founded in 1959 by the late Philip S. Green following an organisation set up after the second world war by representatives from the UK, Denmark, Czechoslovakia and the Netherlands to help to overcome the animosity of the war years. Initially plans were made for home-to-home exchanges between groups from a half dozen European countries. The aim was:

> *. . . to give a deeper insight into science and its applications for the benefit of all mankind and to develop a greater understanding between young people of all nations'* (About LIYSF, no named author, accessed via the LIYSF website, January 2016).

One further relevant point to mention about LIYSF, is that it was based upon the Philip S. Green's belief:

> *'Out of like-interests the strongest friendships grow'.*

Philip S. Green's quote about 'like interests' is an aspect which I believe is well supported by the results of the two questionnaires that follow. Like the original home-to-home

Figure 7.1: Source: Author, Location: 57th LIYSF Event, The Opening Ceremony when the flag bearers representing each nation participating in the forum presented their country's flag, London July 2015

exchanges the programme is based on the sciences (Source: (LIYSF, 2016a), no named author, accessed January, 2016).

7.2 Results and Analysis of Pre-event LIYSF Questionnaire: 2015

In 2015 LIYSF attracted over 450 students ages between 17 and 21 years old to participate in the event. A subset of that cohort were those who were chosen randomly to bear and present their country's national flag. This group were also present at the reception with other guest and officials, held after the LIYSF Opening Ceremony and it was this group that the pre-event survey questionnaire targeted.

The Opening Ceremony reception was intended primarily as a networking and socialising event and time to distribute, self-complete and collect was limited. To optimise the number of responses the questionnaires were worded so as to lend their answers to a Likert scale response. Of fifty questionnaires distributed, forty eight we're returned: a return rate of 90 per cent. The size of the sample base allowed a confidence interval of 90% with an error margin set at 6% (± 2%.) for the results.

Q1 I am attending LIYSF because I think it will help me to make study and career choices

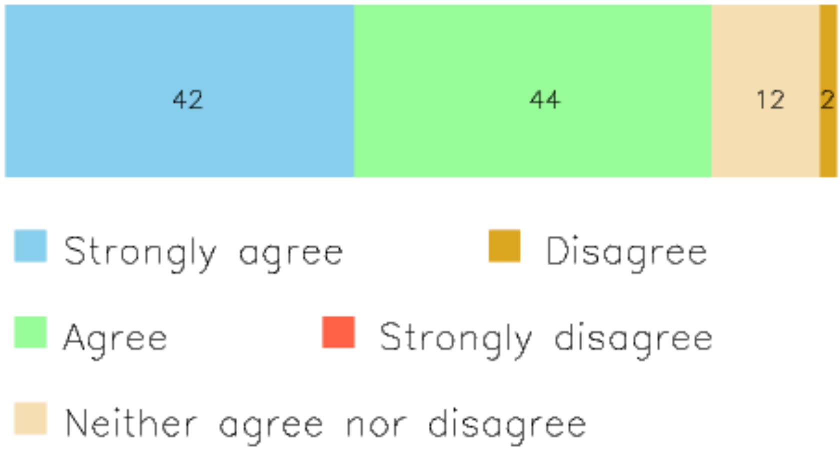

Figure 7.2: Pre-event survey Q1

Out of a total of 48 responses 41 (85 percent) saw the LIYSF event as an aid to making their study and career choices. There are at least two possible reasons for six students who neither agreed nor disagreed with Question 1. The first, that a decision had already been made in respect to their study/career choices, and that therefore they did not look to the event for help in career and study decision making. Secondly that this aspect of the LIYSF programme had not yet occurred to their pre-event perspective. These reasons may also apply to the one 'disagree' response in this category.

Q2 I don't yet know enough about a career in science to make a decision about my study and career decisions

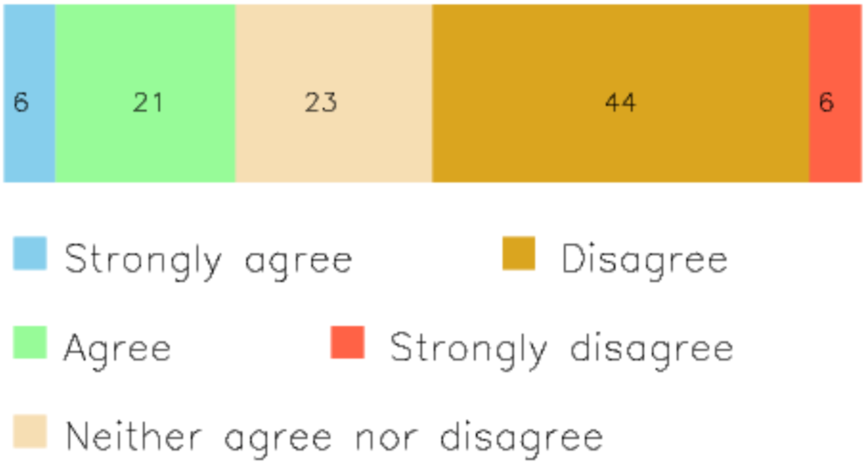

Figure 7.3: Pre-event survey Q2

To Question 2, 50 percent of the subset base disagreed or strongly disagreed that their existing knowledge of science careers was insufficient to inform their future plans. This implies that 50 percent (which includes 11 individuals who neither agreed or disagreed) were less confident about their knowledge of science careers before the Forum.

Q3 Meeting like-minded people my own age interested in science is not always easy in my day-to-day life

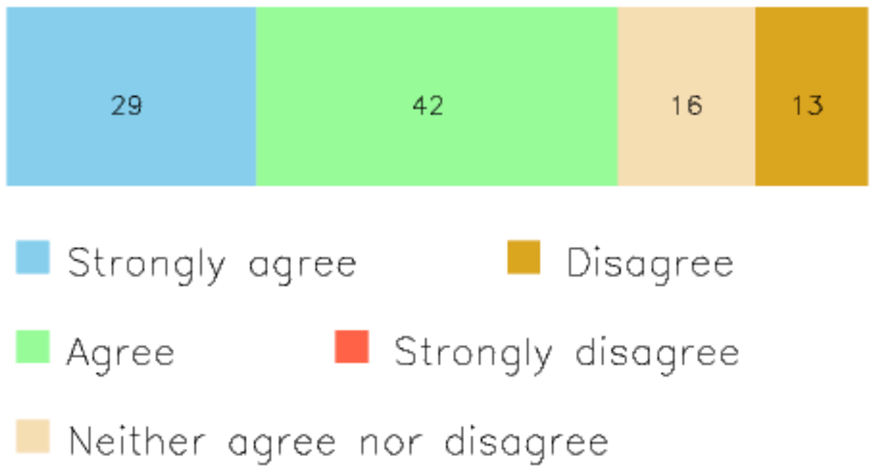

Figure 7.4: Pre-event survey Q3

Of the 48 students who responded to the questionnaire, 71 percent indicated a difficulty in meeting on a daily basis those of a similar age with similar interests in science. This suggests that informal events such as LIYSF which brings like-minded people together offer their participants more than the latest scientific thinking and practice over a wide range of science subjects. It offers additionally the opportunity to meet, work and socialise with those who may be from a very different background but who have fundamental interests in common.

The principle of underpinning like-mindedness (homophily) is that connection is formed between similar people at a higher rate than among those who are dissimilar. The characteristics of similarity can be age, gender, race/ethnicity and education, [1] *or in intelligence, attitude and aspiration.* [2] *Under these circumstances not only are relationships formed more quickly, but they also tend to be strengthened by the number of ties held in common, and durable.* [3]

This suggests implications for the effects of peer influence between young people and their attitudes and aspirations towards their studies and career plans. Where it is desirable to encourage, enthuse and inspire individuals to fully realise their interest for science to the career level, peer influence is an important consideration for those individuals who tend to be in a minority in the classroom and therefore may lack encouragement from

[1] Bott (1929); Loomis (1946)
[2] Almack (1922); Richardson,(1940)
[3] McPherson, (2001)

their classroom peers to pursue their science interests.

Q4 I like science but I don't think I want to make it my career

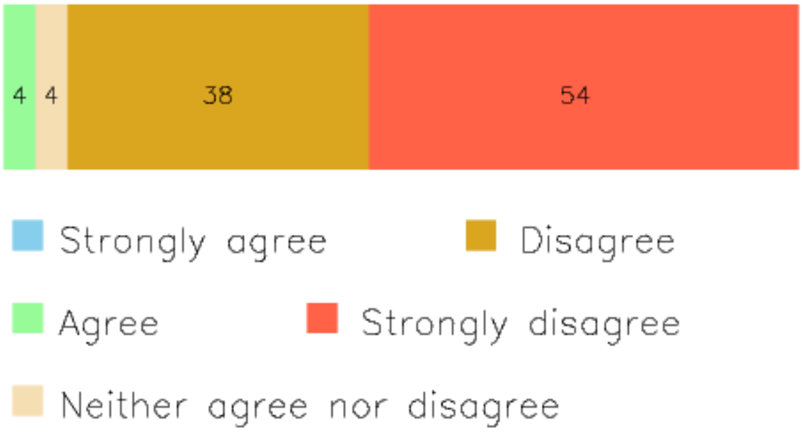

Figure 7.5: Pre-event survey Q4

This was the strongest response of the questionnaire with 92 percent of the respondents disagreeing and strongly disagreeing with the statement that science was not a career for them. Of the small subset of flag bearers (11 percent of the total student population (n=450) participating in the 2015 LIYSF event) this strongly indicates that these particular participants had already decided to consider a career in science.

Where many developed countries report difficulties in recruiting scientists and engineers to the labour market, it would be useful to understand how representative this attitude might be across the whole 2015 LIYSF cohort, and what additional factors might have prompted the young flag-bearing subset to largely assume a positive view towards a science career pathway.

Notes:

Two issues in particular must be noted about this pre-event survey:

The first is the small sample size of 48 flag bearers (11 percent) out of 450-plus LIYSF participating students.

Secondly, there may have been important differences in opinion and attitude between those respondents selected randomly for flag-bearing duties and the rest of the LIYSF participants, and which might have influenced the pre-event responses. The pre-event subset responses therefore cannot claim to be representative of the whole 2015 LIYSF cohort, and the pre-event questionnaire results should not be used to generalise results.

7.3 Questions, Results and Analysis of the Post-event LIYSF Questionnaire: 2015

7.3.1 Introduction

As with the Pre-event survey and given the cost and time considerations in participating in the LIYSF programme, an assumption is made that the respondents to the Post-event survey already have a prior interest in the science subjects. Additionally applicants are selected on evidence of their academic ability (LIYSF, 2016b).

The Post-event survey questions were intended to examine whether exposure over the two week duration of the LIYSF initiative with those who shared similar interests and academic abilities reinforced or changed any intention to follow a pathway into professional science, or affected their career plans in other ways.

Compared to the Pre-event survey, the Post-event survey took a more detailed approach. Of the ten questions posed, questions 1 to 8 offered a number of answer options where all or any could be selected. Also provided for questions 1-8 was a further unrestricted option, *'Other - please specify'*. Because respondents were not restricted to one answer choice only the percentages given to tally the responses were unlikely to total to 100 percent. Question 9 was unstructured in offering participants the chance to freely comment on the LIYSF experience while question 10 requested the respondent's age, gender and home country.

Question 1 *How did you hear about LIYSF?* was aimed at returning a report of the survey findings to the LIYSF organisation in recognition of the assistance given in carrying out the field research. First, in providing the opportunity at the Opening Ceremony for distributing the Pre-event survey, and secondly, for electronically distributing the Post-event questionnaire survey to the LIYSF 2015 database of participants for their self-completion. This ensured the process conformed to current data-protection requirements. It also served to anonymise the survey respondents to the author. The responses to Question 1 do not have a direct bearing on the research questions raised in this thesis and are not included in the findings and analysis.

Questions 2-6 were chosen to determine to what extent, if at all, attending the two-week science forum had changed or affected the study and career plans of the participants. There were significant time and financial implications for those who attended and it is reasonable to assume an existing interest in the sciences among participants. This is likely to be particularly so for young people travelling from overseas, for those students who engaged in fundraising activities to raise their entrance fees, and for those students who presented a science project through the *LIYSF Bazaar*, or entered other competitions for the opportunity to win a place on the LIYSF programme.

Question 7 sought to determine from seven answer options what were the most frequently occurring factors that might make students rethink about pursuing science at HE level.

Question 8 took the reverse approach to look at factors that were considered as the most important to the future career at this stage.

Question 9 offered the opportunity to add comments about the LIYSF experience. This was completed by 60 percent of respondents.

Question 10 requested the age, gender and home country of the respondent. These data were given by 98 percent of respondents.

The percentage points of the responses are aggregated and rounded-up or down to the nearest whole number in the analysis. A sample response rate of 24 percent (n=105) from a population of 450 was returned. The results presented below are aggregated across respondents, and anonymised.

7.3.2 Post-event Survey Findings

Table 7.1: Answer options for question 2

Note: Percentages are rounded to the nearest whole number

	Answer Choices	Responses
2a.	I'm interested in science	91%
2b.	To meet with other like-minded people	66%
2c.	Encouraged by parents or family members	14%
2d.	Encouraged by school or college teachers	31%
2e.	Recommend by a previous LIYSF participant	16%
2f.	To see what opportunities science can offer as a career	40%

Answers to Q2: Why did you apply to take part in the LIYSF conference?

The assumption that those who had participated in LIYSF would share an interest in science was strongly confirmed as Table 7.1 shows. Even those who had not specifically claimed an interest in science were found to have entered national or international competitions to gain their place at LIYSF indicating that science interest was present throughout the sample.

The question of meeting with like-minded others as a reason for applying to LIYSF also attracted a strong response (Table 7.1). In one case, it was given as the only reason for applying to LIYSF. The appeal of this aspect of the LIYSF event was first evident in the Pre-event survey (question 3) where some respondents had also claimed that they had found it difficult in their day-to-day lives to meet with those who shared their interest in science. The appeal of mixing with similar others interested in science was also well represented in the respondents comments. The following four examples were typical of eighteen comments about the enjoyment of meeting with others who shared a common interest. The survey results also showed that this opinion was shared equally between genders.

> *LIYSF was the first time where I felt that I perfectly fit in with this very large group of people in contrast to school were very very few people feel as passionate about science and especially biology as I do.*

> *Meeting people who are interested in the same things as me, going to interesting*

scientific institutions, and hearing lectures from specialists heavily involved in their fields was fantastic.

The opportunity to meet people who are just as enthusiastic about science as I am. Also the explore [sic] *new areas of science and meet experts in every field and hear their story.*

The LIYSF experience was eye opening and outstanding. To realise that there are hundreds, even thousands of other people my age that are as interested in science as I am was profound.

Change - after LIYSF

LIYSF's director Richard Myhill associated participation in LIYSF with a number of changes including the impact on the careers of the participants and the life-time duration of their friendships (Press release LIYSF (2016a)). While the survey data were not able to measure long term effects there were some changes that were measurable in the short-term and which were likely to impact the career direction for LIYSF participants over the longer-term.

For instance in the LIYSF post-event survey Q3 and Q4 were about identifying change in the plans and attitudes of the respondents after their attendance at the LIYSF programme. In this context three levels of change are examined. Absolute change was seen as a change in a previous intention to follow, or not to follow, a career in science; relative change was associated with the specific science subject chosen as a career direction, and changes in attitude were indicated by an expression of more confidence in decisions made about a particular career direction.

Question 3's answers were to establish a basis against which to measure change.

Q3: Before you attended LIYSF, what thoughts did you have about your future study and career plans?

Although the majority of respondents to Q3 claimed to have made a plan to study and work in a science related area, when the results were disaggregated into individual responses it was observed that for most individuals the concept of a 'plan' was in general rather than specific terms. In some cases, for example, respondents who reported making a plan had also answered that they were unsure about the specific science subject to study. Not withstanding these observations it appears that the intention behind the phrase **I had**

Table 7.2: Answer options for question 3.

Note: Percentages are rounded to the nearest whole number

	Answer Choices	Responses
3a.	I had a clear plan for my future career that did not include science	1%
3b.	I had already made a plan to study and work in a science related area	65%
3c.	I knew I wanted to be involved professionally in science, but was not sure what specific subject area	39%
3d.	I did not consider science as a possible career choice	3%
3e.	I had no clear ideas about my future career plans	11%

already made a plan . . . was to imply a definitive role for science study in those respondents.

Just three Individuals claimed they had not considered science as a career. This was a conspicuously different answer to the general findings. In examining the responses of the three individuals, one claimed she decided against studying science subjects, while the intentions of the remaining two were somewhat ambiguous in their conflicting answers making their intentions difficult to discern. One however made a final comment in the survey that she had found LIYSF to be an “enchanting experience” which had “somehow changed” her life. What ‘life changing’ meant in this context however was not explained. Nevertheless, none of the three had answered that they had changed their plans to consider science study, but all three listed their home country as China which might suggest some misunderstanding of language.

Also ambiguous was the single respondent who claimed to have made a clear plan for the future which did not include science and had not subsequently had a change of mind. This was then followed by a request for information about finding employment in a chosen science field and for advice about career pathways from those in the field to help with decision-making. Much clearer from the survey results had been the feeling of uncertainty from many of the respondents about the specific subject choices for study and career pathways. With implications for career guidance this aspect of decision-making is more fully explored later in the chapter.

Q4 seeks to compare respondents plans, views and opinions before and after the LIYSF experience:

Q4: How have your thoughts or plans been affected by participating in LIYSF?

Table 7.3: Answer options for question 4

Note: Percentages are rounded to the nearest whole number

	Answer Choices	Responses
4a.	I have not changed my plans	30%
4b.	I now feel more confident about my chosen career direction	61%
4c.	I have changed my plans	15%
4d.	I didn't realise the wide range of options open to science graduates	28%

As Table 7.3 shows the strong response of those claiming they had felt more confident in their career decisions after the LIYSF event. This included many of those who had previously claimed they had already made a plan to study and work in a science-related area, and others who answered that they had wanted to be involved professionally in science but had been unsure about the specific subject area. Of the two apparently opposing options, **I have changed my plans**, and, **I have not changed my plans,** when the individual responses was scrutinised they were seen not to apply to the 'absolute' change category (defined in this survey as a change in a previous decision to follow, or not to follow a science career pathway), but to changes (or not) to the specific study and career options of the respondents after participating in LIYSF.

This implies that those whose pre-LIYSF plans had included specific subject areas were more likely to be resolved and confident in their choices after LIYSF and had subsequently not changed their plans. While those who had applied to LIYSF to see what opportunities science could offer as a career, were also among those who claimed to be more confident about either choosing their study subjects or changing their chosen career direction.

A further change observed in some respondents following the LIYSF event was in gaining an awareness of the range of options open to science graduates. Twenty-nine individuals comprised this group. Of those forty-five percent had claimed after LIYSF to be more confident about their chosen career plans. A point to note about the post LIYSF survey responses was that they were made almost two months after participating in the event suggesting the influence of the LIYSF event had persevered over that time.

The additional role for LIYSF

The greater confidence shown in the LIYSF participants eventual study choices after participating in LIYSF has highlighted a role for informal science initiatives such as LIYSF to bring about an awareness in their participants of the wider options available in science as a fast moving and dynamic field, and in seeing the wider international nature of the STEM professions. The following five extracts are typical of twelve similar comments made by respondents about participating in LIYSF and the effect it had on their individual study and career choices:

> *I loved it. I met people that were enthusiastic in science, and who also left me enthusiastic about science. I wasn't sure before I attended whether science was the career I really wanted to pursue, but after LIYSF I think science is the best option for me.*

> *It truly opened my eyes to the importance of international collaboration and how there are so many career opportunities within science.*

> *Being able to visit some of the places we did, especially Airbus for me since I'm most interested in engineering, has helped solidify my decision to study Aeronautical Engineering with a deeper look into the aviation industry.*

> *Being able to gain exposure to so many new fields in science - some of which I've never heard of was definitely one of the best parts. Though I had already made up my mind about my career, the lectures sparked my curiosity and made me begin to consider venturing into other fields. The wealth of knowledge available to a participant is incredible and I think that anyone who attends should maximize on this opportunity and take in as much information as possible.*

> *Great. Meeting people who are interested in the same things as me, going to interesting scientific institutions, and hearing lectures from specialists heavily involved in their fields was fantastic. Identifying a best moment is too hard, because everything was great. LIYSF solidified my interest in engineering enormously, and I can't help but be grateful for the opportunity to attend.*

Q5: If you are still uncertain about your study and career plans in science, what additional information could help you decide?

Table 7.4: Answer options for question 5

Note: Percentages are rounded to the nearest whole number

	Answer Choices	Responses
5a.	Information about how easy or difficult it might be to find employment in my chosen scientific field of study	41%
5b.	Information about the graduate starting salaries across various science subjects	22%
5c.	Advice about career pathways from those already working in the field	42%
5d.	Advice about the subjects I need to study to reach my goals	30%
5e.	Advice about what personal qualities are needed to be successful in my studies and career	39%
5f.	Information about the rage of options open to me within the science field at various stages in my studies, eg. Graduate degree, Masters degree and PhD	38%
5g.	Practical advice about studying in the UK (or home country) including fees, scholarships, funding, bursaries, accommodation etc.	25%
5h.	Information about graduate work prospects in the UK	15%
5i.	I have decided against studying science subjects	3%

As Table 7.4 shows the answer options for Question 5 dealt largely with issues associated with entering higher education. The number of responses to each option appeared to be on the high side of what might be expected from a sample of young people having recently attended a science initiative. Although the type of information the students were seeking was unlikely to have been addressed formally by the LIYSF programme, the opportunities for socialising with peers and others might have been expected offer some insight into career pathways from those peers or those already in the field, and the personal qualities needed for success in the chosen studies and career given the age range of the participants (in this survey given as 14 to 22 years).

One of the higher responses was for a call for Information about the labour market demand for the chosen field of study. Concern about the longer term employment prospects after graduation is examined more closely later in the chapter by separating the sample base into UK and non-UK groups and contrasting their answers.

One of the lower response rates was for information about graduate starting salaries. The relative lack of interest for the question of graduate income for the sciences was consistent with the findings of Pian Shu who examined the career choices of MIT graduates in a working paper (16-06) for the Harvard Business School (2015). In an interview by Nicole Torres, Assistant Editor of the Harvard Business Review, Shu, suggested that while future salary mattered, it mattered at a later stage in the career pathway, and was conditional upon decisions already made (Torres, 2015).

There is no empirical evidence in this survey to suggest those respondents had planned to continue their studies in the UK. Nevertheless a report from the British Council published in November 2015 found that STEM students were attracted to the UK (and to the US, Australia and Canada), because of the quality of education, its reputation and the transferable skills attained. These factors were seen at both the graduate and postgraduate level as offering "... enhanced career prospects ..." (Malik, 2015).

The issue of graduate employment in the UK attracted one of the fewest responses for Question 5 but again they came from a wide number of overseas students from countries including Spain, the United States, Tunisia, Jamaica, Australia, Ireland, Poland, New Zealand, Portugal and the Czech Republic, one from the UK, and one from the British Isles (Guernsey). The British Council's findings also commented on employment opportunities from a new survey about international STEM students. The survey found that over a third of the students had indicated that they would seek employment in their (study) destination country after graduating. In terms of offering the best career opportunities however, the UK came a poor fourth in a list which rated the popularity of Australia for career prospects at 72 percent, the US at 71 percent, Canada at 61 percent and the UK at just 42 percent (Malik, 2015).

Answers for Q6: If you have decided on a science-based career what other influences in your school and personal life have helped to shape your decision?

Table 7.5: Answer options for question 6

	Answer Choices	Responses
6a.	School science lessons	70%
6b.	Visiting scientists in the classroom	18%
6c.	Enthusiastic science teachers	64%
6d.	After-school science clubs	20%
6e.	Residential Summer schools	25%
6f.	Summer day schools	6%
6g.	The Space programme (NASA or ESA)	22%
6h.	Visits to science centres and museums	45%
6i.	TV and documentaries	59%
6j.	Books and magazines	53%
6k.	Family and friends	47%

Notable in the answers to question 6 was the high response rates for the influence of science lessons and enthusiastic science teachers which ran counter to the findings of researchers like Osborne & Dillon (2008, p. 7); Lyons (2006, p. 591), who argued like Munro & Elsom (2000, p. 3) that a "dull and content driven National Curriculum" and other time constraints and limitations which restricted extra-curriculum activities, had all contributed to a lack of interest by students in the sciences in the UK.

Classroom concerns however were not supported by the survey findings where the respondents (which included five out of seven of the UK students) highly rated the influence of school science lessons and enthusiastic teachers. It is argued however that the survey sample of the student cohort participating in LIYSF were not likely to be typical of those in the mainstream science class-room, and they may therefore have assumed a more positive perspective to their science lessons and teachers based on their own science interest.

An unexpected result was also observed in the relatively low response rate given to residential summer schools as a source of science influence since the respondents themselves had very recently been participants in LIYSF as a residential summer school. There are at least two possible explanations that are consistent with the low response rate. The first, that many LIYSF participants had appeared to have not only developed their science interest before attending LIYSF, but some had already planned to study and work in science. Their primary sources of influence therefore had evidently preceded their attendance at LIYSF. The second possible explanation is that LIYSF appears not to have been described as a summer school in the organisation's press releases and webpages, but rather as a forum or international conference where the participants were referred to as 'delegates' (LIYSF, 2016a). It is reasonable therefore to assume that LIYSF may not have been recognised by the participants as a residential summer school.

Answers for Q7: What might turn you away from a career in science?

Table 7.6: Answer options for question 7

	Answer Choices	Responses
7a.	A lengthy study period needed for some science subjects (beyond the first undergraduate degree)	18%
7b.	College and university fees	33%
7c.	Leaving home to go to university	2%
7d.	Leaving university with a large debt	34%
7e.	Concern about lack of earning potential while you study	24%
7f.	Concerns about subject difficulty, and in reaching the required academic standards	27%
7g.	Uncertainty about the supply and demand for my skills in my preferred science field	43%

The costs associated with higher education featured prominently in response to Q7 as Table 7.6 shows. But there was evidence of other issues that occupied those contemplating academic study, such as a concern for example about subject difficulty and in reaching the requited academic standards. This issue may arguably apply particularly to the sciences with their perception of being difficult to master (Coe et al., 2008), but a further concern expressed in Q7 was likely to be common across all disciplines, that of leaving home to go to university.

Addressing this fear may be one of the advantages of attending a residential educational initiative irrespective of its aims and intentions, in that it may serve to give young people an experience of mixing educationally and socially in a learning environment that mirrors to an extent that of the university experience. This effect is likely to be enhanced when the initiative is hosted on a university campus.

Will there be a demand for science skills?

Answer option 7g raised an issue about the uncertainty of the supply and demand for skills in the preferred field. This was linked with a similar concern from question 5 where answer 5a called for information about how easy or difficult it might be to find employment in a particular science field. The similar response rates to these two concerns across the sample base suggested that the responses might reflect a national difference. To test this concept the responses were disaggregated into two categories, the UK group and the non-UK group to compare how they had responded to the survey questions about the long-term career concerns.

Table 7.7: UK versus non-UK comparison of study and career choices in percentages
Note: Responses excluded where there was no home country given.
Percentages are rounded to the nearest whole number

	Answer Choices	UK	Non-UK
5a.	Information about how easy or difficult it might be to find employment in my chosen scientific field of study	43%	39%
7g.	Uncertainty about the supply and demand for my skills in my preferred science field	57%	37%

Although both groups were seen to have shared a considerable concern about the longer-term career prospects for their chosen science subjects, it was notably higher for the UK group (Table 7.7).

The results for these two particular concerns suggested a perception in the respondents of a reducing labour market for the sciences. This was a surprising result for the UK group since the dominant argument in the UK had leant heavily over the years towards a persistent claim of a shortfall in the number of UK science graduates against the labour market demand as this thesis has demonstrated e.g. Roberts (2002), CBI (2013) (2015). The results for answers 5a and 7g therefore implied that there was also an awareness, particularly for the UK respondents, of the range of counter arguments which included that of an overall sufficiency of science graduate supply against the demand for STEM skills (Bosworth et al. (2013, p. 8); Smith & Gorard (2011, p. 171); Teitelbaum (2014, p. 3)).

Answer for Q8: What at this time is most important for your future career?

Table 7.8: Answer options for question 8

Note: Percentages are rounded to the nearest whole number

	Answer Choices	Responses
8a.	A good salary and benefits	10%
8b.	A good salary and benefits are important but not enough in themselves	57%
8c.	Being involved in an interesting job	85%
8d.	Enthusiasm for the subject	86%
8e.	The knowledge of contributing to something worthwhile	71%
8f.	Collaborating with, and being in the company of other like-minded people	63%
8g.	Opportunities to travel	46%
8h.	A clear career pathway	19%
8i.	A secure employment position	42%
8j.	A pensionable employment position	16%

While Q7 looked at the negative features to a career in science Q8 lists some of the issues which might be seen as consistent with the life of a STEM professional to gauge their importance to young people contemplating a STEM career themselves. Some of the items listed such as collaborating with likeminded individuals would have been evident to the LIYSF participants during their residential fortnight. For overseas students traveling to the LIYSF as an international conference, would also provide experience of the mobility of the professional scientist, and may act as an encouragement to those considering a STEM career. The question of salary at this stage in the respondents academic progress was again given a low priority. This is consistent with the notion that the question of income assumes a greater importance in science and engineering graduates at later stage and would be conditional on some of the decisions already made (Torres, 2015).

Q9, What other comments would you like to make about the LIYSF experience?

Following the structured format of the earlier questions, Q9 offered respondents the chance of commenting on the LIYSF experience in their own words. This produced sixty-one comments of various lengths, from half pages to one or two words.

Q10, Asked respondents for their age, gender and home country.

The value of Q10 is that the range of the respondents' home countries can be identified to allow some comparisons to be drawn between the domestic and the international respondent groups. For instance, in calculating the results from both groups it is possible to see what opinions and concerns about study and career choices are shared between the two groups and what might reflect national differences in the responses. This type of response rate comparison was carried out for answer options 5a and 7g on the question of the supply and demand for STEM skills.

7.3.3 Conclusions

There was a number of positive findings in the survey about participating in LIFSF and it was clear from the sample of comments by those who had taken part that they had found it both enjoyable and inspirational. The importance of meeting with like-minded others, first raised in the pre-event survey, was well met by the opportunity to spend time academically and socially with others who share interest in the sciences. Additionally the conference atmosphere of the event allowed participants a vicarious experience of the academic and collaborative lifestyle of the professional scientist. There were however some less positive concerns about pursuing a science career expressed in the survey. They focused mainly on the costs associated with Higher Education, exacerbated by the length of time to study for graduate and post-graduate qualifications, and on the longer-term uncertainty of finding employment in the chosen field of study. The graduate salary level was not given as highest priority at the early stage of the students study and career plans.

Change

The question of change taking place in the respondents after exposure to the LIYSF experience was examined in the post-event survey with 'absolute' change defined as a reversal of a decision to pursue or not to pursue a study in science. For this category the survey found no evidence of 'absolute' change. That is those who did, or did not, choose to study science subjects had not changed their minds.

There was some evidence of changing or rethinking subject study choices by widening respondents appreciation of the scope of possible study options, and there was some evidence of attitude change in that respondents reported feeling more confident about their study choices which re-enforced their judgement about pursuing their study choices.

It was concluded that for this particular survey the summer school initiative was unlikely to increase the numbers opting to pursue U/G study for science, where science interest was already developed in the participants and the commitment to pursuing science study had largely been decided.

Chapter 8

Discussion and conclusions

8.1 Recapitulation of purpose and findings

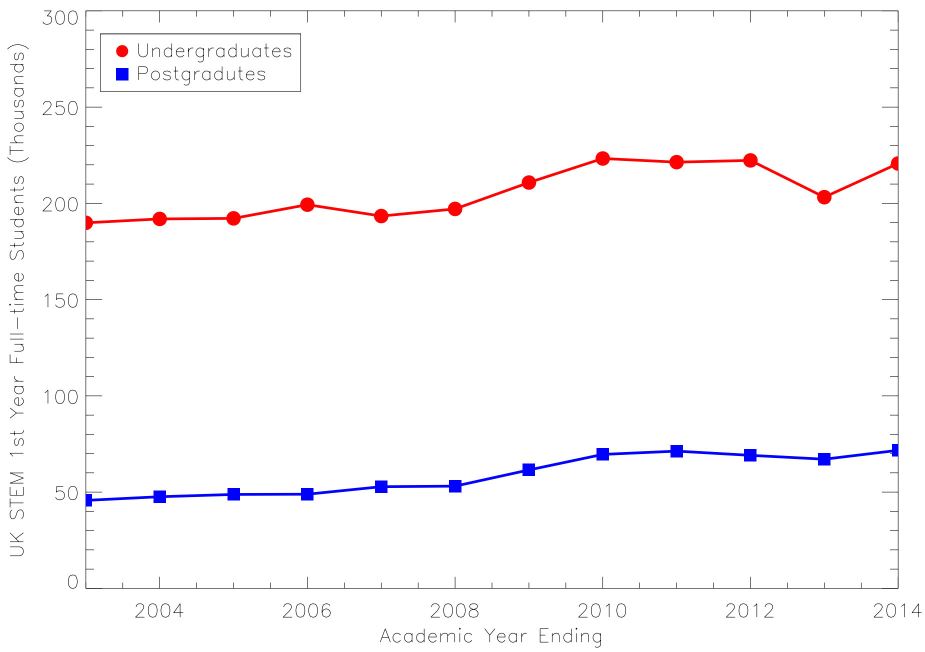

Figure 8.1: Estimated Total Recruitment for Full time First-Year Undergraduate & Post-graduate Numbers for All STEM subjects 2003-2014

Data source: HESA tables listed in Appendix A

This thesis has addressed the research question:

Is there a contemporary crisis in the recruitment to science and technology in the UK?

In analysing HESA data tables over the period 2003 to 2014, one of the key findings in this study has been that overall STEM graduate recruitment was seen to have risen rather than declined over the period in question (see Figure 8.1, reproduced from Chapter 6 on

STEM supply).

This was particularly notable since the cohort recruitment data examined was drawn from a population born at a time when the birthrate was falling (see Figure 3.2).

The rationale for raising the question is a long perceived concern that dates at least from the mid-nineteenth century about the declining uptake of science in the UK, and has evolved to continue to this day. The evidence was examined for the historical concern in three accounts over three particular time periods. Charles Babbage's persuasion of a decline of science in England in the 1830s, Sir Frederick Dainton's 1968 'swing away' from science by British school children, and Sir Gareth Robert's policy report in the early 2000s about the UK science supply chain from the primary classroom to higher education and beyond.

While the evidence, accounts and reports of each of the cases was considered insufficient to justify their authors' concerns and assertions, nevertheless, the debates that followed them were instrumental in bringing about policy changes to encourage the uptake of science by young people. While all three authors were members of the Royal Society, and both Dainton and Roberts received knighthoods within a year or so of their education reports, it is likely that their influence and assertions had contributed to the propagation of a persistent perception of a decline in science interest, which eventually developed into a widely held acceptance by some, particularly by the industry lobbyists, the Confederation of British Employers (CBI), of an overall shortfall in the number of UK scientists and engineers against employer demand (CBI, Education and Skills Surveys, 2008-2015).

The empirical question of the thesis critically examined the claim of a shortage of science and engineering graduates in comparison with the demand for such skills from employers. This was approached firstly by comparing official figures for the annual number of graduates (first degree and postgraduate) produced over a thirteen year period from 2003 to 2015. The figures showed an overall increase in graduate numbers over that interval, despite the fact that the graduate population examined had been drawn from a generation with a falling birthrate.

Estimating a level of demand for STEM skills utilised two proxy indicators: firstly estimates of vacancy rates for STEM graduates, and secondly graduate starting salary levels. In respect of the vacancy rate two areas in 2015, Engineering and technology, and Computer Science, showed a substantial shortfall in supply when compared to vacancy numbers (Data compiled by Adzuna for November 2015). This was particularly notable since the vacancy numbers represented a monthly demand while the supply numbers represented the annual graduate supply. One complicating factor however is that participation in careers in both subject areas are augmented by individuals who choose to follow routes other than through a university to gain their qualifications. While there are several alternative routes into these specialised subject areas, consistent data on, for example, apprenticeships are not reliably or readily available. To a lesser extent the Physical Sciences category also showed a shortfall of around 9,000 graduates between their annual production rate and the monthly vacancy rate (for teachers and lecturers) for 2015. Numbers for this subject area however are not likely to be augmented by alternative qualifications and routes. Evidence of rises in vacancy rates over the five year period from 2005 to 2015, implied unmet demand for IT and Telecommunication graduates, and to a lesser extent for Engineering and Industry skills, with vacancy rates increasing for those occupations by a very notable 160 and 21 percent respectively. In the case of IT and telecommunications this may be due to the ongoing upgrades of mobile telephone networks.

The second proxy indicator, graduate starting salary levels for 2015, were examined for fourteen STEM occupations (which included six engineering subjects), listed in the top twenty-five out of a comprehensive list of seventy occupations compiled by the *Complete University Guide.* Two STEM subjects namely Dentistry and Chemical engineering commanded the highest starting salaries in the top two positions, with the majority of STEM occupations clustered around the high to mid-salary range of £25,000-£27.000 a year. This indicated a relatively high to mid-level demand for those skills. However when the salary figures were adjusted for inflation over the preceding five years, most of the twenty-five occupational groups listed had faced a real-term reduction in their starting salaries. Only four occupations had managed to resist the year-by-year erosion of their earnings to make positive increases in their salary levels, and only one of those occupations held any relevance to STEM skills: Librarianship and IT (this slightly unusual pairing was categorised by the *Complete University Guide*). Those findings implied that, although there was a demand for new STEM graduates indicated by the relative starting salary levels for a number of science occupations, the demand could not be considered as *growing.*

The thesis also included the results from both a pre- and a post-event questionnaire-based surveys of young people aged between 16 and 21, who attended the London International Youth Science Forum LIYSF in 2015. Many policy initiatives to encourage science interest have been produced over the years. They follow very varied formats from classroom based guest lectures, to museum and science fairs. The aim of LIYSF is to offer young people from the UK and elsewhere with an expressed interest in science not only to engage with those high-level guest lecturers involved in a wide range of science and technologies fields breaking new ground in research, but to experience the 'conference' atmosphere in the company of an international group of similarly-minded young people. The pre-survey results indicated that although all respondents had a prior interest in science, the majority had attended LIYSF to gain help in making study and career choices. They also reported experiencing some difficulty in meeting with like-minded people in their day-to-day life. From the pre-event responses it was understood that the majority of respondents had already chosen to pursue careers in science or technology.

The post-survey questionnaire was designed to test whether the two-week event had reinforced or changed the participants' minds, in either choosing to follow or not to follow a science career pathway. While there was evidence of changes between possible future career choices, there was no evidence that the event had brought about major changes of original intentions. What was clear in the findings, despite their expressed science interest, was that many respondents had little idea of what might be available to them in terms of science-based careers or of the academic pathways to access them. For the UK-based contingent, this suggested that career advice before the crucial GCSE and A Level selection of exam subjects was either lacking, insufficient, had not been sought, or not sought through the best informed channels.

It was further found that young people were stimulated by the company of similar others, lecturers and students alike, where their interests in science and technology were shared. From participants' responses this was often seen as the one of most rewarding aspects of attending the forum. LIYSF was a residential experience, and it is likely that this feature enhanced contact time between attendees through the inclusion of a social element in the event as well as the core educational opportunities on offer. This type of initiative, while offering a rich and varied programme of lectures, projects and events reaches out to those *already committed* in their intention to follow science at the advanced educational level and as a likely future career. Alternative approaches would be necessary if the intention was to encourage young people in general to develop an *initial* interest in science.

8.2 Relationship with previous research

Given the perceived shortfall in numbers studying the sciences as a prevailing concern, the issue of STEM graduate supply, along with the education supply chain was seen in the early

2000s (see for example Roberts Review in 2002) as an important and contentious issue. The other side of the equation, estimated levels of demand for STEM skills, was largely overlooked in the STEM supply debates. However the question of supply without reliable means to determine its scale or sufficiency led to a range of approaches in estimating a level of demand.

8.2.1 Demand Literature

Some research approaches made use of voluntary employer surveys and anecdotal concerns about trust in business and the general difficulty of recruitment (see Citibank with the *Edelman Trust Barometer*, 2015, and for example the CBI, *Education and Skills Surveys*, 2008-2015). While the CBI in particular was vociferous about the importance of the adequacy of a STEM skill supply to support the future economic development and the competitiveness of the UK, the issue of demand and of increasing supply by increasing salary levels appeared to have been overlooked. Moreover, some firms were seen to operate an internal labour market. This means that wages are tied to the job rather than to the worker with salary levels based on job evaluation and in-house tradition. Only entry-level workers are recruited from outside with existing staff promoted as vacancies arise (Mason, 1999, p. 3).

Mason also observed in his study for the National Institute of Economic and Social Research:

> *'Such employers are reluctant to respond to difficulties in recruiting engineers and scientists by raising salaries for new recruits and thus disturbing existing salary structures". He further observed: "In many cases it was feared that salary adjustments might be ineffective in solving recruitment problems as well as causing 'knock-on' effects on graduate salaries elsewhere in their firms.'*
>
> Source: Mason, Research Brief 112, 1999.

While this approach may act to reduce labour turnover and maintain in-house pay differentials, constrained salary levels may not be conducive to attracting outside talent (Mason, Department for Education and Employment, Research Brief 112, 1999, page 3 of 4).

Some studies, such as Wilson's et al., *Working Futures* focused upon historical levels of demand as a basis for projecting future workforce needs. This type of research makes use of economic models and econometrics to incorporate a range of historical economic variables including employment and qualifications levels. Such approaches were seen to influence the reports of the DfES (2006) (*Supply and Demand for STEM, Research Report no. 775*), and other official documents such as two UKCES *Labour Market Story* reports both of 2014, *An Overview,* and *The UK Following Recession. Working Futures* methodology has, since the early 2000s, become a dominant approach in UK contemporary supply and demand studies. The aim of the series is to project future workforce trends a decade ahead, and to revise projections every two to three years, both in quantitative terms and in the types of occupations understood from the calculations most likely to grow or decline. Wilson et al, in compiling the reports, clearly and openly acknowledged the general unpredictability of extrapolating such futuristic projections from past patterns by reminding readers the figures were intended only as indicative estimates of future employment trends and that they depended on the constancy of certain past variables.

Drawing on historical employment data for the decade 2004 to 2014, this thesis reviewed the accuracy of the Wilson et al. projections. While the findings largely confirmed their forecasts that highly skilled employment numbers would grow, some directional and numerical differences were evident. There was a notable departure, for example, from the projection that unskilled or semi-skilled workers as a category would be in serious decline by 2014. Official employment figures however, showed that category to be (just) in growth.

8.3 Retrospective reflections on methodology: A positivistic and multiple-methods approach, within an analytical framework

The thesis employed a multiple-methods approach in gathering and analysing data, none of which can be considered as definitive, but rather as reinforcing each other. For this investigation a realist approach often referred to as ‘positivism’ was chosen as the basis underpinning the whole investigation. This particular school of thought assumes the existence of sets of facts which can help to characterise and explain a given set of circumstances, such as in the collection of data used to give quantitative estimates of the supply of STEM graduates over a given time period. It tends to be less used in the social sciences than in the natural sciences. It was seen however as a practicable approach in what was largely a quantitative investigation, where statistics were used to draw conclusions about supply and demand for STEM skills. This thesis as a whole has been framed in an analytical framework in drawing a contextual understanding and implications from the available data. A positivistic analytical approach was also found to be useful to derive meaning from the data produced by the two survey questionnaires.

Secondary data was utilised to estimate both the level of graduate supply and the demand for their skills.The question of estimating supply relied upon a time series data-set using secondary data drawn from the annually collected official HESA data tables. Estimating a level of demand required the utilisation of two proxy indicators: estimated graduate vacancy data, and graduate starting salary levels. Analysing the incidence and levels of these two factors allowed an estimate of demand to be inferred. The pre- and post-survey questionnaires however produced a quantity of primary data in response to a series of pre-set questions. There was a difference in the methods used for each questionnaire.

Whereas the pre-LIYSF questionnaire made use of a psychological device known as a Likert-type approach which allowed respondents to express a value opinion or attitude towards a given statement, the post-event questionnaire offered respondents a tick-box approach to pre-set questions which best represented their feelings on a number of issues related to the LIYSF event. Both approaches were easily quantifiable by totalling the response numbers to each question. The post-questionnaire also included the opportunity for respondents to freely comment on the effects LIYSF experience. Where this was taken-up, a researcher subjective analysis for meaning and relevance to the issues of LIYSF's influence on study and career choices in the sciences and technology, was employed.

In this way, the multiple-methodological approach has largely served well the various quantitative, and at times the qualitative, needs of the investigation. It has been effective across the disparate requirements of collecting primary data from the two survey questionnaires, the compilation of secondary data over thirteen year period to estimate a measure for the supply of STEM graduates, and the analysis of secondary data over time for the vacancy rates and salary levels to estimate a level of UK STEM skills demand.

The methodological approach was however less useful when it came to the more subtle question of why employers have not been responding to the alleged scarcity of STEM skills by raising rates of pay. The available data, and the methods adopted, could not illuminate the reasons underlying paradoxical features of the ways in which salary levels are set. A more qualitative approach might offer a greater insight.

8.3.1 Research Strengths and Limitations

The strengths of the investigation have been in the multiple-methods approach, which allowed some of the main the findings to be supported through the triangulation of the several approaches and a range of diverse data sources.

The pre-event LIYSF survey questionnaire, for example, used a Likert scale to indicate the strength of subjective responses over a range of relative values. This had a number of advantages for both the researcher and the respondents; the questions were straightforward to answer in an agreed/disagreed type of approach using a tick-box system for the interviewees to complete. It is a useful method, especially when time is a constraint, as it was in the case for example when it was administered at the official reception following the LIYSF opening ceremony. The intended student respondents, as a subset of the total LIYSF 2015 student population, were in attendance at the reception to socialise and network with guests and organisers. In the circumstances, to ensure the maximum number of students were able to respond to the questionnaire, it had to be quick and easy to understand and able to be completed in the minimum time so students had sufficient time to circulate. While this objective was achieved, the advantage of speed presented an obvious compromise between maximising the response rate and seeking the greatest accuracy, detail and thoughtfulness of the responses. There was no means of checking that this was achieved in the data returns. This was a limitation of the approach.

One way to avoid this might have been to have asked the event organisers to email the pre-event questionnaire to the potential participants in advance of the opening ceremony. I was however reluctant to do this since the post-event questionnaires could only be distributed after the event, thanks to the assistance of the LIYSF organisation, since personal access to the LIYSF database of participants would have breached data confidentiality additional requests would have placed a further administrative burden on the LIYSF organisers.

A strength of the questionare investigation was however evident in the efficiency of the *Survey Monkey* organisation chosen as a provider of web-based surveys. The organisation was not only able to allay concerns about the practicability of using LIYSF as a third party for the dispersal of the post-event questionnaire, but in painlessly delivering the responses directly and anonymously to my own email inbox ready for analysis.

There were further limitations however in respect of the 2015 LIYSF survey questionnaires. While the event presented an opportunity to deliver both a pre and post-event questionnaire about the effects of the event on the study and career choices of young people, the population used for the survey was clearly not representative of the wider population. LIYSF's criteria for the selection of participants included age (16-21), the requirement that those attending should already be studying science and have passed or about to pass the exams for university entrance. They must also be able to meet the considerable costs of attending and of travelling to the event in London. This meant that the results of the 2015 post-event survey questionnaire were not generalisable over the general student population. Moreover the respondents in the pre-event questionnaire though randomly drawn, were a sub-set of the 2015 LIYSF student population, in their selection for additional flag-bearing duties at the opening ceremony. The resultant small sample size of the flag-bearers (11 percent of the total participant population of 450-plus), meant that this sub-group could not be assumed to be representative of the total LIYSF 2015 cohort population.

8.3.2 Problems arising during the research

The secondary data collection to consider the question of graduate supply was drawn directly from the official annual HESA data tables. But problems of consistency in the way the student recruitment data were collected and presented by HESA over time were complex and considerable. Finding a way to link data tables, where the occupations and methods of collecting data had changed, was problematic and needed some thought as to how best to achieve a feasible link between relevant tables. This was achieved by disaggregating the HESA data and recalculating the figures for each separate discipline between those annual data tables where collection methods had changed. The totals were then best-matched between consecutive tables to follow the existing trend. This was an example of the inconsistency of the official data.

A further complication involved changes in the Standard Occupational Classification (SOC) coding from 2010. This had the effect of moving groups between occupational classifications after that date, and the effects of the change needed to be reconciled between occupational data tables over the time periods affected. This was achieved by calculating the percentage differences between the tables either side of the changes and adding the difference to one and subtracting it from the other. Since Wilson's projections for 2004 to 2014, tested in this research, were formulated prior to the change, it is likely to have affected his forecast.

The ways in which various studies and reports categorised the science and technology based occupations were not always consistent. The use of the acronym 'STEM?'was largely abandoned beyond its higher education (HE) reference, and a number of other terms used. For example the 'activities' of those included in the *Times Top One Hundred Employers* list which were used by the Graduate Market in 2015 were based on the occupations of those employers. This introduced terms like *Oil and energy, Engineering and industrial, IT and telecommunications*, and so on in their data tables. *The Complete Graduate Guide* data which provided the basis for the top twenty-five starting salaries table for graduates, for example, disaggregated engineering data into subgroups using terms like Chemical engineering, Mechanical engineering, Aeronautical and manufacturing engineering, Electronic and Electrical engineering, and so on.

For some categories and occupations this left the extent of the STEM content somewhat ambiguous until checked through employment agencies like *Adzuna* and *Target Jobs* to see what qualifications were likely to be in demand for what occupations, and through the course content of engineering courses such as those offered by Sheffield and Strathclyde Universities to determine what roles made up the workforce. A further complication was highlighted in *The Complete University Guide's* salary levels list, in the way the authors paired some subjects/occupations with others. This included, for example, associating Librarianship with IT, as a single category, whereas in other data sets IT was associated with Telecommunications.

Vacancy Rates

Access to the *Labour Force Survey* and the *Employment Vacancy* data produced by Office for National Statistics (ONS), as one of the potential proxy indicators of demand, was thwarted. Having applied for, and been granted accredited, researcher status, I found that the data sought was considered 'sensitive'. As such it carried additional requirements for data access. First the submission of a project proposal to demonstrate the 'public good' in the use of the data, followed by the attendance and passing of a *Safe User of Research Data Environments* (SURE) course in London. In all the whole process would have taken around six weeks to receive approval from the data owner. A further condition difficult to comply with, was the requirement that supervisors associated with the project should apply for and obtain accredited researcher status, and attend the course.

An alternative resource was found in the online database of job vacancies from the online employment agency *Adzuna.* While this was useful, the database naturally changed month by month as new vacancies were added and those filled were deleted. While a good time to draw maximum graduate vacancy data was understood to be around the summer months (the time of students' graduations), data covering the interval from June to August were not available in November, although *Adzuna* did produce an annual aggregated vacancy total at the end of the year. Lack of access to summer data was a situation not anticipated in the research planning stage.

A further concern was in counting the vacancy data. While many organisations will use an online job search agency, such as *Adzuna*, other organisations recruit through graduate fairs, from students who have interned, or had work experience with the employing firm, others through word of mouth, by direct approach and in other ways. This indicates that some vacancies are unlikely to have been listed on an agency web site, and therefore the vacancy rate data used in this thesis were unlikely to be no more than useful approximations. Nevertheless they were sufficient to highlight an undersupply of graduates, in some cases and therefore to indicate a level of demand existed, but not an oversupply of graduates.

Salary Levels

Using salary levels as proxy indicators assumes that the orthodox approach of labour economics reveals for example a shortfall in skilled recruits through raised salaries, and that salary levels are an adequate indicator of the relationship between the demand and supply for skilled labour. However, Bosworth et al., in a study of the labour market economics, raised a number of issues (which the authors termed 'peculiarities') that were seen to have influenced job seekers (Bosworth et al., 1996, p. 4). Of these, not one was entirely focused on the question of salary. Moreover, according to a research study by Mason, for some of the firms that operated an internal labour market, the issue of raising salary levels to attract staff was seen by the employers as likely to disrupt the stability of in-house salary structures. For this reason such employers were understood to be reluctant to raise salaries to attract graduates (Mason, 1999, p. 3).

It is important to keep in mind that Bosworth's et al., list of peculiarities was published in 1996 when higher education (HE) was free to students. Today, students face rising costs for their HE and can anticipate leaving university with a considerable debt. This suggests that salary levels may assume a greater importance in career choice among future graduates.

8.4 Implications of the findings

The supply of STEM graduates against levels of labour-market demand has been examined in this research for evidence of a crisis in UK recruitment. Against the persistent notion of an overall scarcity of STEM graduate supply, in 2015 when considering salary levels as indicators of demand, the picture was rather mixed. While there was evidence of a shortfall in some engineering disciplines, the gradual erosion of the salary levels when adjusted for inflation over the previous five year period suggests that although there was a demand for their services, it was not a growing demand. Nonetheless, the aggregate number of STEM graduates had risen, as had the supply of new graduates in many STEM fields.

This might be explained by noting that the data were collected over a time period which included the 2009 financial crisis and the recessionary period that followed. Even if those factors had been relevant they would not explain why four occupations: Building, Librarianship (linked with IT by the list compilers), Land and Property Management, and East and South Asian studies, experienced a continual growth in their salaries over the preceding five years by 5, 4, 9 and 7 percent respectively. This uneven pattern of salary growth suggests that either employers were unwilling to increase salary levels for STEM occupations (and the other occupations in the top twenty-five salary list in Table 6.6, from which this data were drawn), or that there was not sufficient demand for STEM skills to warrant a competitive approach to salary levels, or that a state of equilibrium prevailed between supply and demand for STEM occupations. If that had been the case, it would have cast further doubt on the reliability of forecasts of future shortages of STEM skills. Moreover it may be that factors such as, the type of work, the location, and so on, as Bosworth et al., suggested, was in 1996, sufficient to attract new graduates (Bosworth et al., 1996, p. 4).

There are some further indications that salary rates vary according to the professional field and the capacity in which STEM skills are employed. The Oil and Energy field for example, which employs many engineers, offered a salary range in 2015 above the mid-rate for engineers. The financial services sector as potential employers of those with mathematics and physics skills, were also likely to offer more competitive salaries than those in for example academia. This implies that skills are valued differently between occupational fields.

Taking vacancy rates into account, the picture for demand again appears to have changed. Table 6.2 provides a comparison between the *annual* STEM graduate supply subject-by-subject and the *monthly* vacancy rate subject-by-subject for November 2015. While some STEM occupations on the list showed an apparent oversupply of graduates, this could not be taken at face value. The oversupply of major occupational groups is likely to include a number of 'hidden' sub-groups. *Subjects Allied to Medicine* for example incorporates the nursing profession. This was an occupation included in the government's shortage of occupation list for November 2015. Inclusion in the shortage list implies, that although *Subjects Allied to Medicine* produced the greatest number of graduates among the STEM subjects in 2015, there was still a substantial undersupply, particularly in the nursing profession, against the demand for their services.

On the other hand, an undersupply noted in Table 6.2 between the *annual* production of STEM graduates for some occupations compared against the *monthly* vacancy rate also suggested a substantial shortfall in graduate numbers. These major groups included Physical sciences, Computer science, and the Engineering and Technology occupations. It is important to note however that the last two occupational categories are likely to have been augmented by those workers who opted for a non-university route to gaining their qualifications.

One area also shown in Table 6.2 as an oversupply is the Biological sciences. Over 4,055 vacancies for biology teachers and lecturers, this suggests that any oversupply in biology numbers may have been clustered at the first degree level, since university requirements for lecturers are more likely to be at the postgraduate level, while for state school teachers at least a first degree and a postgraduate teaching certificate is a usual requirement. There is a further consideration however when considering the Biological sciences as an oversupply without understanding how many vacancies remain unfilled each month and how many overspill from month-to-month. If, for instance, monthly vacancy levels of 4,000 plus are multiplied over twelve months, then the annual supply of 17,000 Biological science graduates would be appear to be insufficient, particularly since the academic route is the only UK route to such qualifications in this discipline.

Taking salary levels as indicative of the level of market demand, it is notable that salaries for the Biological sciences were not included in the top twenty-five salary list (Table 6.6), However Table 6.5 gives estimated salary levels for the Biological sciences, along with Agriculture, as one of the lowest paid of the STEM subjects listed for 2015. Moreover, whereas the salaries for Agriculture had only suffered a one percent reduction over the five years of the study, for Biology the real value of earnings was cut by seven percent over the same time period. This suggested that an oversupply may be depressing salaries where the demand for the Biological science graduates was lower for this STEM group than for others listed in Table 6.5.

8.5 Recommendations and policy implications

While there are clear differences in demand levels between some STEM subjects and occupations, the evidence of an overall scarcity of STEM graduates was not found in this research. Moreover, the question of a crisis in recruitment was also unfounded by the evidence. On the contrary, recruitment in STEM undergraduate degrees in the UK was seen to have been rising over the thirteen year period of the research, despite a decline in the cohort population birthrate. This raises the question of a number of unrealistic assumptions in terms of the claims about the supply of STEM skills, and of the labour market level of demand for STEM skills. It suggests a need to revisit and revise the policies of government, industrial and professional bodies as they relate to science and technology, so that they accord more closely with the empirical findings of this study.

There is a further perspective to be considered about the supply and demand for STEM skills highlighted in the findings, that of prospective science and engineering students. This is apparent in the post-event survey questionnaire when in answer to the question *"What might turn you away from science?"* Sixty-one percent responded with the answer *"Uncertainty about the supply and demand for skills in my preferred field".*

Although it should be kept in mind that the respondents included overseas students as well as those from the UK, there is an important point arising from the LIYSF post-event questionnaire that calls for UK policy change. This is the concern about the degree of ignorance that young people, some interested enough in science to spend time and effort to fundraise the costs required to participate in the LIYSF event, evidently had little knowledge of the range of opportunities available to them once they achieve a science or technology qualification. These were young people on the brink of a university education, at home or abroad, negotiating their futures, for some of them, with insufficient knowledge to make informed career choices. Clearly, the question of supply and demand for their future choices was a factor of importance to those who responded to the related survey questions.

While the lag time between training and seeking employment is always likely to witness changes in employment opportunities, the policy for career guidance should ensure that advice, particularly in the sciences and technology where progress and advances are dynamic, are up-to-date, appropriate and available at the crucial point of subject choice in the UK schools from GCSE onwards.

8.5.1 Recruitment Patterns

Emerging from this study's research which may contribute towards the perception of an insufficiency in the number of graduates, and also help to explain the notable decline in recruitment to HE in the computer sciences, is the analysis of HE recruitment patterns seen over 2003 to 2015. It applies particularly to the computer sciences, but was also observed, according to Shadbolt's pre-report briefing of 2015, to affect mathematics and the physical sciences. The issue of Shadbolt's concern was seen in the lower employment rates and the lower earnings of those with a black or minority background (BME), when compared with similarly qualified white students (2015). This appears to be linked to an unconscious bias of employers, or those involved in recruiting graduates (to employment) to tend towards employing those seen as similar to themselves across a number of variables, including culture and background as well as interests (McPherson et al., 2001; Rivera, 2012). This suggests some greater awareness is needed, possibly by policy intervention, of the consequences of discrimination, in terms of both practical and ethical concerns in the potential availability of graduate supply through the education supply chain onward and in addressing equality in the workplace.

A further and unexpected outcome of compiling the recruitment data into a graphical form, which holds implications for policy considerations, was the emergence in some cases of quite specific recruitment patterns seen in the resulting plots. One particular example was seen in the recruitment of medical doctors. For this STEM discipline it would be reasonable to expect that an upward trend would be seen in recruitment levels in line with a rising UK population of around six million over the period of the study (2003 to 2015), according to undated World Bank and ONS figures (2016). Instead the graph showed recruitment levels had flat-lined for NHS doctors over the thirteen years of the study strongly suggesting that the number of future medical practitioners would fall below that likely to be needed. Particularly, it now appears, for doctor numbers in general practice according to the National Health Executive (NHE, 2016).

Where estimations for future quantitative requirements for UK doctors need to take lengthy training times into account, recruitment levels for medical students must be set more realistically against population growth if they are to meet the future demands of a growing and an ageing UK population.

8.6 The contribution to knowledge

The contribution to knowledge of this research lies in the in-depth analysis of the structure and pattern of student recruitment in Science, Technology, Engineering and Mathematics (STEM) in the UK over the period 2003 to 2015, and in the comparison with further research and available evidence that can serve as an indicator of demand in the market for STEM skills. The analysis has identified several relevant factors, contextual, political and financial, affecting recruitment, as the examples outlined above have indicated, with implications for policy approaches.

The major contribution however lies in answering the research question,

Is there a contemporary crisis in the recruitment of UK STEM graduates?

While there are clear differences in demand levels between some STEM subjects and occupations, the evidence of a recruitment crisis in the sciences and in engineering over the period 2003 to 2015 is not found in this study as suggested in Figure 8.1.

8.7 Extending the research

In considering how this research could be extended, one obvious approach would be to further the investigation into the multifaceted question of the demand for STEM skills. The difficulty of directly estimating levels of demand has become clear in this thesis. Now other approaches need to be devised to quantify and explain with a statistical grasp, the paradoxical issues of demand.

There are also qualitative questions to raise in any future research. At the very basis of concern, as Mason had asked in 1999, why are employers reluctant to offer higher salaries against the persistent perception of a need for greater numbers of science and engineering graduates? Particularly so when they are assumed to possess the skills long lauded as essential to creativity and innovation. A possible disruption of salary levels in firms internal labour markets has been offered as one reason by Mason, but there may well be others equally plausible. Moreover the dynamic of the STEM skills labour market may well have changed since Mason was writing at the end of the 20th century.

The question of a pool of science and engineering graduates waiting and ready for selection by choosy employers was raised early in the thesis in considering an overall supply of STEM graduates. Could this be practicable - and ethical? Or does the notion of exploitation of those for whom science and technology hold an appeal for its own sake, become an issue of concern as I previously suggested?

There is also the question of a seeking a greater degree of specialisation in skills demanded by some employers, against the view that a broader and more flexible approach to training within disciplines, and possibly across disciplines in suitable cases, would alleviate shortages. How feasible is a flexible approach for stakeholders, that is, for HE teaching establishments, for students and for employers? And how useful or restrictive in terms of supply and demand might greater specialisation be for industry and the employment opportunities for graduates?

To help to understand the factors and implications involved in such questions, it would greatly help if the collection of relevant data along these lines were being systematically and consistently gathered, in suitable forms, and made available in the public domain. This is fundamental need for policy making.

Where the availability and consistency of data is a concern in the UK, it appears that the United States has an advantage in terms of the scope and availability of data relating to the US supply and demand for STEM skills. This becomes evident through online data searches. One example is seen in the lack of UK literature dealing with the time STEM vacancies takes to fill. This data can be useful as an additional variable in supporting the estimates of supply levels, or in indicating a shortfall in conditions of employment. While this aspect appears to be overlooked in the UK, it is however addressed and readily available in literature form in the USA.

The UK however is not alone in its concern about a shortfall in detailed and consistent data sources in estimating UK STEM supply and demand. Wilson's, et al., *Working Futures* reports of the early 21st century also voiced concern about data availability and consistency. While an Economic Commission report in 2015, in asking *Does Europe need more STEM graduates?*, wrote of similar concerns in EU member states about inadequate data to reliably inform policy making across EU countries (2015, p. 4).

8.8 Final conclusions

In looking back into historical accounts of UK concern about science and the contemporary context of STEM supply and demand, it is tempting to think a negative approach to the state of science in the UK represents the default attitude of stakeholders and commentators in considering question of the availability of science and technology skills. Although no convincing statistical evidence was found in this research study to suggest a contemporary crisis in STEM recruitment, nor a subsequent overall shortfall in STEM graduate numbers against demand, it is difficult to overlook the persistent perception of many stakeholders that STEM skills have always been, and remain, too few for the demand, mismatched to employers needs, of a poorer quality relative to previous graduate cohorts, too specialised or insufficiently specialised, or simply located in the wrong place (geographically speaking).

This last concern includes the location of STEM industries. Despite the creative and innovation advantages of clustering knowledge intensive industries together, this clearly creates a real difficulty for employers located elsewhere, and for potential STEM employees unable to move or commute. Nevertheless, were such issues and other concerns successfully addressed, it is also tempting to think the perception of a shortfall in graduate numbers would persist if, as Kurt Lewin suggested, “As a rule, the possession of correct knowledge does not suffice to rectify false perception” (Lewin, 1948, p. 61).

But it is clear that are clear advantages for employers to perpetuate the perception. Actively encouraging young people to embrace a science or engineering degree helps to widen the STEM supply pool of hopeful candidates. Not only does it allow for a greater choice among candidates, more than that, the larger the supply, the greater the competition between candidates, and, if orthodox labour market economics prevail, the lower the price paid for labour. As a theory of supply and demand it is a concept that goes some way towards explaining the relatively low salary levels seen in this research, particularly for engineering skills.

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Appendix A

HESA Tables

A.1 STEM plot data sources

A.1.1 Data for Figure 5.3, Total first year undergraduates and postgraduates

Data for 2002/03 to 2008/9, Table 1b (undergraduates) and 1d (postgraduates), HESA Students in Education, First year full-time undergraduates by qualification aim, domicile, age, subject area, location of institution and gender

Data for 2009/10 to 2014/15, HESA Students, Qualifiers and Staff data tables: subject0910.xls through to subject201415.xls.

A.1.2 Data for Figure 5.4, First year full-time undergraduates

Data for 2002/03 to 2008/9, Table 1b (undergraduates), HESA Students in Education, First year full-time undergraduates by qualification aim, domicile, age, subject area, location of institution and gender.

Data for 2009/10 to 2014/15, HESA Students, Qualifiers and Staff data tables: subject0910.xls through to subject201415.xls.

A.1.3 Data for Figure 5.5, First year part-time undergraduates

Data for 2002/03 to 2008/9, Table 1f, HESA Students in Education, First year part-time undergraduates by qualification aim, domicile, age, subject area, location of institution and gender.

Data for 2009/10, HESA Students, Qualifiers and Staff data tables: subject0910.xls

Data for 2010/11 to 2014/15, Table 4d, HESA Students in Education, First year full-time postgraduates by qualification aim, domicile, age, subject area, location of institution and gender

A.1.4 Data for Figure 5.8, Graduate results

Data for 2002/03 to 2008/9, Table 14, HESA Students in Education. HE qualifications obtained in the UK by mode of study, domicile, gender and subject area.

Data for 2009/10 to 2014/15, HESA Students, Qualifiers and Staff data tables: qualsub0910.xls to qualsub1415.xls

A.1.5 Data for Figure 5.10, First year full-time postgraduates

Data for 2002/03 to 2008/9, Table 1d, HESA Students in Education, First year full-time postgraduates by qualification aim, domicile, age, subject area, location of institution and gender.

Data for 2009/10 to 2014/15, HESA Students, Qualifiers and Staff data tables: subject0910.xls through to subject201415.xls.

A.1.6 Data for Figure 5.11, First year part-time postgraduates

Data for 2002/03 to 2008/9, Table 1h, HESA Students in Education, First year part-time postgraduates by qualification aim, domicile, age, subject area, location of institution and gender

Data for 2009/10 to 2014/15, HESA Students, Qualifiers and Staff data tables: subject0910.xls through to subject1415.xls

A.1.7 Data for Figure 5.12, Higher degree results

Data for 2002/03 to 2008/9, Table 14, HESA Students in Education. HE qualifications obtained in the UK by mode of study, domicile, gender and subject area.

Data for 2009/10 to 2014/15, HESA Students, Qualifiers and Staff data tables: qualsub0910.xls to qualsub1415.xls

A.1.8 Data for Figure 5.13, Total first year undergraduate and postgraduate students

Data as for Figure 5.4, Figure 5.5, Figure 5.10 and Figure 5.5.

Appendix B

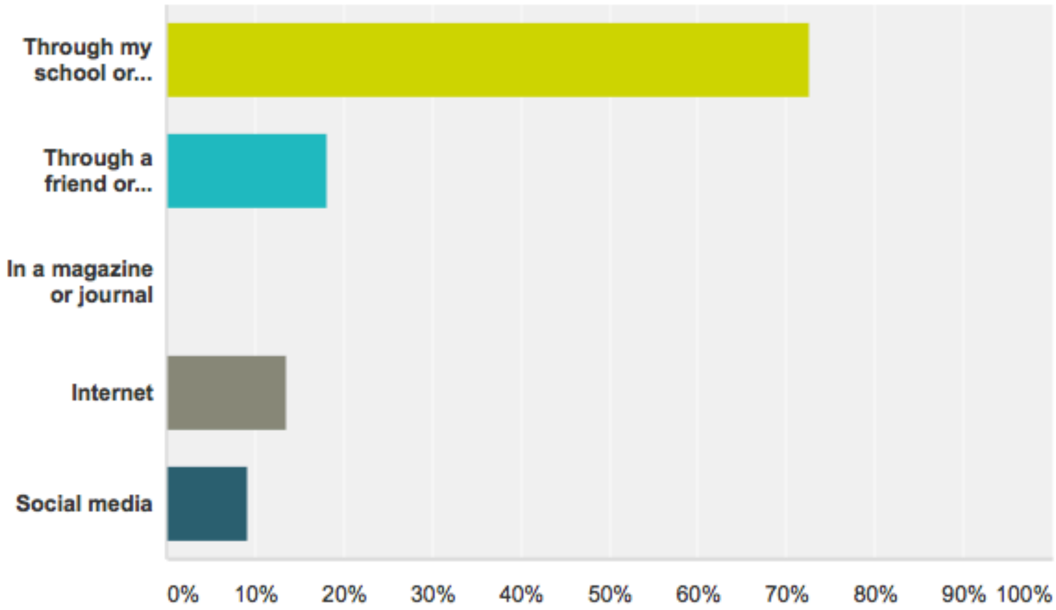
LIYSF Survey

B.1 Survey 1

Results from the LIYSF survey are on the following pages.

How did you hear about LIYSF? (please select all that apply)

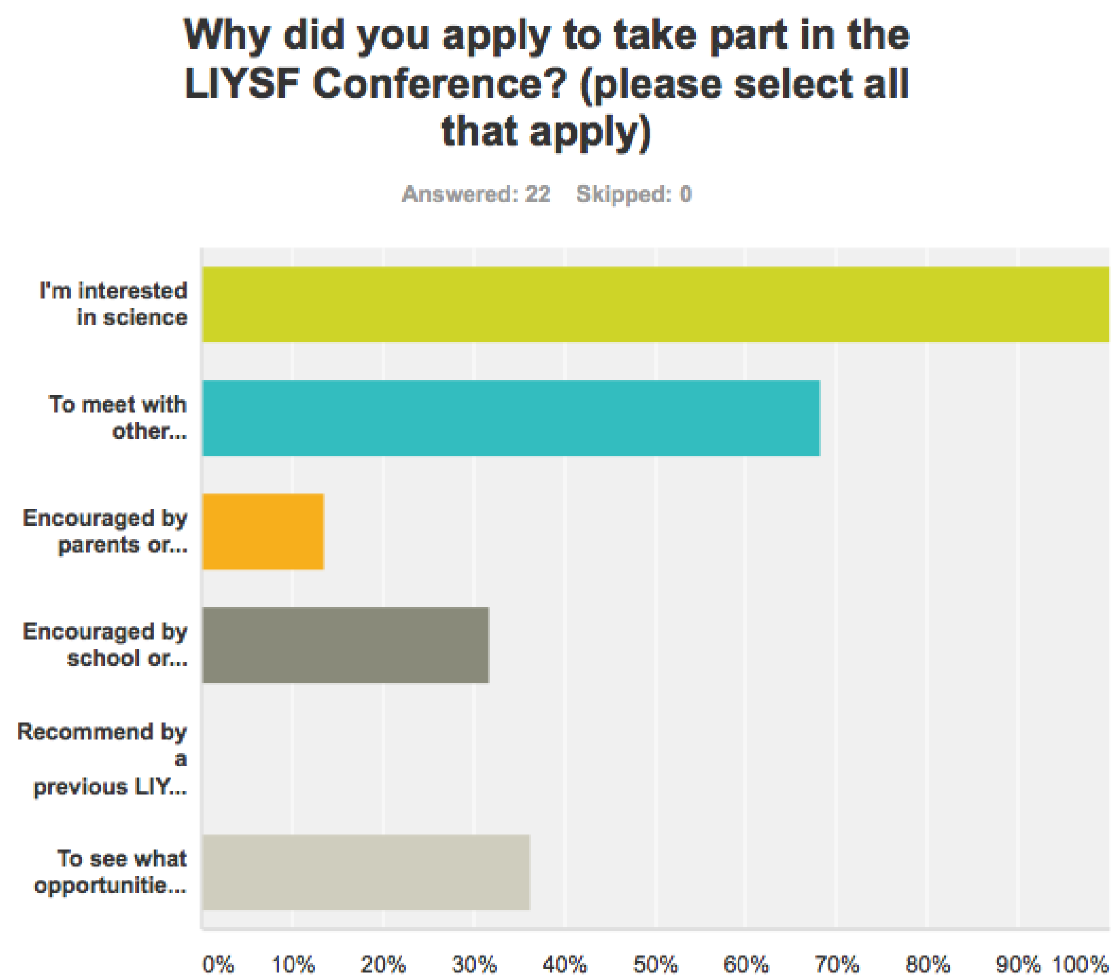
Answered: 22 Skipped: 0



Answer Choices	Responses	
Through my school or college	72.73%	16
Through a friend or colleague	18.18%	4
In a magazine or journal	0.00%	0
Internet	13.64%	3
Social media	9.09%	2
Total Respondents: 22		

Comments (1)

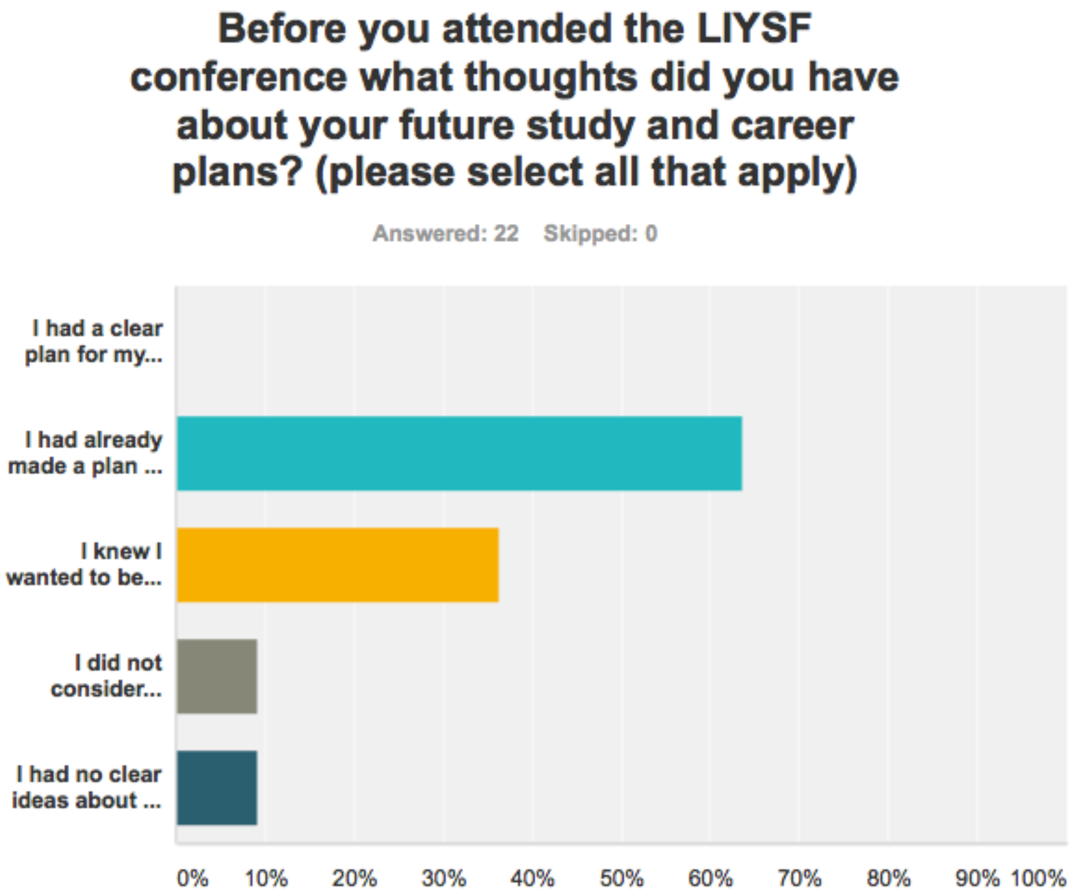
Figure B.1: Survey 1, Question 1



Answer Choices	Responses	
I'm interested in science	100.00%	22
To meet with other like-minded people	68.18%	15
Encouraged by parents or family members	13.64%	3
Encouraged by school or college teachers	31.82%	7
Recommend by a previous LIYSF participant	0.00%	0
To see what opportunities science can offer as a career	36.36%	8
Total Respondents: 22		

Comments (1)

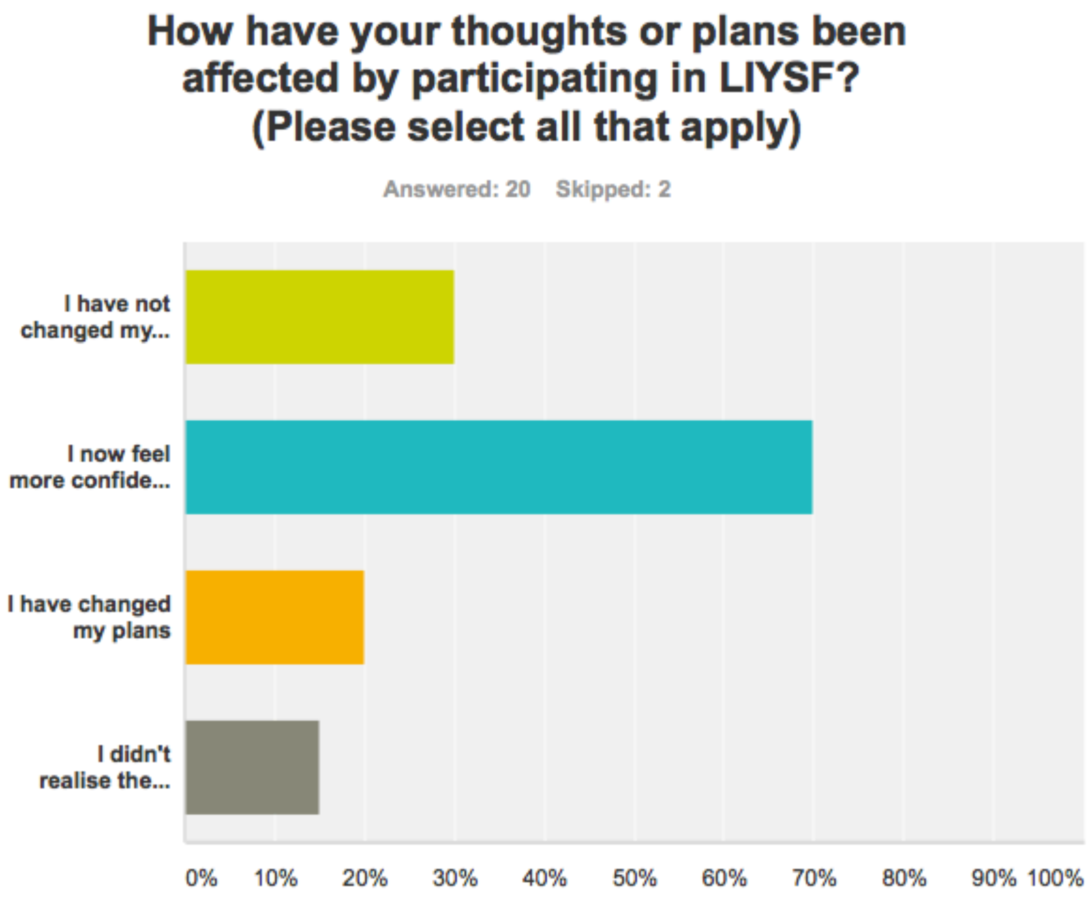
Figure B.2: Survey 1, Question 2



Answer Choices	Responses	
I had a clear plan for my future career that did not include science	0.00%	0
I had already made a plan to study and work in a science related area	63.64%	14
I knew I wanted to be involved professionally in science, but was not sure what specific subject area	36.36%	8
I did not consider science as a possible career choice	9.09%	2
I had no clear ideas about my future career plans	9.09%	2
Total Respondents: 22		

Comments (0)

Figure B.3: Survey 1, Question 3



Answer Choices	Responses	
I have not changed my plans	30.00%	6
I now feel more confident about my chosen career direction	70.00%	14
I have changed my plans	20.00%	4
I didn't realise the wide range of options open to science graduates	15.00%	3
Total Respondents: 20		

Comments (1)

Figure B.4: Survey 1, Question 4

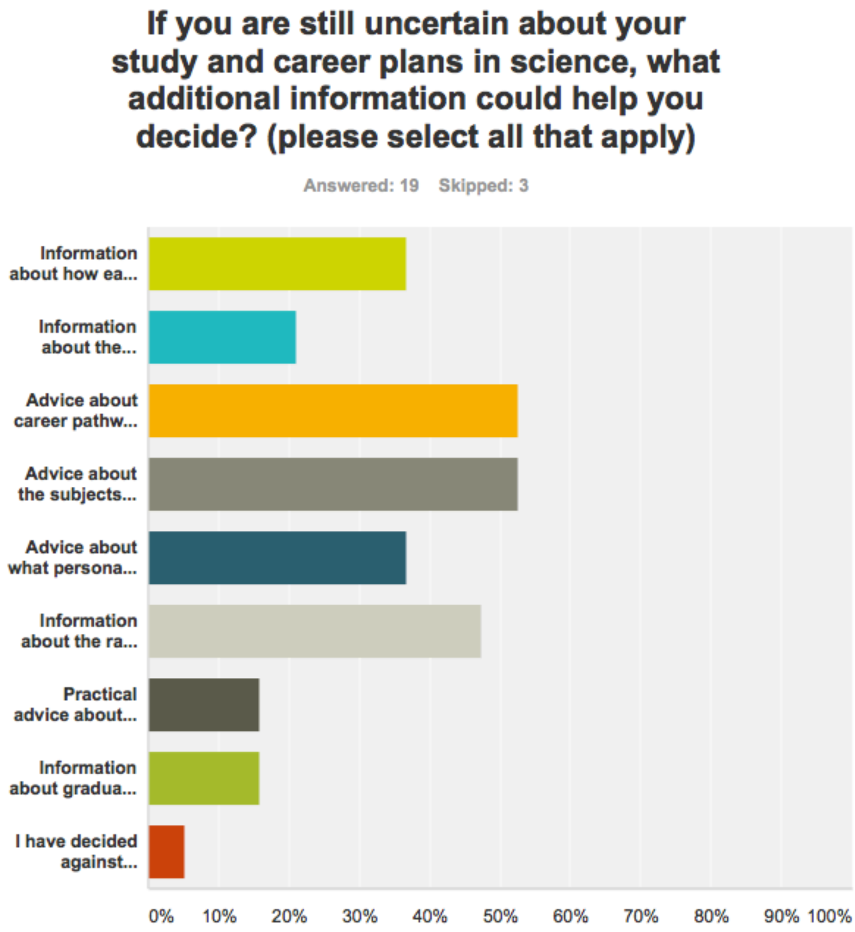


Figure B.5: Survey 1, Question 5

Answer Choices	Responses	
Information about how easy or difficult it might be to find employment in my chosen scientific field of study	36.84%	7
Information about the graduate starting salaries across various science subjects	21.05%	4
Advice about career pathways from those already working in the field	52.63%	10
Advice about the subjects I need to study to reach my goals	52.63%	10
Advice about what personal qualities are needed to be successful in my studies and career	36.84%	7
Information about the rage of options open to me within the science field at various stages in my studies, eg. Graduate degree, Masters degree and PhD	47.37%	9
Practical advice about studying in the UK (or home country) including fees, scholarships, funding, bursaries, accommodation etc.	15.79%	3
Information about graduate work prospects in the UK	15.79%	3
I have decided against studying science subjects	5.26%	1
Total Respondents: 19		

Comments (0)

Figure B.6: Survey 1, Question 5

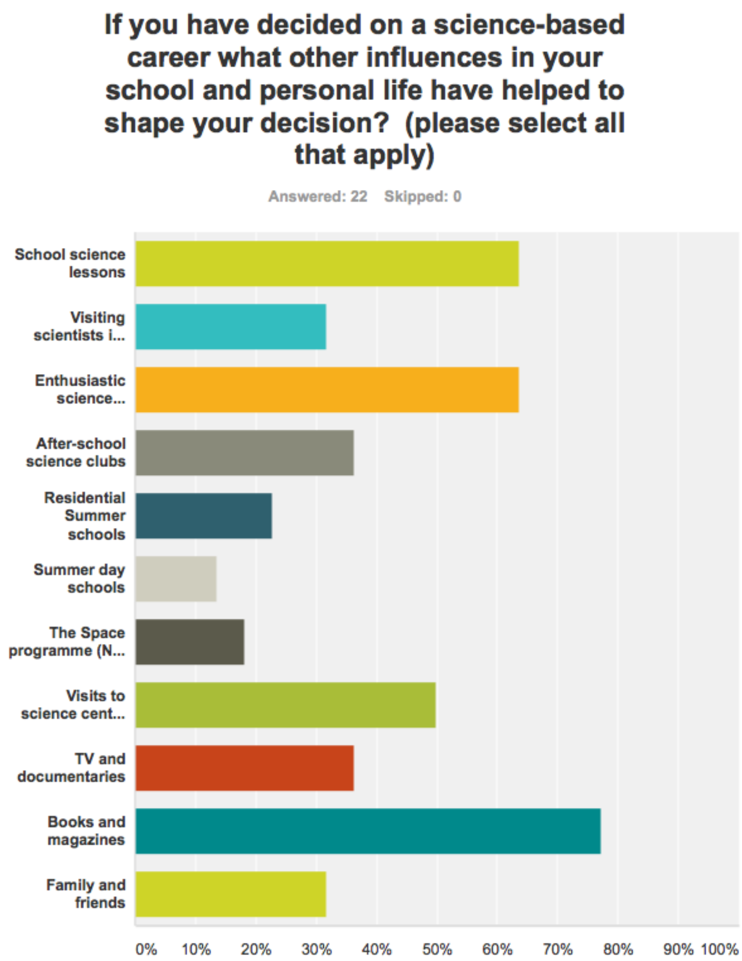
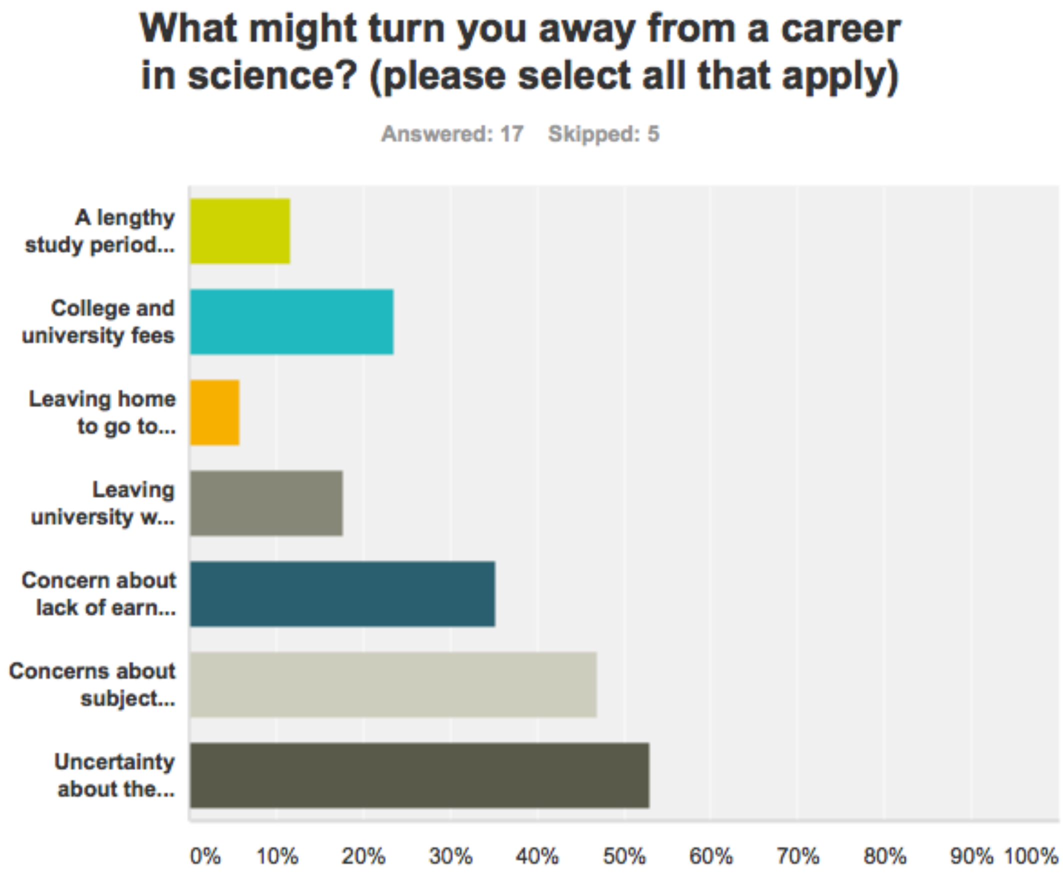


Figure B.7: Survey 1, Question 6

Answer Choices	Responses	
School science lessons	63.64%	14
Visiting scientists in the classroom	31.82%	7
Enthusiastic science teachers	63.64%	14
After-school science clubs	36.36%	8
Residential Summer schools	22.73%	5
Summer day schools	13.64%	3
The Space programme (NASA or ESA)	18.18%	4
Visits to science centres and museums	50.00%	11
TV and documentaries	36.36%	8
Books and magazines	77.27%	17
Family and friends	31.82%	7
Total Respondents: 22		

Comments (1)

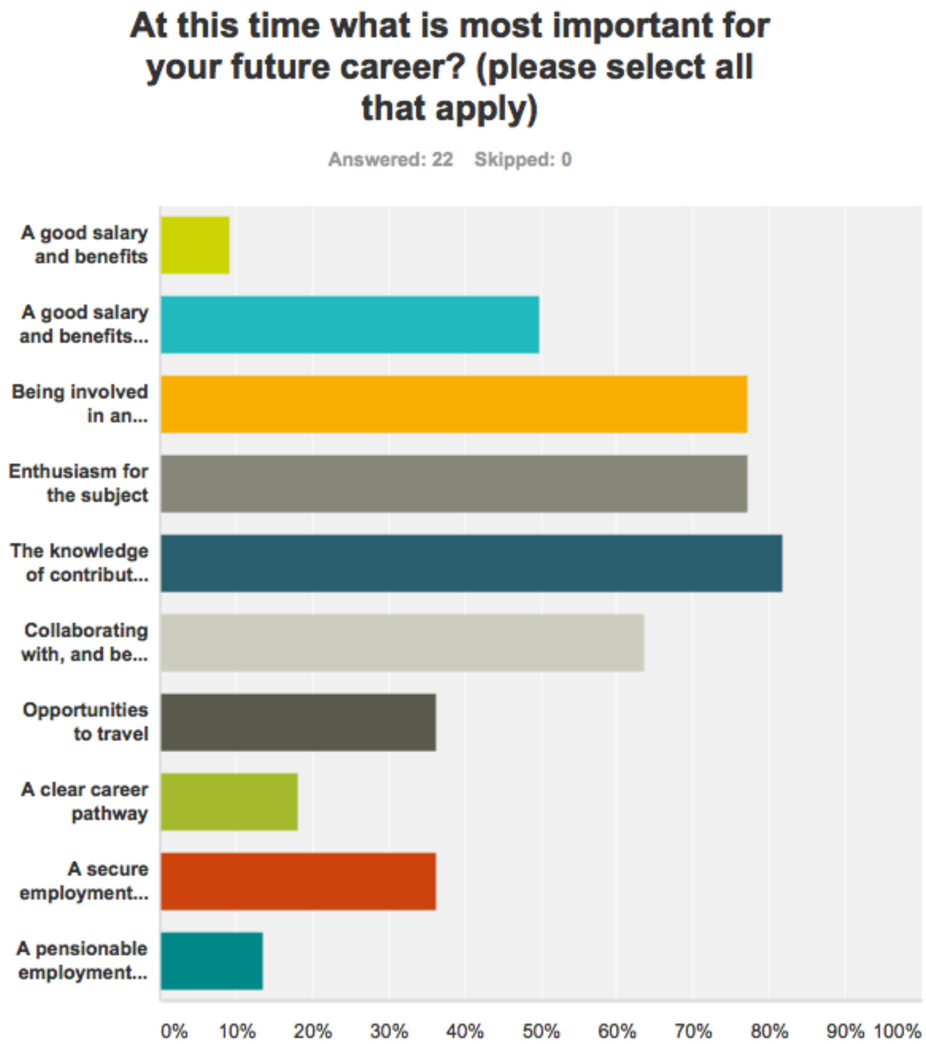
Figure B.8: Survey 1, Question 6



Answer Choices	Responses	
A lengthy study period needed for some science subjects (beyond the first undergraduate degree)	11.76%	2
College and university fees	23.53%	4
Leaving home to go to university	5.88%	1
Leaving university with a large debt	17.65%	3
Concern about lack of earning potential while you study	35.29%	6
Concerns about subject difficulty, and in reaching the required academic standards	47.06%	8
Uncertainty about the supply and demand for my skills in my preferred science field	52.94%	9
Total Respondents: 17		

Comments (3)

Figure B.9: Survey 1, Question 7



Answer Choices	Responses	
A good salary and benefits	9.09%	2
A good salary and benefits are important but not enough in themselves	50.00%	11
Being involved in an interesting job	77.27%	17
Enthusiasm for the subject	77.27%	17
The knowledge of contributing to something worthwhile	81.82%	18
Collaborating with, and being in the company of other like-minded people	63.64%	14
Opportunities to travel	36.36%	8
A clear career pathway	18.18%	4
A secure employment position	36.36%	8
A pensionable employment position	13.64%	3
Total Respondents: 22		

Figure B.10: Survey 1, Question 8

B.2 Survey 1. Student comments on the LIYSF experience.

1. more lab visit do experiments by ourselves two nights of science bazaar

- Age 17
- Gender female
- Home country Taiwan

2. 100% would recommend

- Age 17
- Gender Female
- Home country Taiwan

3. A great experience both personally and proffesional

- Age 17
- Gender Male
- Home country Spain

4. This is a fantastic opportunity for students interested in science to explore more. I become more interested in chemistry which I have decided to study before going to LIYSF and I start to focus on other fields of science as well after attending various lectures presented in LIYSF

- Age 18
- Gender Female
- Home country China

5. LIYSF encouraged me not only to science career, but also to medicine, as there were many inspiring lectures on that subject as well.

- Age 17
- Gender Female
- Home country Poland

6. Definitely worthwhile. Some lectures had changed my concept toward important issues, while others aroused my passion for the subject.

- Age 18
- Gender F
- Home country ROC(Taiwan)

7. It was ok. But those who have a difficult time with people in general isnt LIYSF a place for.

- Age 19
- Gender Male

8. I changed a lot after attending into the program. I became more confident and carry out more critical thinkings. I like to ask question now. So I think joining in this program is very helpful. You can be inspired by so many passionate people who have the same interests as you do. And they work so hard on what they like. It's a perfect opportunity for learning and meeting friends.

- Age 16
- Gender Female
- Home country China

9. I actually enjoy the atmosphere between peers and professors, and I feel free to discuss, cooperate and study.

- Age 17
- Gender Male
- Home country P. R. China

10. LIYSF has given me a broader view on different areas of sciences and a more thorough understanding on the work of scientists and researchers, as well as given me a chance to meet students from all over the world who are enthusiastic about science just like I do. It's an experience of discovering myself and strengthening what I really love. More importantly, I started to have some clearer ideas on the potential career of being a researcher, which is something I don't have before attending LIYSF. It made me more certain with the career path I chose and that's one of the reasons why LIYSF is such an important experience in my life.

- Age 16
- Gender Female
- Home country China

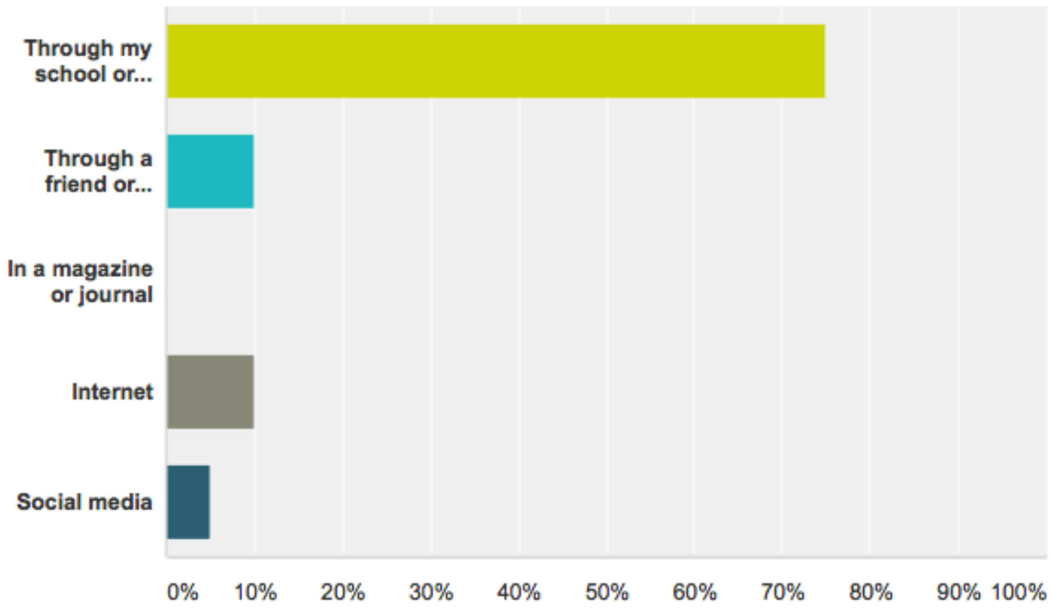
11. fabulous journey ever with so many like-minded friends abroad

- Age 18
- Gender Female
- Home country China

B.3 Survey 2

How did you hear about LIYSF? (please select all that apply)

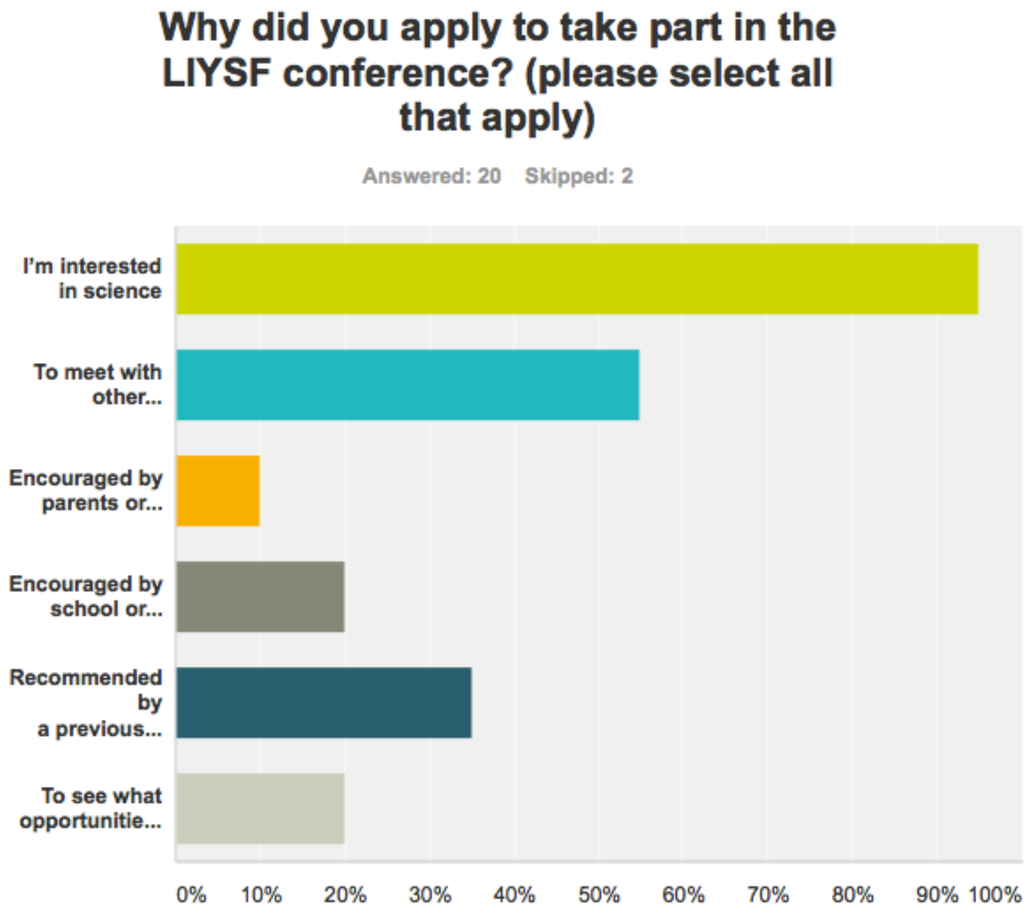
Answered: 20 Skipped: 2



Answer Choices	Responses	
Through my school or college	75.00%	15
Through a friend or colleague	10.00%	2
In a magazine or journal	0.00%	0
Internet	10.00%	2
Social media	5.00%	1
Total Respondents: 20		

Comments (2)

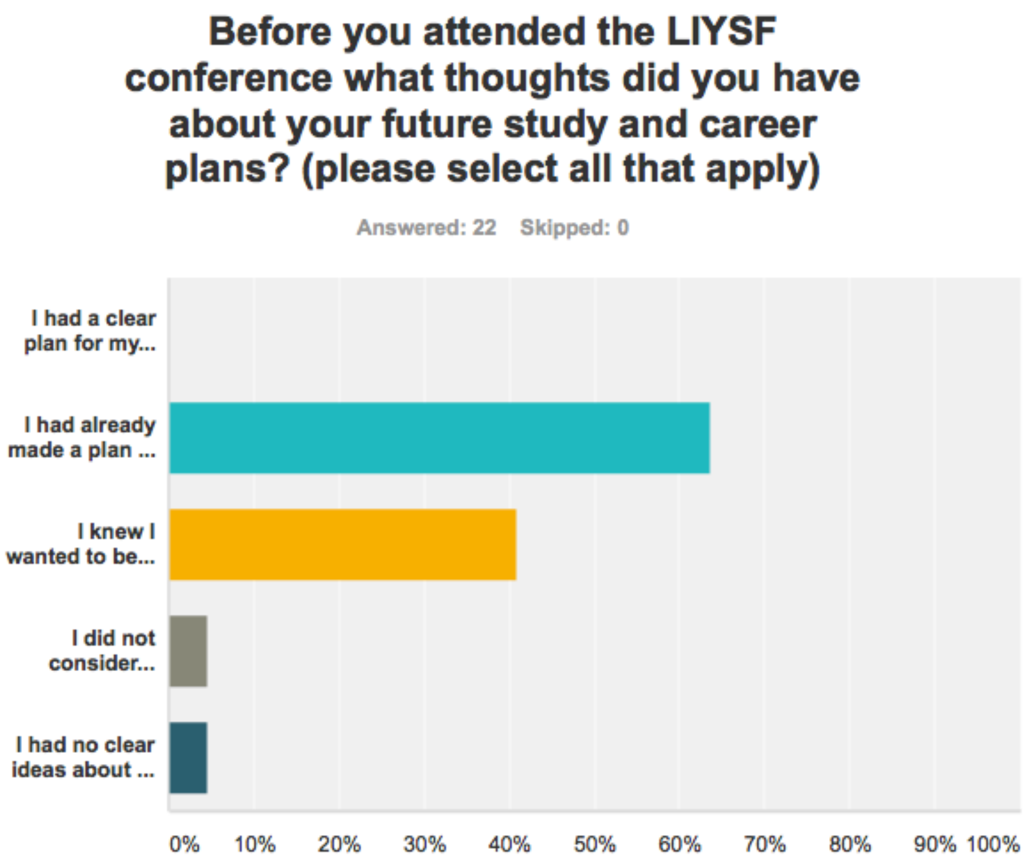
Figure B.11: Survey 2, Question 1



Answer Choices	Responses	
I'm interested in science	95.00%	19
To meet with other like-minded people	55.00%	11
Encouraged by parents or family members	10.00%	2
Encouraged by school or college teachers	20.00%	4
Recommended by a previous LIYSF participant	35.00%	7
To see what opportunities science can offer as a career	20.00%	4
Total Respondents: 20		

Comments (2)

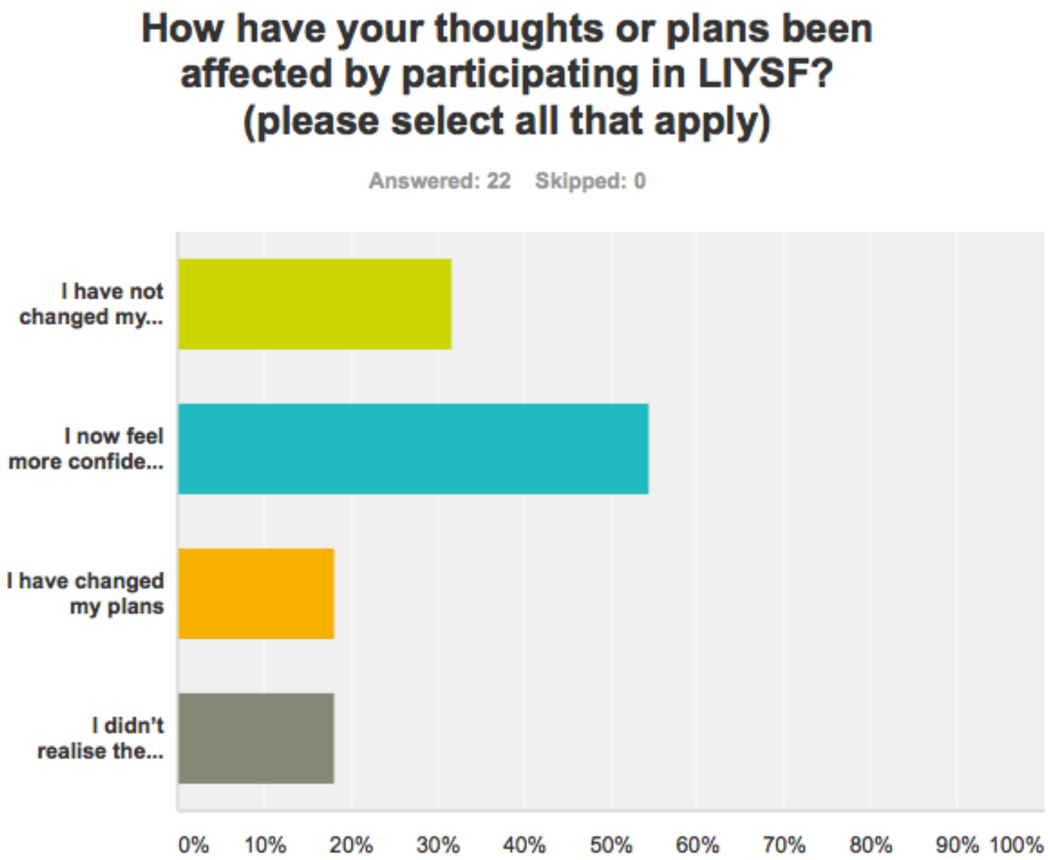
Figure B.12: Survey 2, Question 2



Answer Choices	Responses	
I had a clear plan for my future career that did not include science	0.00%	0
I had already made a plan to study and work in a science related area	63.64%	14
I knew I wanted to be involved professionally in science, but was not sure what specific subject area	40.91%	9
I did not consider science as a possible career choice	4.55%	1
I had no clear ideas about my future career plans	4.55%	1
Total Respondents: 22		

Comments (0)

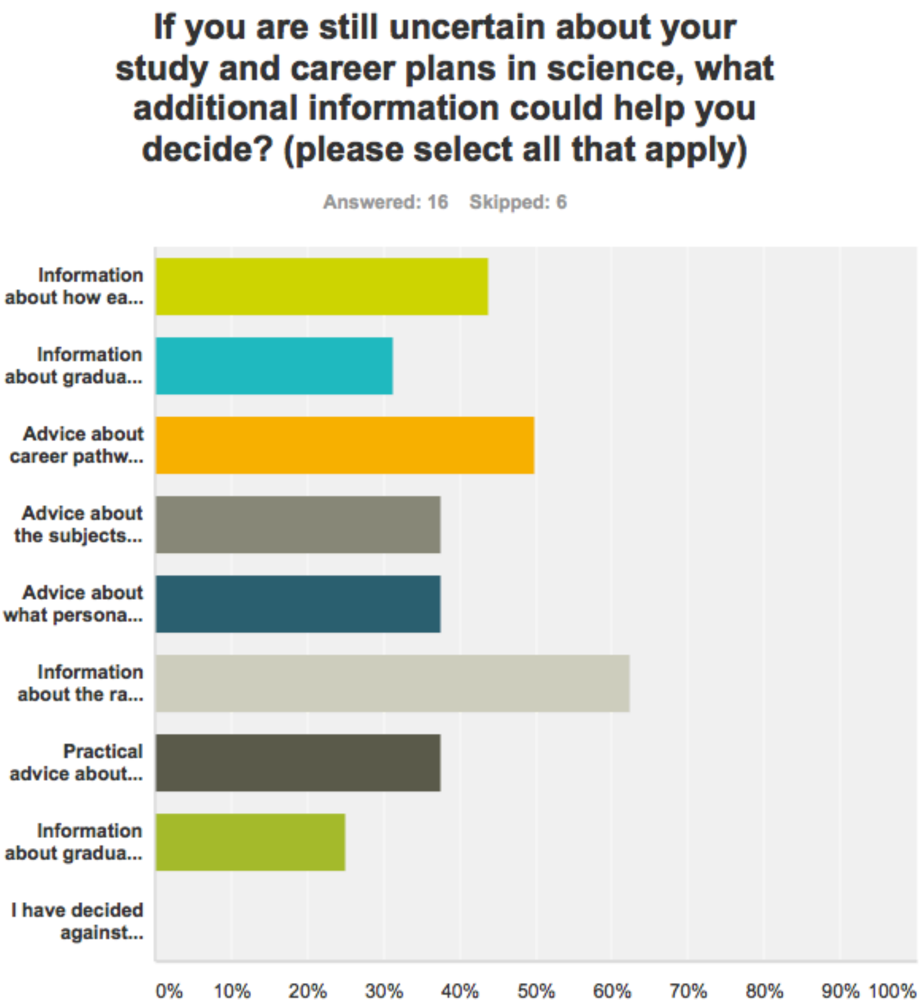
Figure B.13: Survey 2, Question 3



Answer Choices	Responses	
I have not changed my plans	31.82%	7
I now feel more confident about my chosen career direction	54.55%	12
I have changed my plans	18.18%	4
I didn't realise the wide range of options open to science graduates	18.18%	4
Total Respondents: 22		

Comments (0)

Figure B.14: Survey 2, Question 4



Answer Choices	Responses	
Information about how easy or difficult it might be to find employment in my chosen science field of study	43.75%	7
Information about graduate starting salaries across various science subjects	31.25%	5
Advice about career pathways from those already working in the field	50.00%	8
Advice about the subjects I need to study to reach my goals	37.50%	6
Advice about what personal qualities are needed to be successful in my studies and career	37.50%	6
Information about the range of options open to me at various stages in my studies,eg. Graduate, Masters degree and PhD	62.50%	10
Practical advice about studying in the UK (or home country) including fees, scholarships, funding, bursaries, accommodation etc.	37.50%	6
Information about graduate work prospects in the UK	25.00%	4
I have decided against studying science subjects	0.00%	0
Total Respondents: 16		

Figure B.15: Survey 2, Question 5

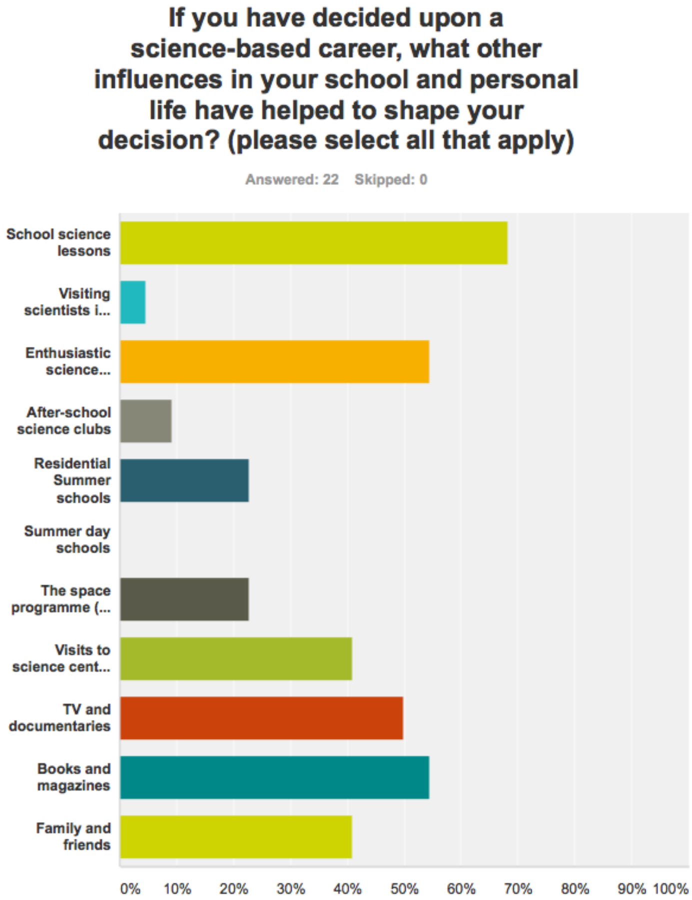


Figure B.16: Survey 2, Question 6

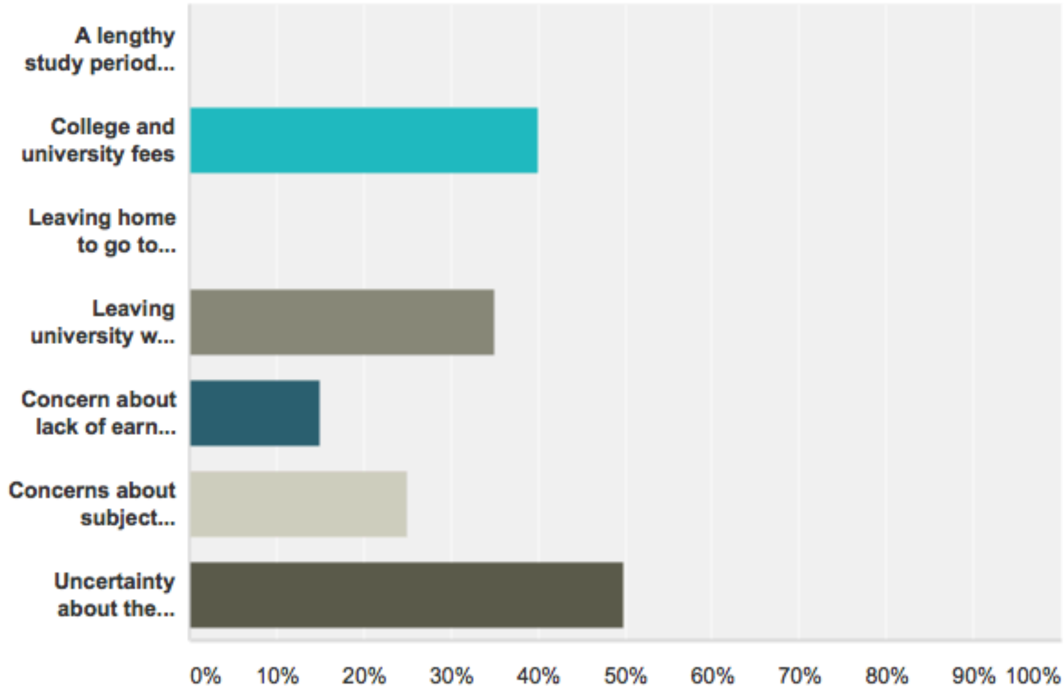
Answer Choices	Responses	
School science lessons	68.18%	15
Visiting scientists in the classroom	4.55%	1
Enthusiastic science teachers	54.55%	12
After-school science clubs	9.09%	2
Residential Summer schools	22.73%	5
Summer day schools	0.00%	0
The space programme (NASA or ESA)	22.73%	5
Visits to science centres and museums	40.91%	9
TV and documentaries	50.00%	11
Books and magazines	54.55%	12
Family and friends	40.91%	9
Total Respondents: 22		

Comments (1)

Figure B.17: Survey 2, Question 6

What might turn you away from a career in science? (please select all that apply)

Answered: 20 Skipped: 2



Answer Choices	Responses	
A lengthy study period needed for some science subjects (beyond the first undergraduate degree)	0.00%	0
College and university fees	40.00%	8
Leaving home to go to university	0.00%	0
Leaving university with a large debt	35.00%	7
Concern about lack of earning potential while you study	15.00%	3
Concerns about subject difficulty and reaching the required academic standards	25.00%	5
Uncertainty about the supply and demand for my skills in my preferred science field	50.00%	10
Total Respondents: 20		

Comments (1)

Figure B.18: Survey 2, Question 7

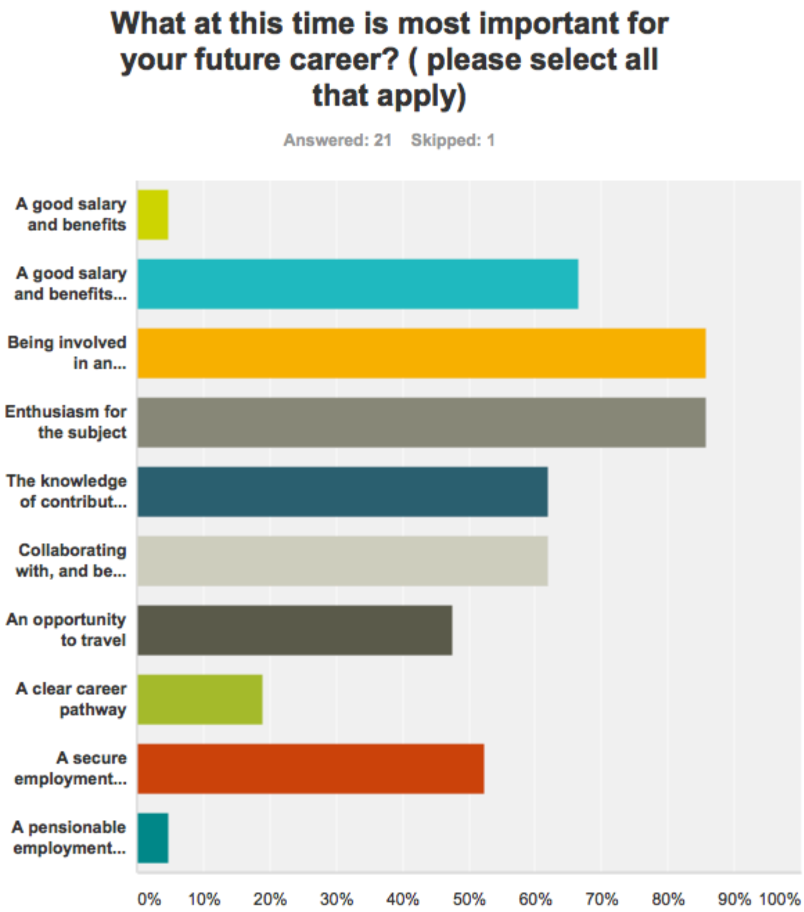


Figure B.19: Survey 2, Question 8

Answer Choices	Responses	
A good salary and benefits	4.76%	1
A good salary and benefits are important but not enough in themselves	66.67%	14
Being involved in an interesting job	85.71%	18
Enthusiasm for the subject	85.71%	18
The knowledge of contributing to something worthwhile	61.90%	13
Collaborating with, and being in the company of other like-minded people	61.90%	13
An opportunity to travel	47.62%	10
A clear career pathway	19.05%	4
A secure employment position	52.38%	11
A pensionable employment position	4.76%	1
Total Respondents: 21		

Comments (1)

Figure B.20: Survey 2, Question 8

B.4 Survey 2. Student comments on the LIYSF experience.

1. LIYSF is a enchanting experience. I am so glad I took part in it as my life was somehow changed. I will always cherish the menmories from LIYSF

- Age 16
- Gender Female
- Home country China

2. A useful and interesting experience that helped me to understand what I really like and what I want to learn. An experience that teached me that it's not important your social status, your gender, your religion or your citizenship if you want to learn something you have to do it.

- Age 19
- Gender Female
- Home country Italy

3. It was an amazing experience that I would recommend to anyone interested in science. It really has something for everyone.

- Age 17
- Gender Male
- Home country Belgium

4. Great. Meeting people who are interested in the same things as me, going to interesting scientific institutions, and hearing lectures from specialists heavily involved in their fields was fantastic. Identifying a best moment is too hard, because everything was great. LIYSF solidified my interest in engineering enormously, and I can't help but be grateful for the opportunity to attend.

- Age 17
- Gender Male
- Home country Australia

5. The experience thay I've gained at this forum is one that I will always carry with me for the rest of my life. I have never been so comfortable with myself and what I know and being able to share and build on it with such a large group of like minded individuals from all over the world has made it (the experience) much more than I could have ever expected. Furthermore, being able to visit some of the places we did, especially Airbus for me since I'm most interested in engineering, has helped solidify my decision to study Aeronautical Engineering with a deeper look into the aviation industry.

- Age 20
- Gender Male
- Home country Trinidad and Tobago

6. The best experience of my life to date. Life changing, unforgettable and exciting.

- Age 17
- Gender Female
- Home country England

7. It was a challenging experience that taught me a lot about science and what university life is. I certainly enjoyed it!

- Age 18
- Gender Female
- Home country Cyprus

8. I really enjoyed LIYSF; it was one of the most amazing experiences of my life. Every aspect of the forum was engaging, informative and fun. Being able to gain exposure to so many new fields in science - some of which I've never heard of - was definitely one of the best parts. Though I had already made up my mind about my career, the lectures sparked my curiosity and made me begin to consider venturing into other fields. The wealth of knowledge available to a participant is incredible and I think that anyone who attends should maximize on this opportunity and take in as much information as possible. Aside from the educational aspects, the forum's social value is second to none. Making new friends from so many different countries was, by far, the best part of the trip. I loved getting the chance to experience new cultures and to understand how young scientists like myself think. This is the part that makes the forum a once in a lifetime opportunity. The

friendships made at LIYSF are long lasting and real: even now, I still keep in touch with my friends daily via Facebook, Snapchat and Instagram. I would give anything to get the chance to go back in time and relive my LIYSF experience.

- Age 18
- Gender Male
- Home country Jamaica

9. To me who already worked in science field, LIYSF let me know there are large amount people who are passionate about science. Now, I am doing my PhD research and I love to do it. I love travel and I plan to go abroad to do research after finishing it. I couldn't predict that much about my future, but I think I will definitely work in the field.

- Age 20
- Gender Male
- Home country China

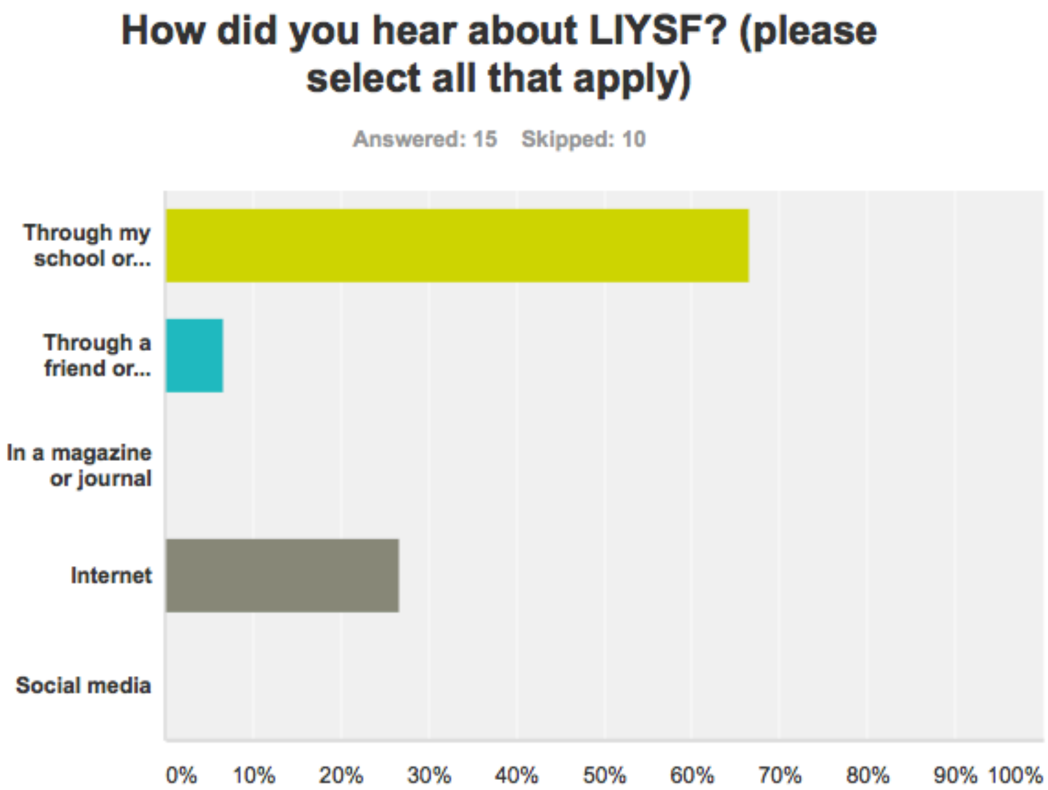
10. Amazing. I've grown so much as a person. Not only have I learned a lot, but I met some amazing people, who will stay with me forever. Of course I will not see all of them again, bur only meeting them and to hang out with them for 2 weeks was so special.

- Age 16
- Gender Female
- Home country Netherlands

11. I found the lectures very interesting and they confirmed my passion for studying science at a higher level

- Age 17
- Gender Female
- Home country England

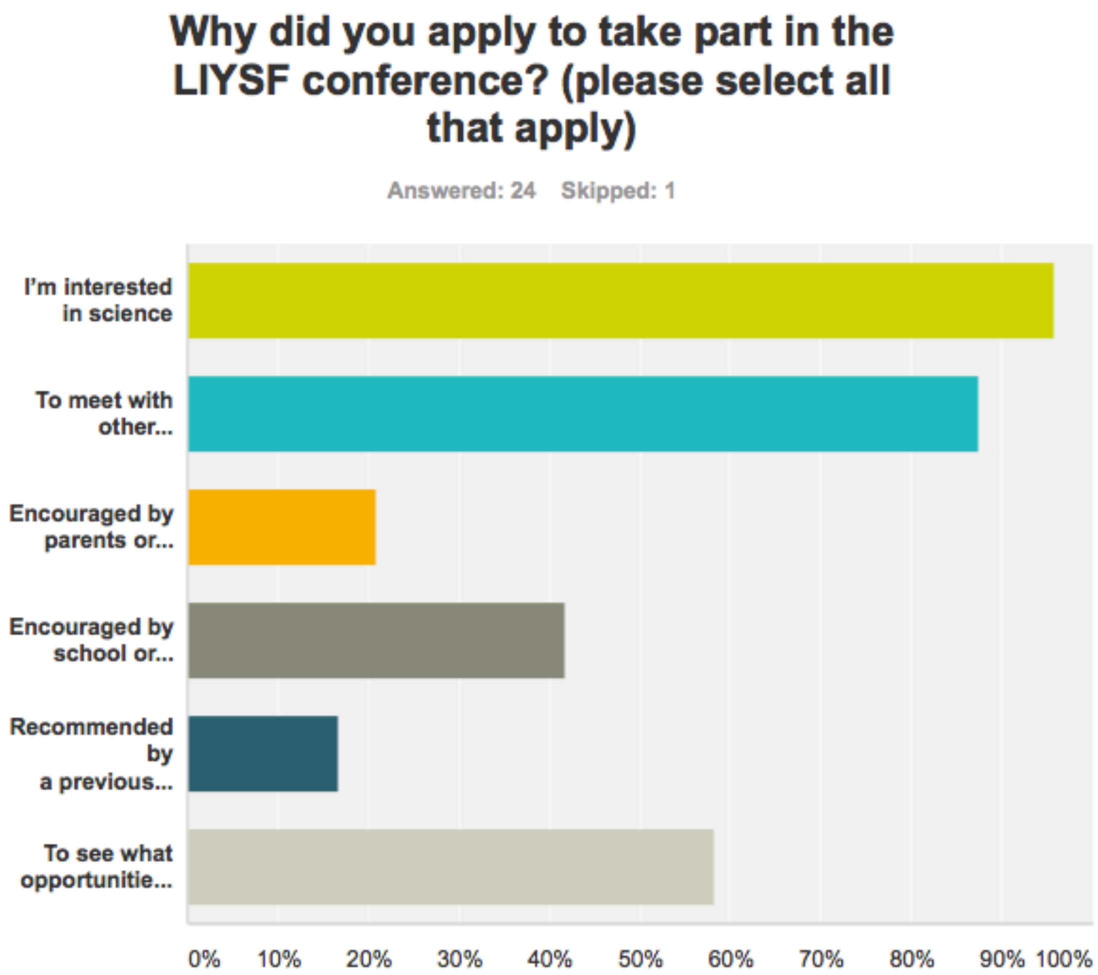
B.5 Survey 3



Answer Choices	Responses	
Through my school or college	66.67%	10
Through a friend or colleague	6.67%	1
In a magazine or journal	0.00%	0
Internet	26.67%	4
Social media	0.00%	0
Total Respondents: 15		

Comments (12)

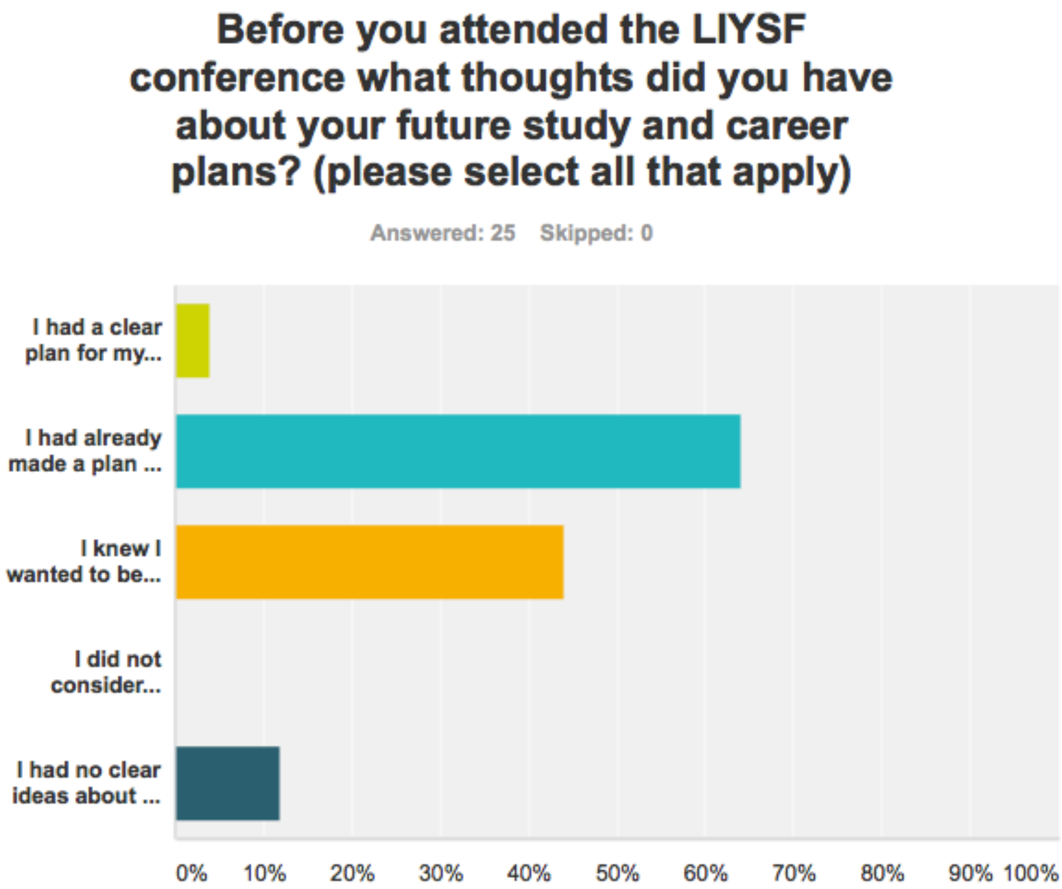
Figure B.21: Survey 3, Question 1



Answer Choices	Responses	
I'm interested in science	95.83%	23
To meet with other like-minded people	87.50%	21
Encouraged by parents or family members	20.83%	5
Encouraged by school or college teachers	41.67%	10
Recommended by a previous LIYSF participant	16.67%	4
To see what opportunities science can offer as a career	58.33%	14
Total Respondents: 24		

Comments (1)

Figure B.22: Survey 3, Question 2



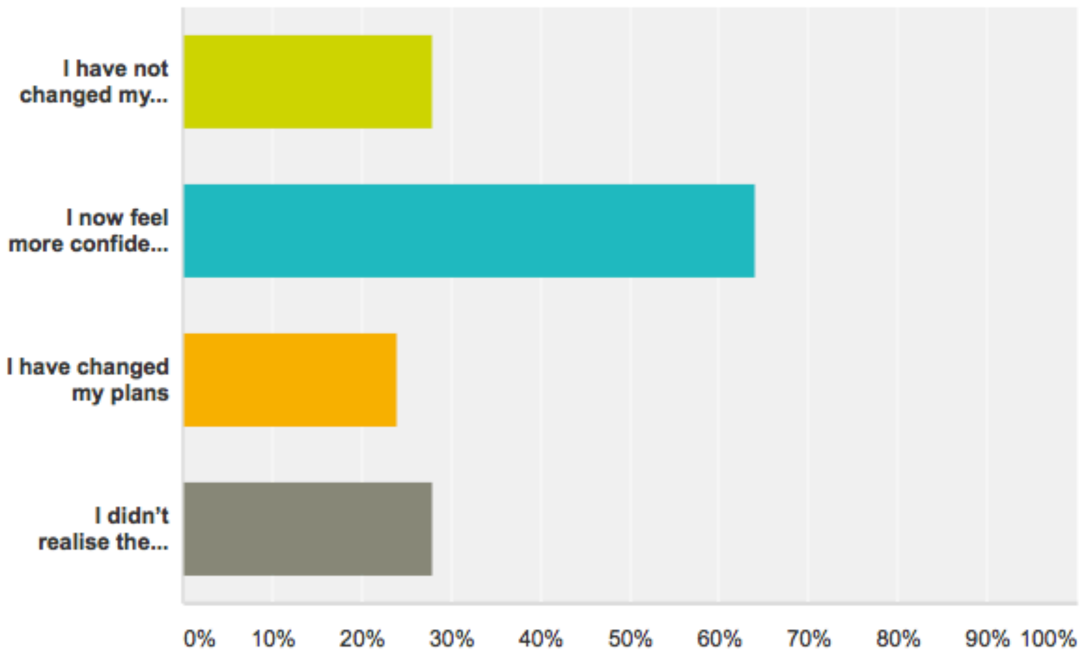
Answer Choices	Responses	
I had a clear plan for my future career that did not include science	4.00%	1
I had already made a plan to study and work in a science related field	64.00%	16
I knew I wanted to be involved professionally in science, but was not sure what specific subject area	44.00%	11
I did not consider science as a possible career choice	0.00%	0
I had no clear ideas about my future career plans	12.00%	3
Total Respondents: 25		

Comments (1)

Figure B.23: Survey 3, Question 3

How have your thoughts or plans been affected by participating in LIYSF? (please select all that apply)

Answered: 25 Skipped: 0



Answer Choices	Responses	
I have not changed my plans	28.00%	7
I now feel more confident about my chosen career direction	64.00%	16
I have changed my plans	24.00%	6
I didn't realise the wide range of options open to science graduates	28.00%	7
Total Respondents: 25		

Comments (3)

Figure B.24: Survey 3, Question 4

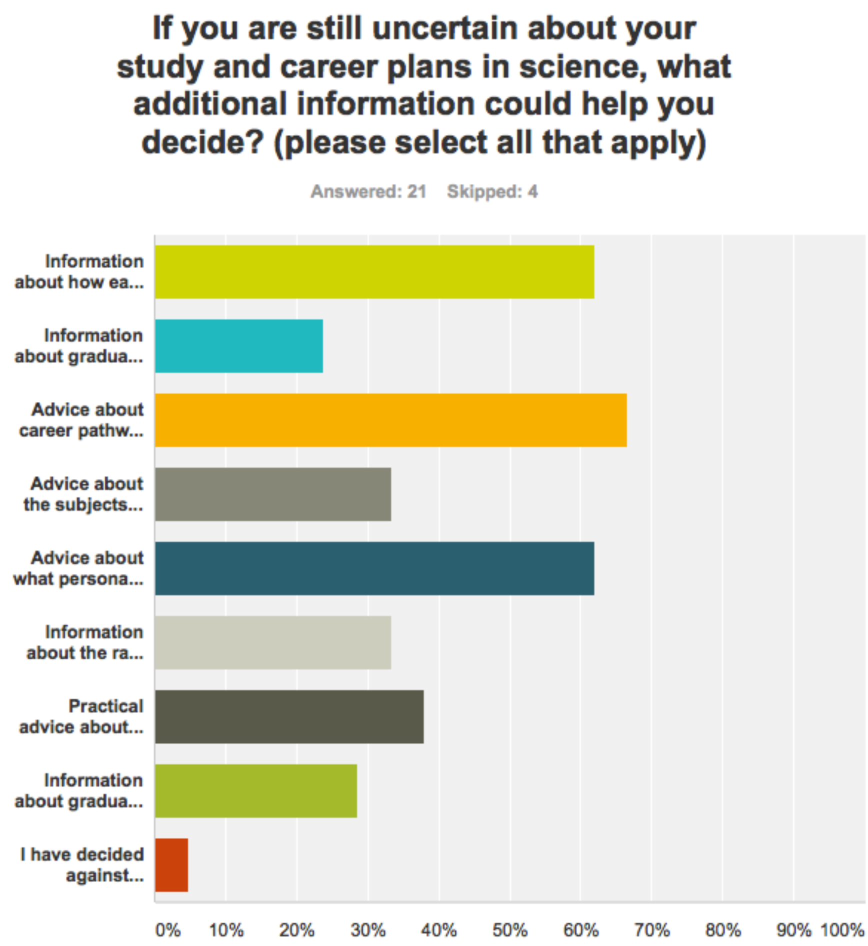


Figure B.25: Survey 3, Question 5

Answer Choices	Responses	
Information about how easy or difficult it might be to find employment in my chosen science field of study	61.90%	13
Information about graduate starting salaries across various science subjects	23.81%	5
Advice about career pathways from those already working in the field	66.67%	14
Advice about the subjects I need to study to reach my goals	33.33%	7
Advice about what personal qualities are needed to be successful in my studies and career	61.90%	13
Information about the range of options open to me at various stages in my studies,eg. Graduate, Masters degree and PhD	33.33%	7
Practical advice about studying in the UK (or home country) including fees, scholarships, funding, bursaries, accommodation etc.	38.10%	8
Information about graduate work prospects in the UK	28.57%	6
I have decided against studying science subjects	4.76%	1
Total Respondents: 21		

Comments (1)

Figure B.26: Survey 3, Question 5

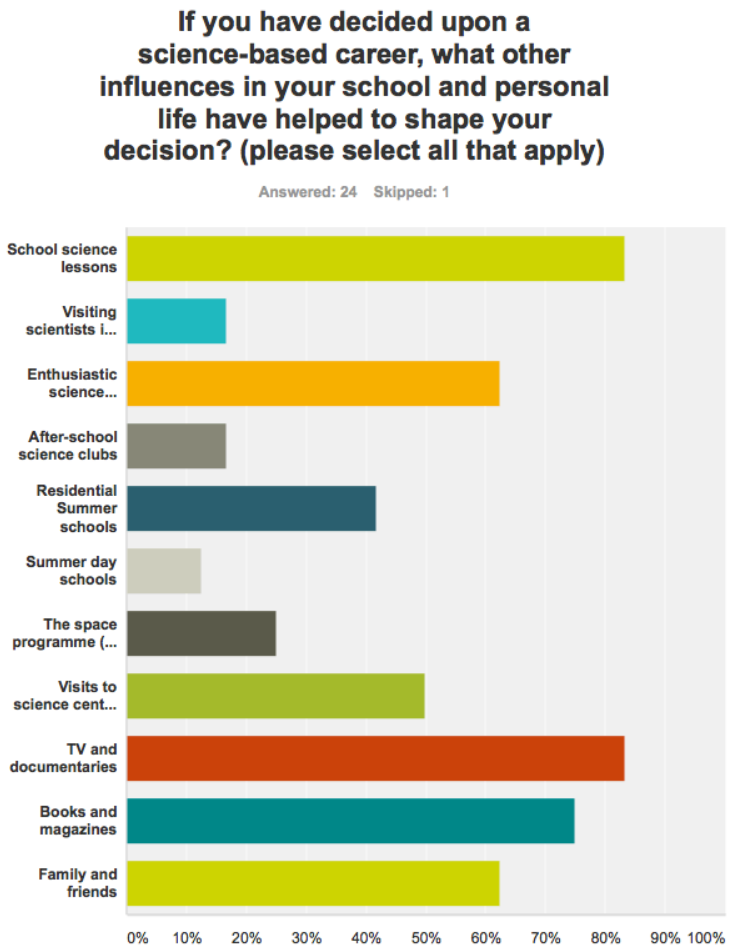
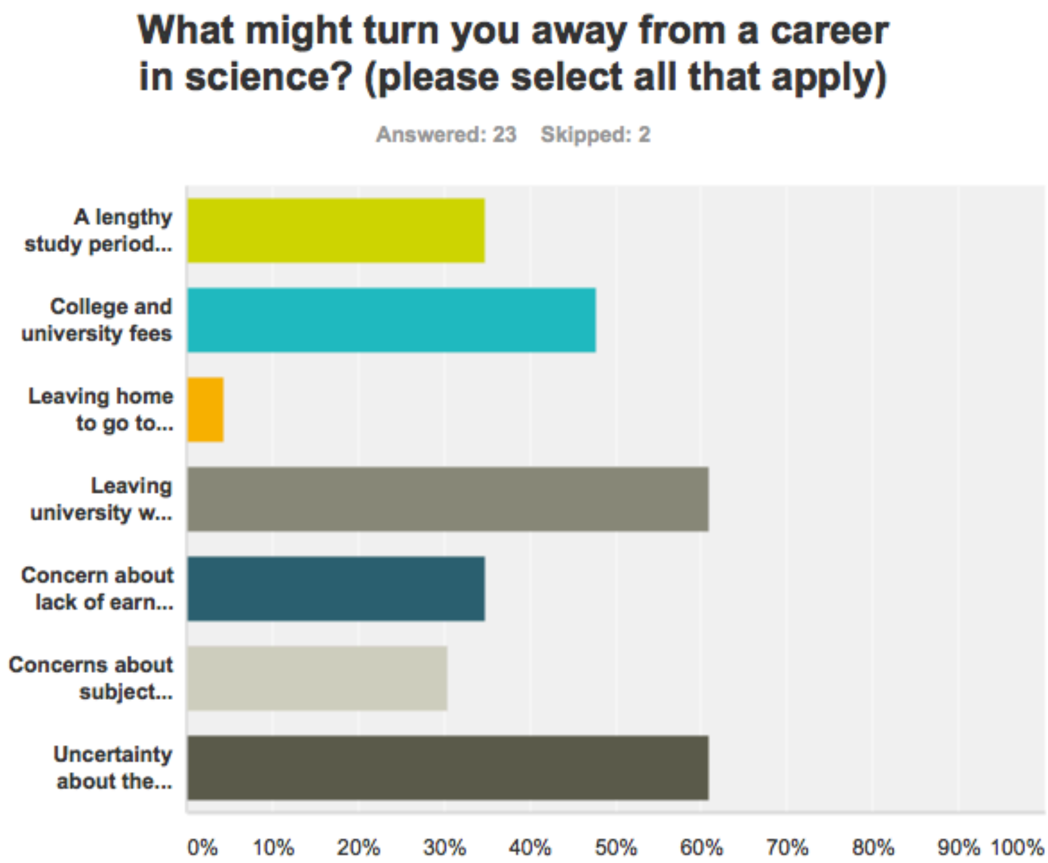


Figure B.27: Survey 3, Question 6

Answer Choices	Responses	
School science lessons	83.33%	20
Visiting scientists in the classroom	16.67%	4
Enthusiastic science teachers	62.50%	15
After-school science clubs	16.67%	4
Residential Summer schools	41.67%	10
Summer day schools	12.50%	3
The space programme (NASA or ESA)	25.00%	6
Visits to science centres and museums	50.00%	12
TV and documentaries	83.33%	20
Books and magazines	75.00%	18
Family and friends	62.50%	15
Total Respondents: 24		

Comments (1)

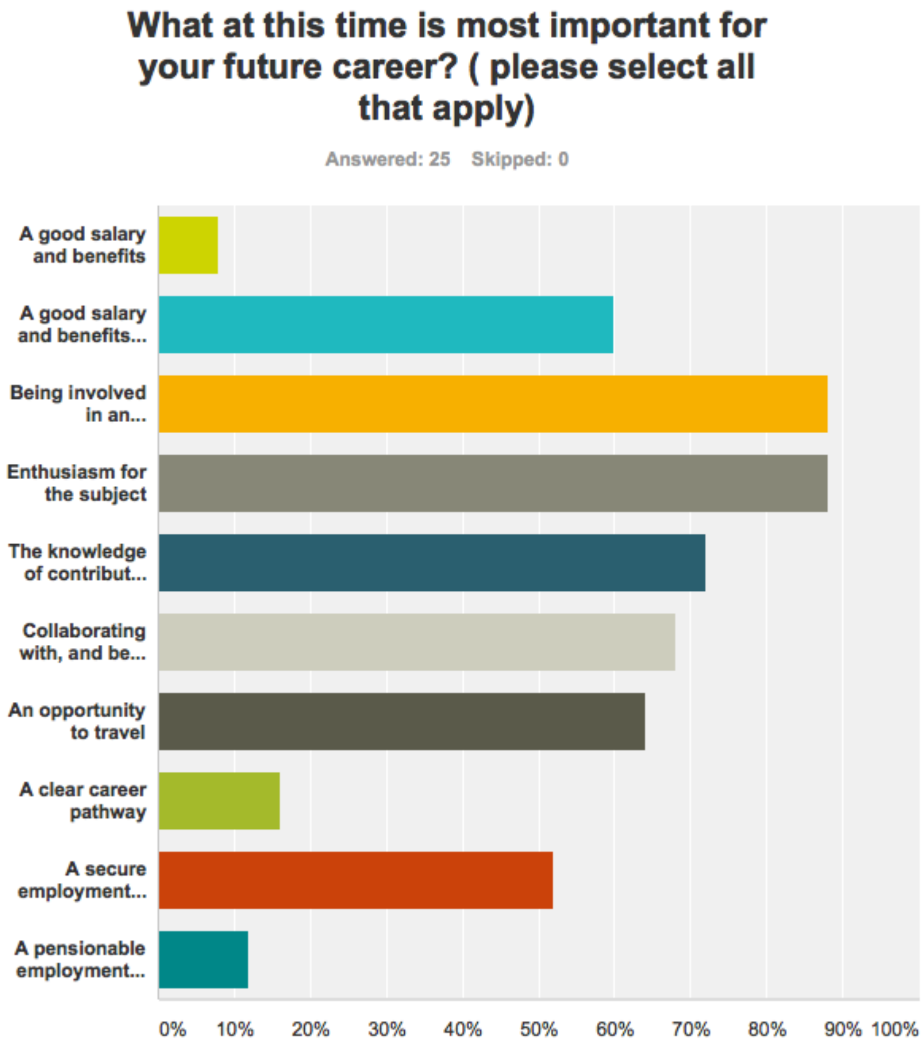
Figure B.28: Survey 3, Question 6



Answer Choices	Responses	
A lengthy study period needed for some subjects (beyond the first undergraduate degree)	34.78%	8
College and university fees	47.83%	11
Leaving home to go to university	4.35%	1
Leaving university with a large debt	60.87%	14
Concern about lack of earning potential while you study	34.78%	8
Concerns about subject difficulty and reaching the required academic standard	30.43%	7
Uncertainty about the supply and demand for skills in my preferred field	60.87%	14
Total Respondents: 23		

Comments (4)

Figure B.29: Survey 3, Question 7



Answer Choices	Responses	
A good salary and benefits	8.00%	2
A good salary and benefits are important but not enough in themselves	60.00%	15
Being involved in an interesting job	88.00%	22
Enthusiasm for the subject	88.00%	22
The knowledge of contributing to something worthwhile	72.00%	18
Collaborating with, and being in the company of other like-minded people	68.00%	17
An opportunity to travel	64.00%	16
A clear career pathway	16.00%	4
A secure employment position	52.00%	13
A pensionable employment position	12.00%	3
Total Respondents: 25		

Figure B.30: Survey 3, Question 8

B.6 Survey 3. Student comments on the LIYSF experience.

1. It was amazing, seemed to be quite a number of bio-chem students, making it hard for a physics minded student like myself to find others interested in physics. Lectures were good on a wide range of topics, my last specialist lecture forced me to pick a more environmental science over physics as there were no physics options.

- Age 17
- Gender Male
- Home country Australia

2. Amazing. The opportunity came at the right moment in time. I am starting university tomorrow and before the forum I was nervous and unsure about my decision to study biochemistry. There I got in touch with amazing biochemists and I realised I made the right choice. Sharing this journey with like-minded people from all over the world changed my life. I owe a lot to those two weeks. London became my second home and LIYSF is my new family.

- Age 19
- Gender Female
- Home country Slovenia

3. It was an amazing experience where I got to meet new people from different countries. I discussed scientific ideas but also socialized with many people and made new friends. I would recommend LIYSF to anyone interested in science-related subjects and careers but also to people who are not doing any science subjects at school because during the two weeks there it was not only about science, it was about international collaboration and communication to achieve a better world, something that anyone can contribute whether they love science or not.

- Age 18
- Gender Male
- Home country Cyprus

4. A brilliant chance to meet and make friends with like minded people and be inspired by what they're doing and feel confident that no matter where in science I go there will be

people there who are of similar interests. Meet brilliant scientists and see amazing places to be inspired about what a career in science can allow you to understand, explore, be a part of, and achieve with your collaborators.

- Age 16
- Gender Male
- Home country Australia

5. I found LIYSF to be an incredibly insightful experience such that I was able to meet so many like minded people and gain a deeper understanding of science on a global scale. It truly opened my eyes to the importance of international collaboration and how there are so many career opportunities within science.

- Age 17
- Gender Female
- Home country Australia

6. A specialist lecture on science communication would have been helpful for me in addition to the lecture by Huw James.

- Age 16
- Gender Female
- Home country Australia

7. It was truly amazing to meet so many noble scientists and listen to their unique and dynamic lectures. LIYSF introduced me to so many different fields of science and got me interested in some areas which I've never considered pursuing before. Through the programme, I have also made many new friends from all around the world, who are equally interested in science and I'm sure that these friendships will last a lifetime.

- Age 16
- Gender Female
- Home country Singapore

8. Currently I have been accepted early into a University here in Australia and am planning on studying a Bachelor of Arts in Architecture. However - Should I not enjoy Architecture as I hope I will, I am still open to transferring into a Bachelor of Science.

- Age 18
- Gender Male
- Home country Australia

9. Best two weeks of my life. Seriously. The opportunities were amazing but the best part was meeting all the other students from around the world. Just so incredibly eye-opening and interesting. Made some really great friendships that will hopefully last for a long, long time.

- Age 18
- Gender Male
- Home country Australia

10. I feel though I would have liked subjects like Civil and Environmental Engineering/Science (not only Renewable Energy) to be also encorporated somewhere in the program with a visit or lecture. But with the program in 2015 I still felt it all worked together and was enough for me to I learn more than I realised in every field of science. I cant wait to study science and engineering at university and help make a difference.

- Age 18
- Gender Female
- Home country Australia

11. I think I'm unsure about taking a science-related career because I'm unsure whether I like science. Of course, I don't dislike science - I like it more than almost any other subjects. But sometimes I feel that I want to become a scientist because of money or recognition, not just science itself. I think I'll naturally find my way as I live on. If I really did like science, then I'll naturally follow that path.

- Age 17
- Gender Female
- Home country South Korea

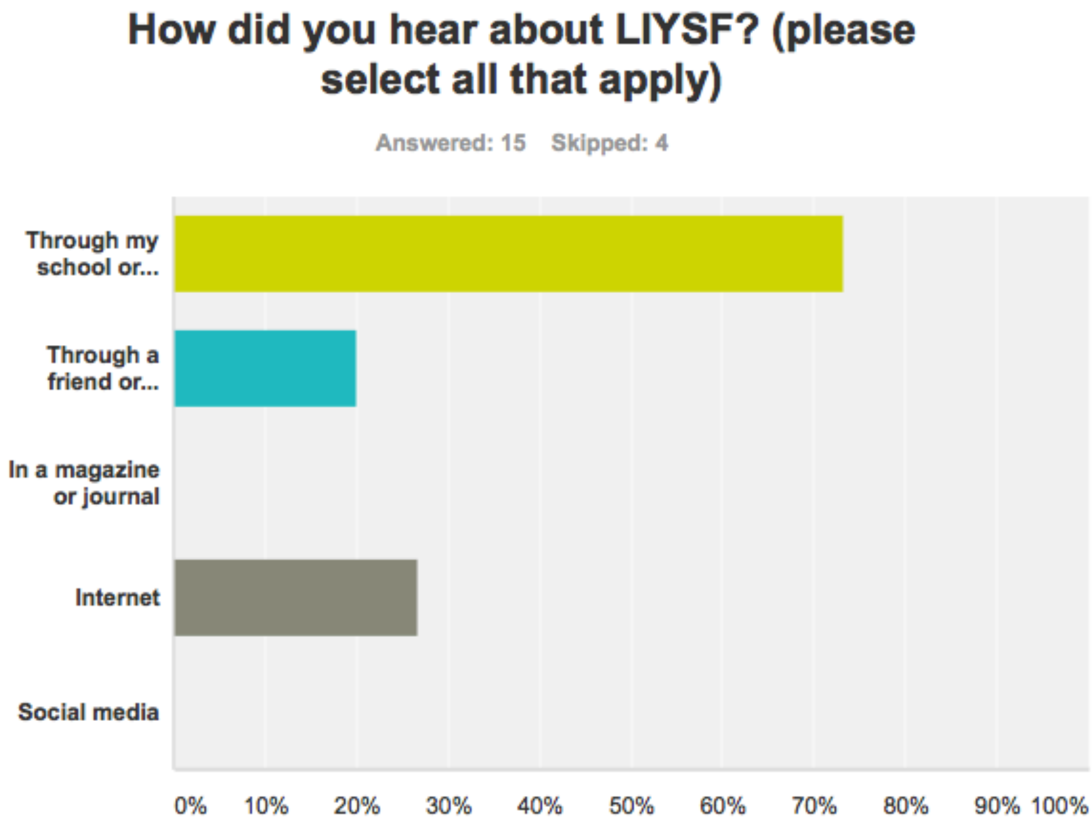
12. It was an amazing twee weeks full of interesting science and having the best fun in the world with people like me

- Age 17
- Gender Male
- Home country the Netherlands

13. The LIYSF experience was eye opening and outstanding. To realise that there are hundreds, even thousands of other people my age that are as interested in science as I am was profound. In addition to the amazing academic visits, the social program was comprehensive and covered various fun activities throughout the forum. Something that the Australian version of the LIYSF does is a rest day in the middle of the forum, where students get allocated a host in Canberra and can catch up on sleep for an entire day. Throughout the late social gatherings and conversations I had during the LIYSF, I found myself only being able to get about 3-6 hours of sleep each night. I know that there are logistical issues associated with arranging a rest day in London rather than Canberra, but it is still a great idea for the large number of students who are already very tired by the halfway point of the forum.

- Age 17
- Gender Male
- Home country Australia

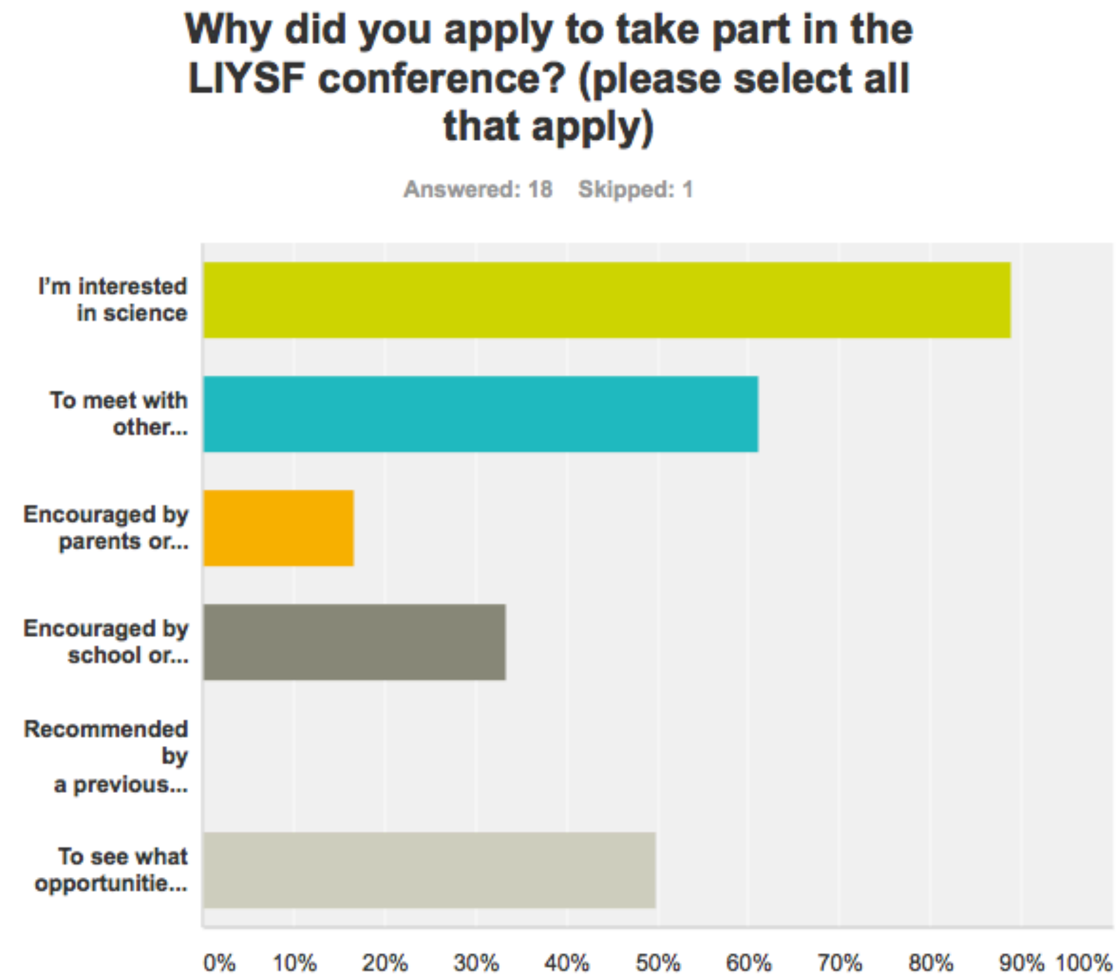
B.7 Survey 4



Answer Choices	Responses	
Through my school or college	**73.33%**	11
Through a friend or colleague	**20.00%**	3
In a magazine or journal	**0.00%**	0
Internet	**26.67%**	4
Social media	**0.00%**	0
Total Respondents: 15		

Comments (4)

Figure B.31: Survey 4, Question 1



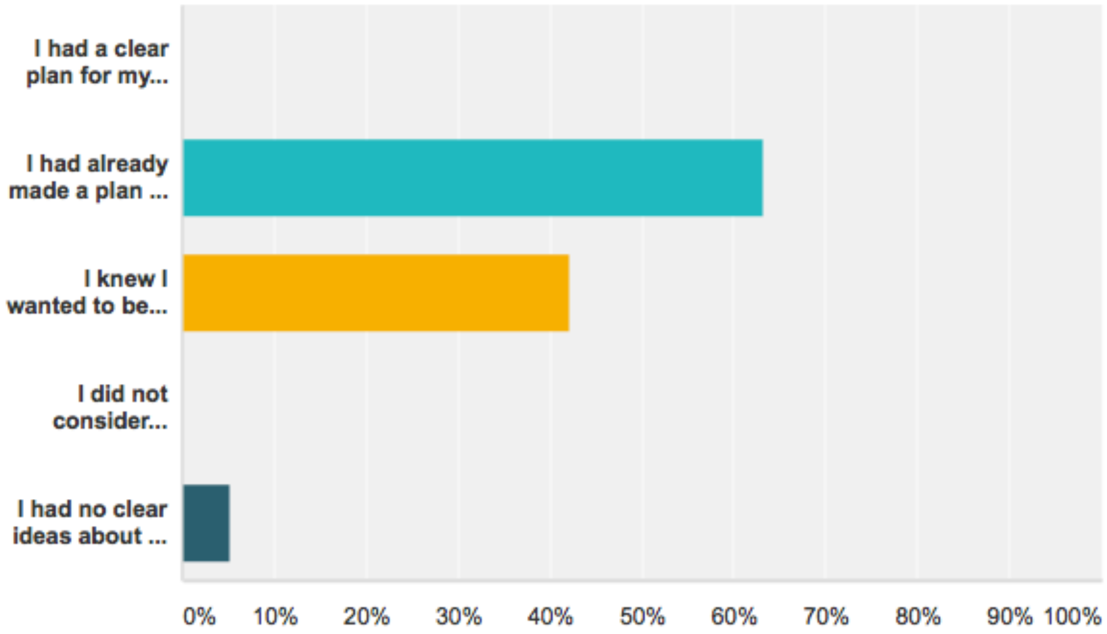
Answer Choices	Responses	
I'm interested in science	88.89%	16
To meet with other like-minded people	61.11%	11
Encouraged by parents or family members	16.67%	3
Encouraged by school or college teachers	33.33%	6
Recommended by a previous LIYSF participant	0.00%	0
To see what opportunities science can offer as a career	50.00%	9
Total Respondents: 18		

Comments (3)

Figure B.32: Survey 4, Question 2

Before you attended the LIYSF conference what thoughts did you have about your future study and career plans? (please select all that apply)

Answered: 19 Skipped: 0



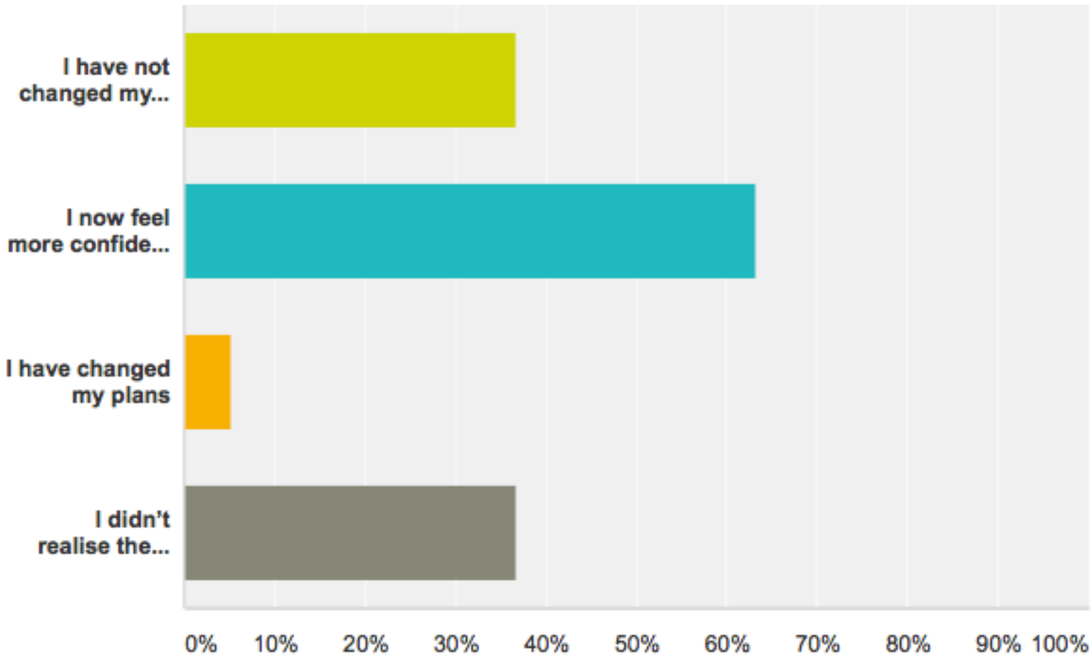
Answer Choices	Responses	
I had a clear plan for my future career that did not include science	0.00%	0
I had already made a plan to study and work in a science related field	63.16%	12
I knew I wanted to be involved professionally in science, but was not sure what specific subject area	42.11%	8
I did not consider science as a possible career choice	0.00%	0
I had no clear ideas about my future career plans	5.26%	1
Total Respondents: 19		

Comments (0)

Figure B.33: Survey 4, Question 3

How have your thoughts or plans been affected by participating in LIYSF? (please select all that apply)

Answered: 19 Skipped: 0



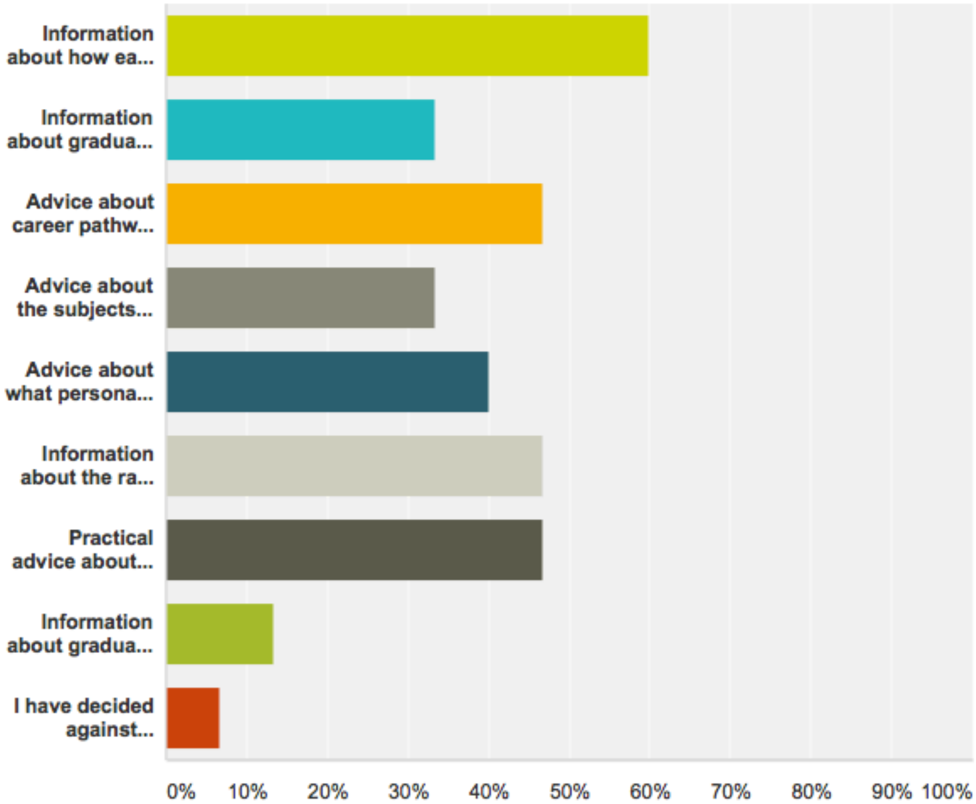
Answer Choices	Responses	
I have not changed my plans	36.84%	7
I now feel more confident about my chosen career direction	63.16%	12
I have changed my plans	5.26%	1
I didn't realise the wide range of options open to science graduates	36.84%	7
Total Respondents: 19		

Comments (1)

Figure B.34: Survey 4, Question 4

If you are still uncertain about your study and career plans in science, what additional information could help you decide? (please select all that apply)

Answered: 15 Skipped: 4



Answer Choices	Responses	
Information about how easy or difficult it might be to find employment in my chosen science field of study	60.00%	9
Information about graduate starting salaries across various science subjects	33.33%	5
Advice about career pathways from those already working in the field	46.67%	7
Advice about the subjects I need to study to reach my goals	33.33%	5
Advice about what personal qualities are needed to be successful in my studies and career	40.00%	6
Information about the range of options open to me at various stages in my studies,eg. Graduate, Masters degree and PhD	46.67%	7
Practical advice about studying in the UK (or home country) including fees, scholarships, funding, bursaries, accommodation etc.	46.67%	7
Information about graduate work prospects in the UK	13.33%	2
I have decided against studying science subjects	6.67%	1
Total Respondents: 15		

Figure B.35: Survey 4, Question 5

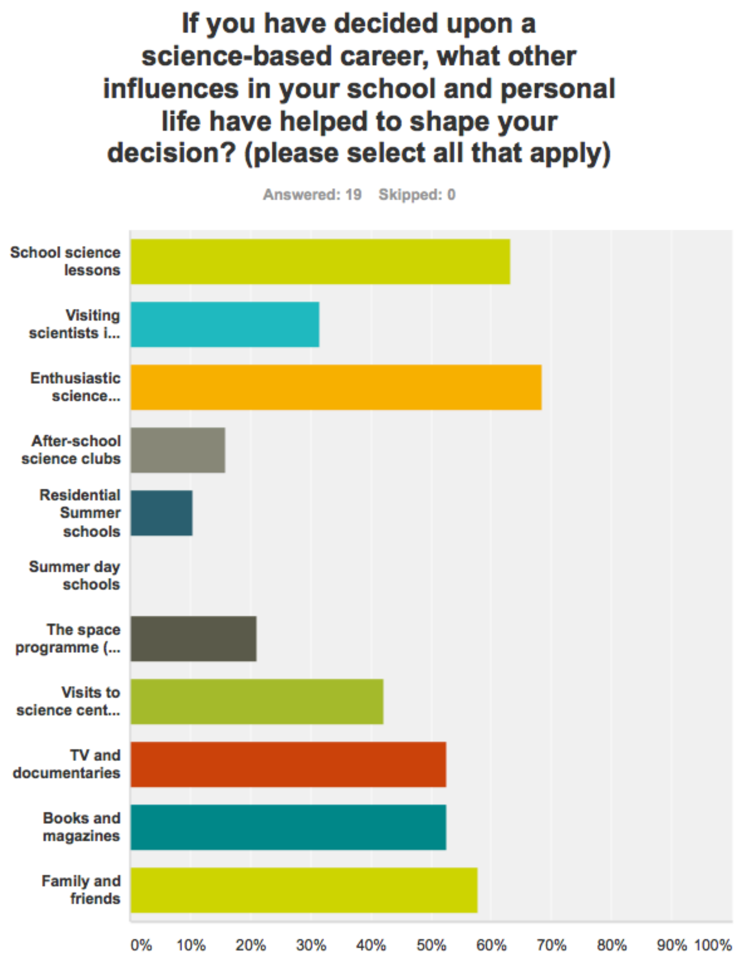
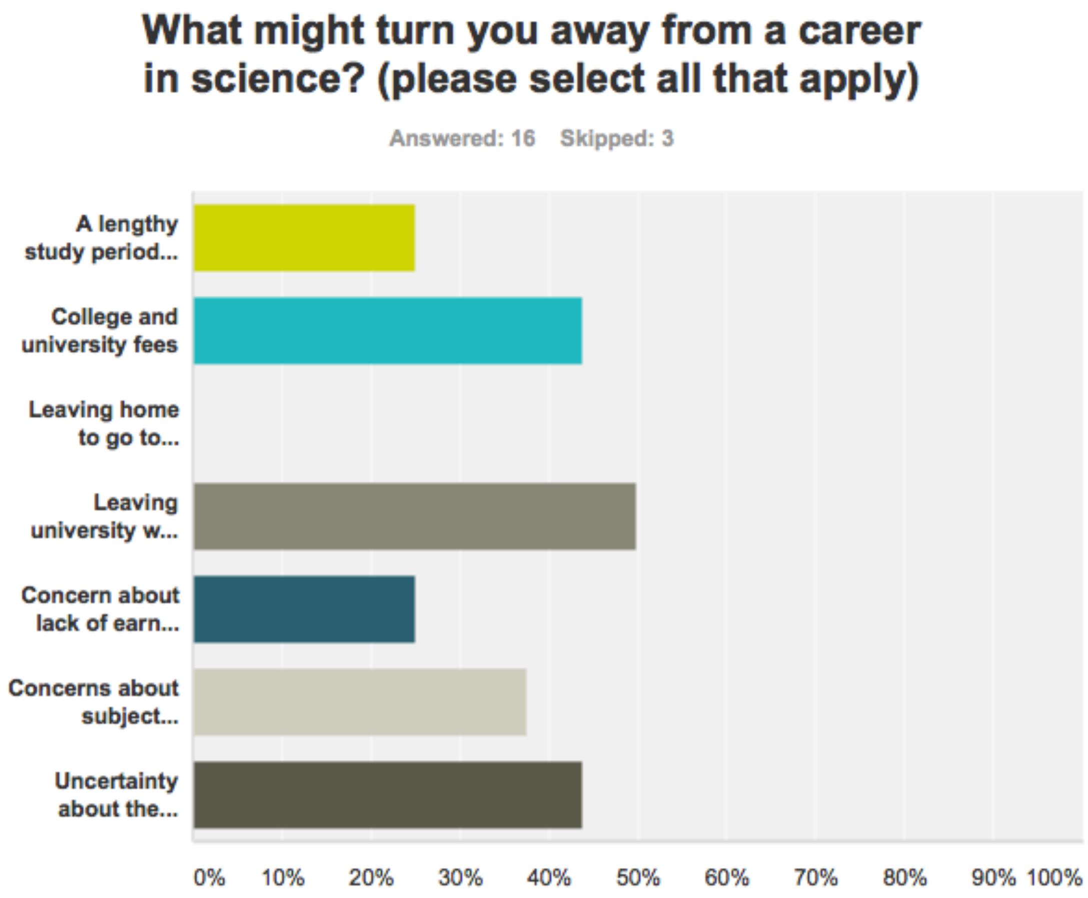


Figure B.36: Survey 4, Question 6

Answer Choices	Responses	
School science lessons	63.16%	12
Visiting scientists in the classroom	31.58%	6
Enthusiastic science teachers	68.42%	13
After-school science clubs	15.79%	3
Residential Summer schools	10.53%	2
Summer day schools	0.00%	0
The space programme (NASA or ESA)	21.05%	4
Visits to science centres and museums	42.11%	8
TV and documentaries	52.63%	10
Books and magazines	52.63%	10
Family and friends	57.89%	11
Total Respondents: 19		

Comments (3)

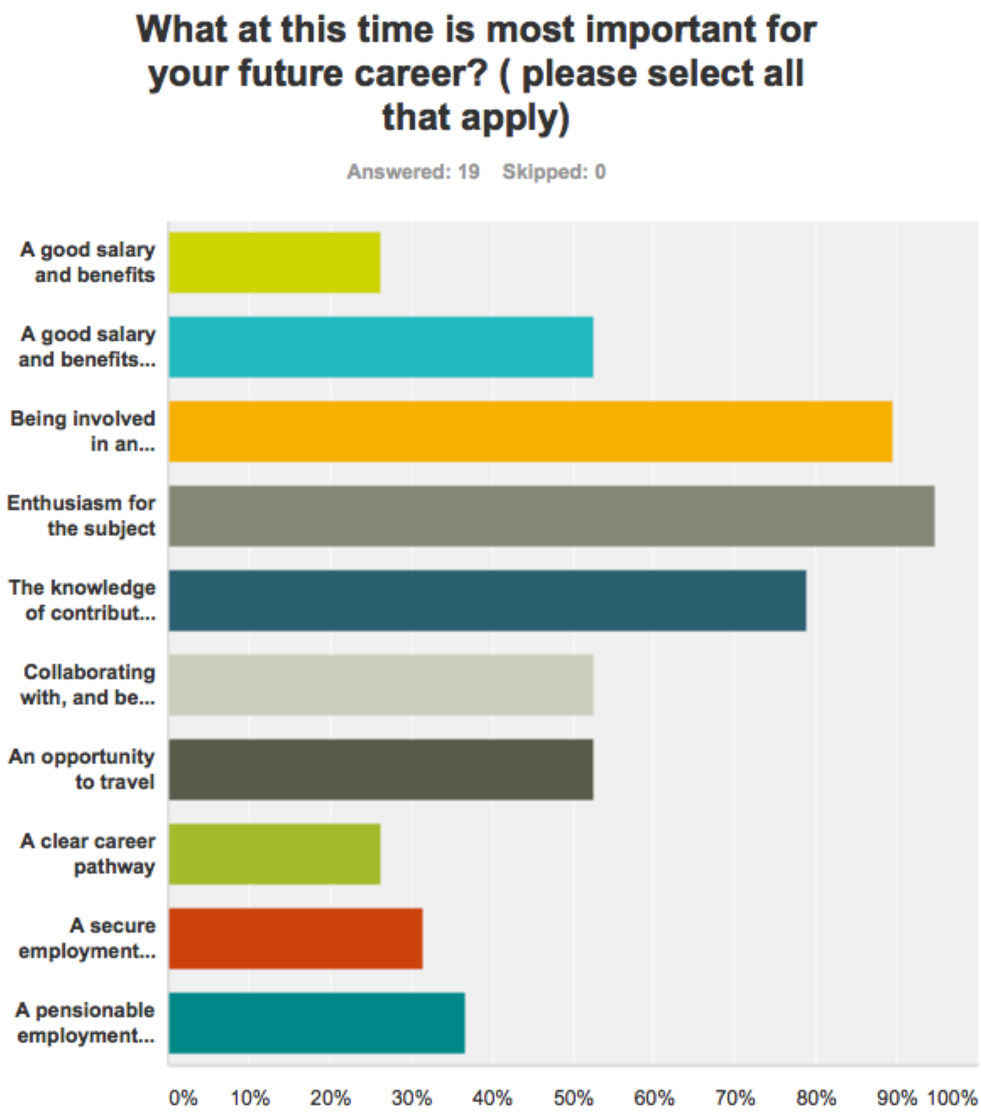
Figure B.37: Survey 4, Question 6



Answer Choices	Responses	
A lengthy study period needed for some subjects (beyond the first undergraduate degree)	25.00%	4
College and university fees	43.75%	7
Leaving home to go to university	0.00%	0
Leaving university with a large debt	50.00%	8
Concern about lack of earning potential while you study	25.00%	4
Concerns about subject difficulty and reaching the required academic standard	37.50%	6
Uncertainty about the supply and demand for skills in my preferred field	43.75%	7
Total Respondents: 16		

Comments (2)

Figure B.38: Survey 4, Question 7



Answer Choices	Responses	
A good salary and benefits	26.32%	5
A good salary and benefits are important but not enough in themselves	52.63%	10
Being involved in an interesting job	89.47%	17
Enthusiasm for the subject	94.74%	18
The knowledge of contributing to something worthwhile	78.95%	15
Collaborating with, and being in the company of other like-minded people	52.63%	10
An opportunity to travel	52.63%	10
A clear career pathway	26.32%	5
A secure employment position	31.58%	6
A pensionable employment position	36.84%	7
Total Respondents: 19		

Figure B.39: Survey 4, Question 8

B.8 Survey 4. Student comments on the LIYSF experience.

1. I felt completely at home amongst so many like-minded young scientists. It is great to see how much today's youth is interested in science and willing to study science in order to achieve amazing and ambitious goals. The lectures were very engaging and interesting, but I personally would have included more areas of science (this year I felt the programme was very Biology-based). The LIYSF inspired and motivated me to pursue an international university degree - perhaps not now, but definitely in future. I intend to study Materials Engineering and work in research or teaching. I truly believe the Forum was an unique addition to my curriculum and it surely will help me in my future scientific endeavours.

- Age 16
- Gender Female
- Home country Brazil

2. Fun, inspiring and smart... Science is simply common sense at its best.

- Age 17
- Gender Female
- Home country India

3. I would like to see more computer science related lectures

- Age 19
- Gender Male
- Home country Mexico

4. I knew there were amazing things in science, but I didn't know there were so many of those.

- Age 17
- Gender Male
- Home country Germany

5. LIYSF had been a fantastic and enriching experience from the social point of view, but also thanks to the wide range of lectures we had the privilege to attend. For me it has

been a life changing experience since it confirmed my interest on engineering and allowed me to chose the specific field I wanted to study. In fact, even if I was previously thinking of biomedical engineering, I have finally changed my mind for mechanical engineering (possibly with management). I am sure that without the opportunity of visiting scientific departments, I would have taken the wrong decision.

- Age 16
- Gender Female
- Home country Italy

6. I would highly recommend it to anyone who is even vaguely interested in science. The only thing I would've added is to make the forum longer.

- Age 18
- Gender Male
- Home country South Africa

7. LIYSF was amazing and life changing. It blew my mind as to how many amazing people are out there and how much potential we have for the future.

- Age 17
- Gender Female
- Home country New Zealand

8. The opportunity to meet people who are just as enthusiastic about science as I am. Also the explore new areas of science and meet experts in every field and hear their story.

- Age 16
- Gender Female
- Home country Australia

9. I really enjoyed it. It was great so great to meet so may people form all over the world.

- Age 19
- Gender Female
- Home country Switzerland

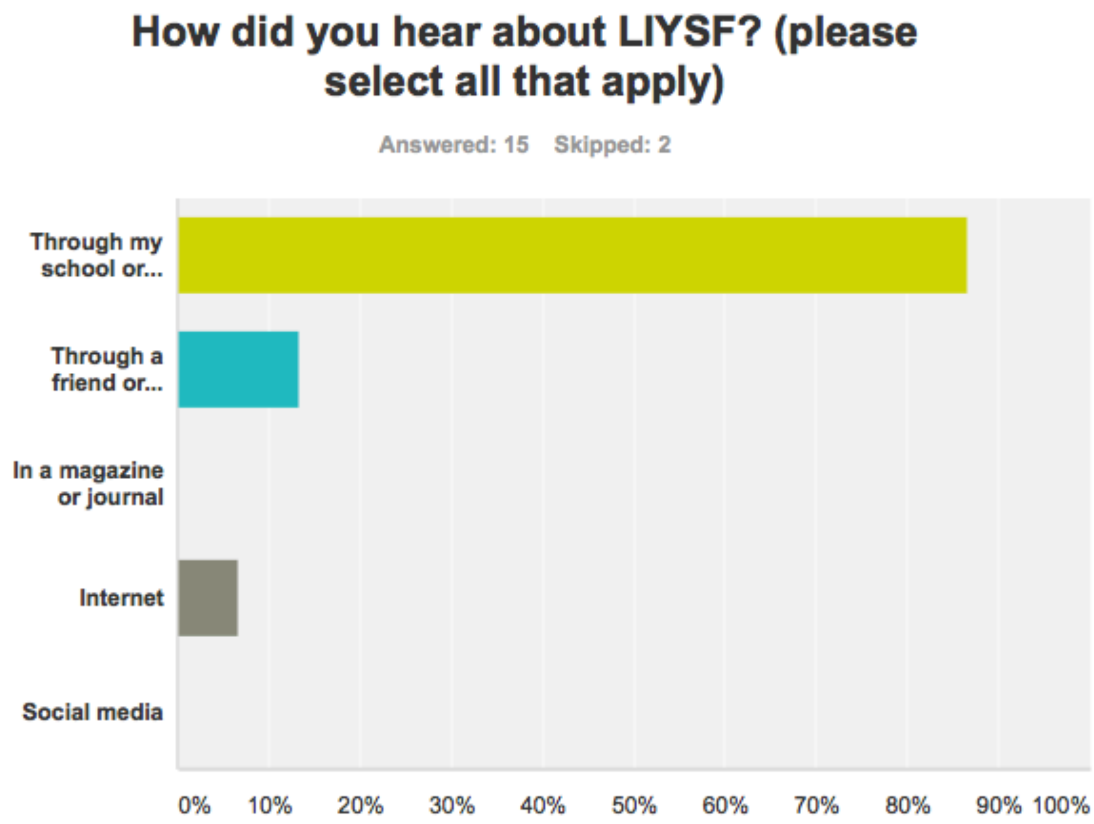
10. t was an amazing experience. I finally fit in. My love for science has grown. I've met incredible people and I learned so much. It is something that I would, for sure, do again. I want to show other people that science can change our lives, for the better. I ,for example, want to be a gynecologist and I want to help people in a different way from what researchers are helping. I want to give people happiness. And nothing would make me more happy.

- Age 17
- Gender Female
- Home country Portugal

11. I thoroughly enjoyed my experience at LIYSF. It was an incredible and life changing opportunity and it was a great honour to be able to attend. It has allowed me to gain a much stronger understanding of future career and research options that I wouldn't have otherwise had the chance to experience firsthand. It has opened my eyes to the cutting edge science that is happening around the world and as a result of this it has ignited in me an even stronger passion for science and a drive for success. The opportunity inspired me to want to make a difference through science and mathematics and so it is now because of this opportunity that I am now planning on studying a Bachelor of Science next year, with a view to integrating my interests in mathematics and biology. Now with a clear idea of exactly what cutting edge and interesting careers could follow this.

- Age 18
- Gender Female
- Home country New Zealand

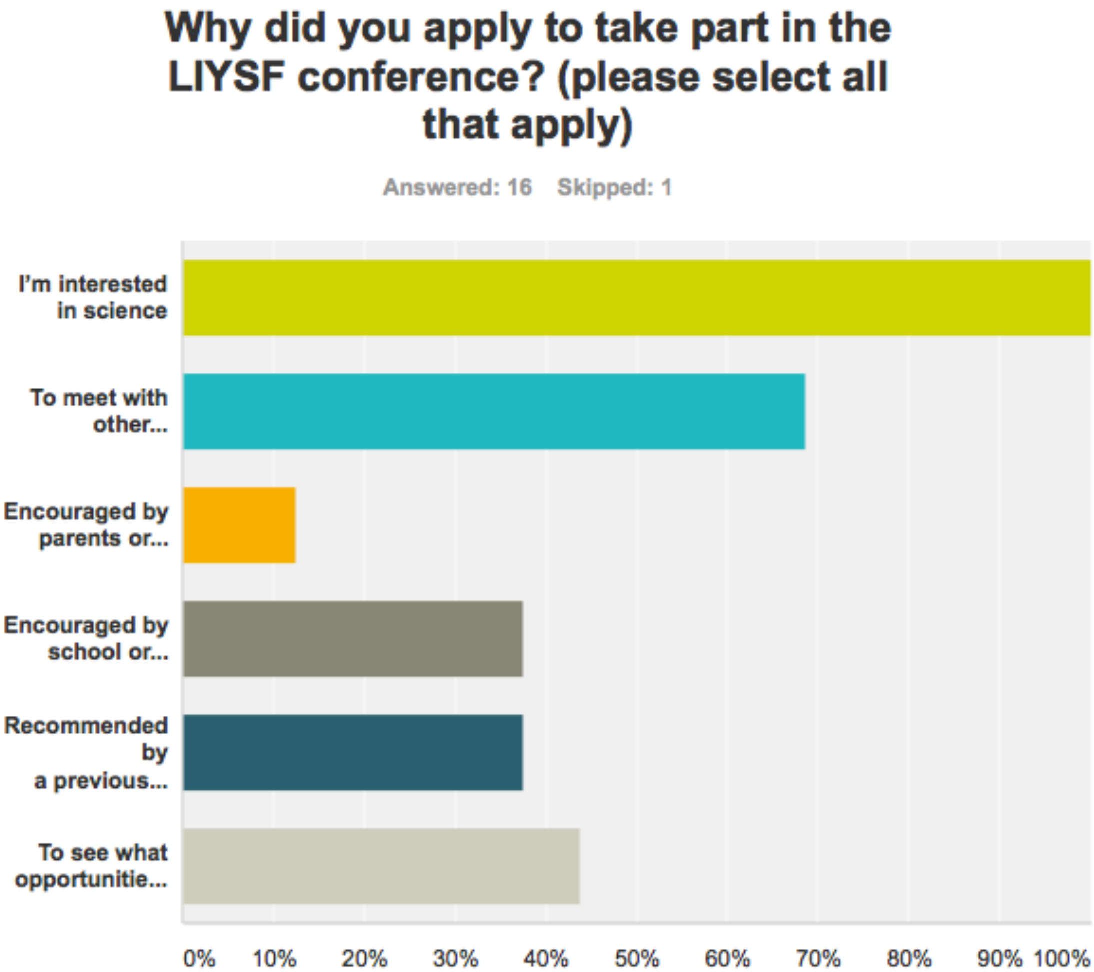
B.9 Survey 5



Answer Choices	Responses	
Through my school or college	86.67%	13
Through a friend or colleague	13.33%	2
In a magazine or journal	0.00%	0
Internet	6.67%	1
Social media	0.00%	0
Total Respondents: 15		

Comments (3)

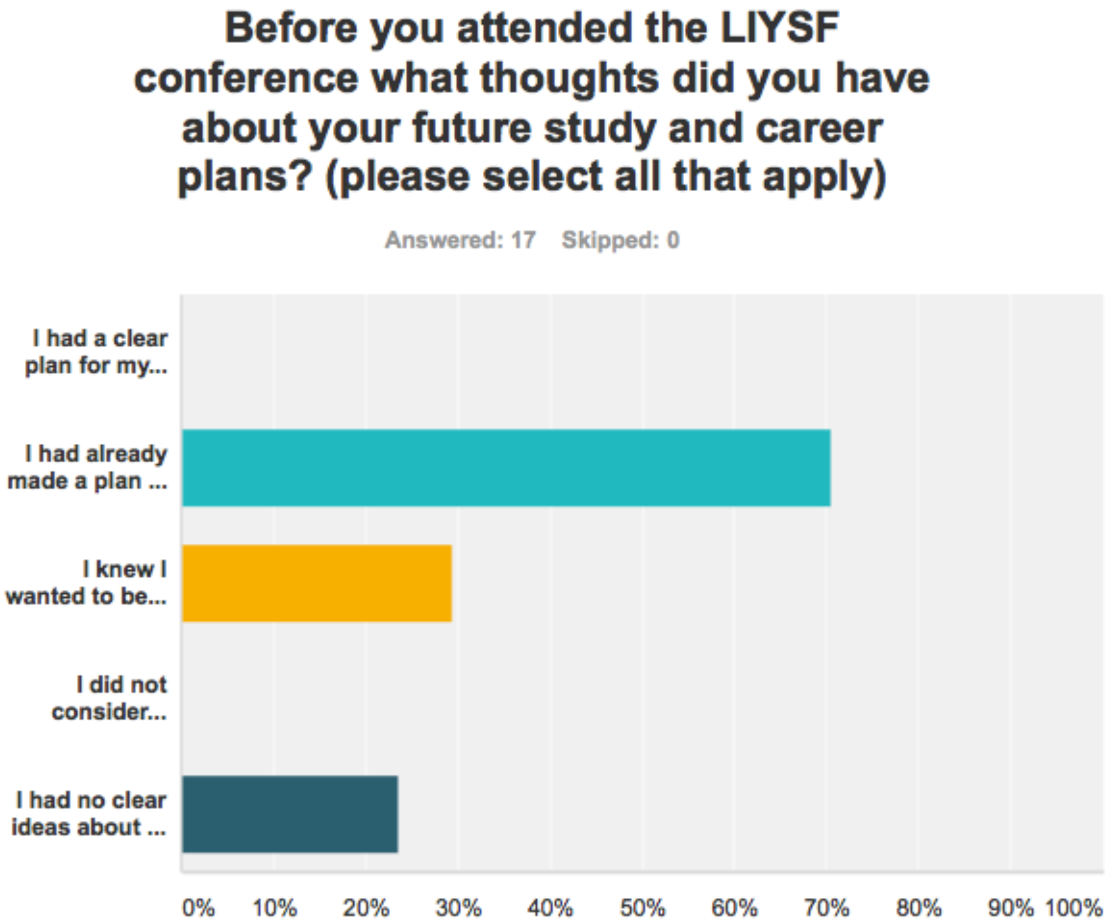
Figure B.40: Survey 5, Question 1



Answer Choices	Responses	
I'm interested in science	100.00%	16
To meet with other like-minded people	68.75%	11
Encouraged by parents or family members	12.50%	2
Encouraged by school or college teachers	37.50%	6
Recommended by a previous LIYSF participant	37.50%	6
To see what opportunities science can offer as a career	43.75%	7
Total Respondents: 16		

Comments (2)

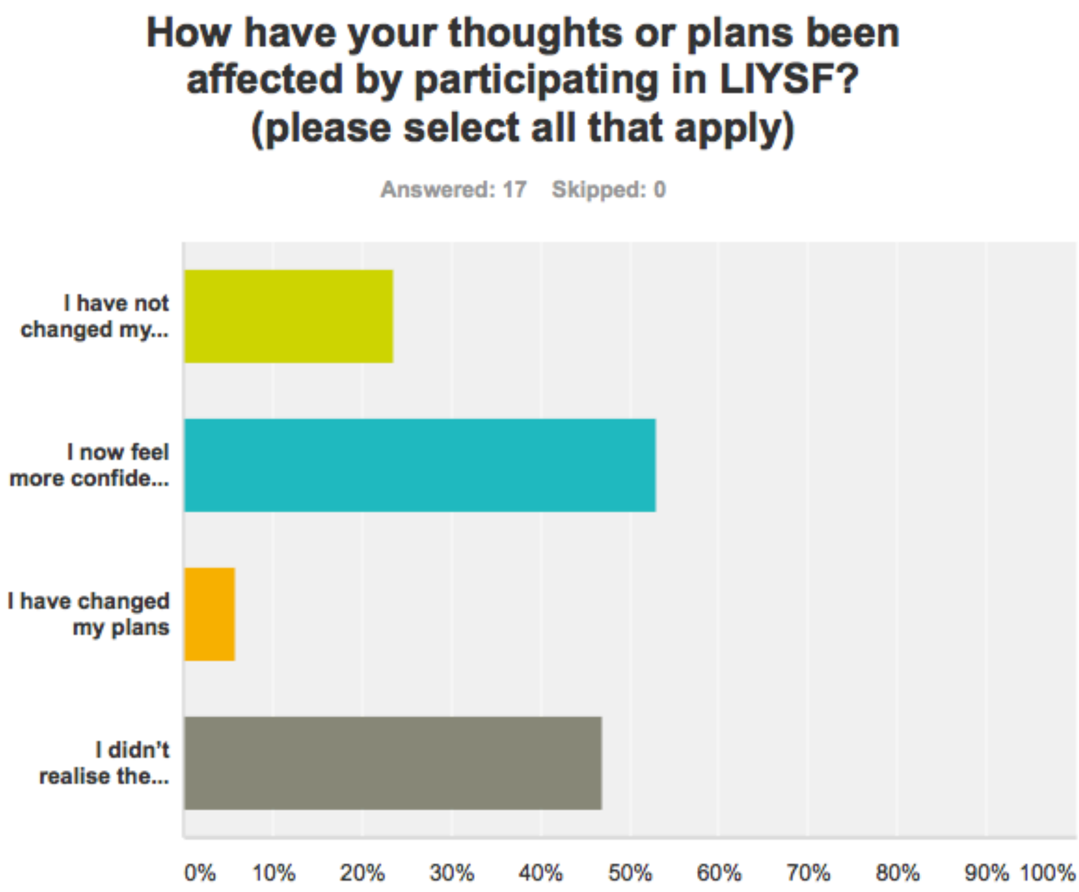
Figure B.41: Survey 5, Question 2



Answer Choices	Responses	
I had a clear plan for my future career that did not include science	0.00%	0
I had already made a plan to study and work in a science related field	70.59%	12
I knew I wanted to be involved professionally in science, but was not sure what specific subject area	29.41%	5
I did not consider science as a possible career choice	0.00%	0
I had no clear ideas about my future career plans	23.53%	4
Total Respondents: 17		

Comments (0)

Figure B.42: Survey 5, Question 3



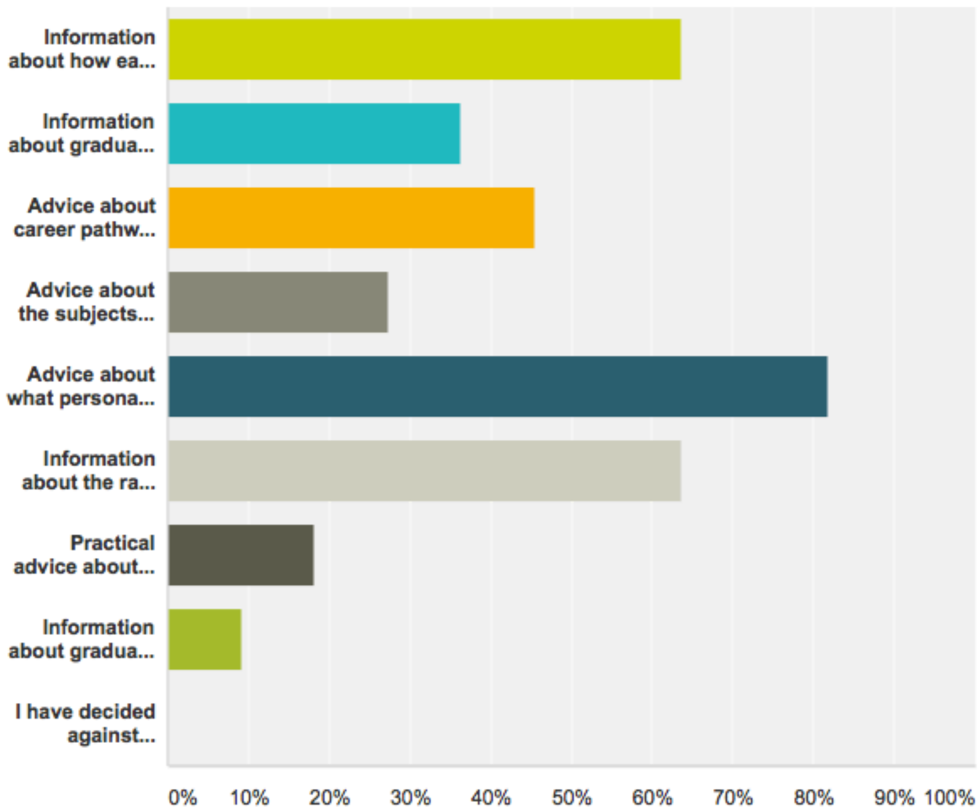
Answer Choices	Responses	
I have not changed my plans	23.53%	4
I now feel more confident about my chosen career direction	52.94%	9
I have changed my plans	5.88%	1
I didn't realise the wide range of options open to science graduates	47.06%	8
Total Respondents: 17		

Comments (0)

Figure B.43: Survey 5, Question 4

If you are still uncertain about your study and career plans in science, what additional information could help you decide? (please select all that apply)

Answered: 11 Skipped: 6



Answer Choices	Responses	
Information about how easy or difficult it might be to find employment in my chosen science field of study	63.64%	7
Information about graduate starting salaries across various science subjects	36.36%	4
Advice about career pathways from those already working in the field	45.45%	5
Advice about the subjects I need to study to reach my goals	27.27%	3
Advice about what personal qualities are needed to be successful in my studies and career	81.82%	9
Information about the range of options open to me at various stages in my studies,eg. Graduate, Masters degree and PhD	63.64%	7
Practical advice about studying in the UK (or home country) including fees, scholarships, funding, bursaries, accommodation etc.	18.18%	2
Information about graduate work prospects in the UK	9.09%	1
I have decided against studying science subjects	0.00%	0
Total Respondents: 11		

Figure B.44: Survey 5, Question 5

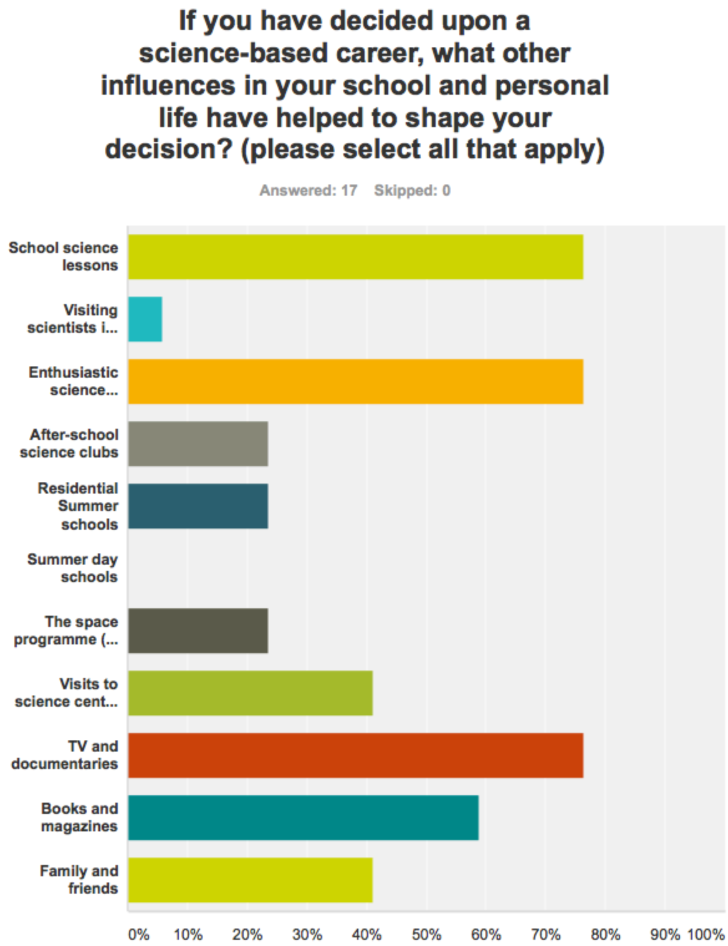
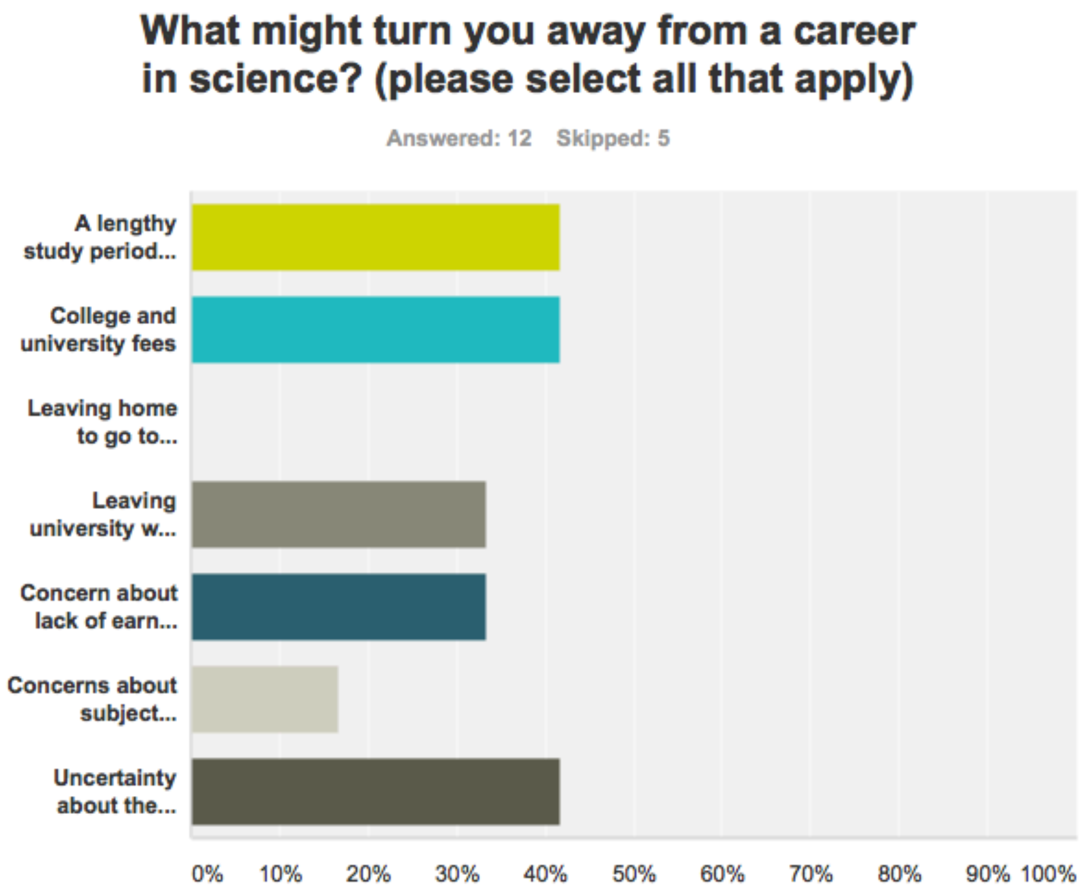


Figure B.45: Survey 5, Question 6

Answer Choices	Responses	
School science lessons	76.47%	13
Visiting scientists in the classroom	5.88%	1
Enthusiastic science teachers	76.47%	13
After-school science clubs	23.53%	4
Residential Summer schools	23.53%	4
Summer day schools	0.00%	0
The space programme (NASA or ESA)	23.53%	4
Visits to science centres and museums	41.18%	7
TV and documentaries	76.47%	13
Books and magazines	58.82%	10
Family and friends	41.18%	7
Total Respondents: 17		

Comments (0)

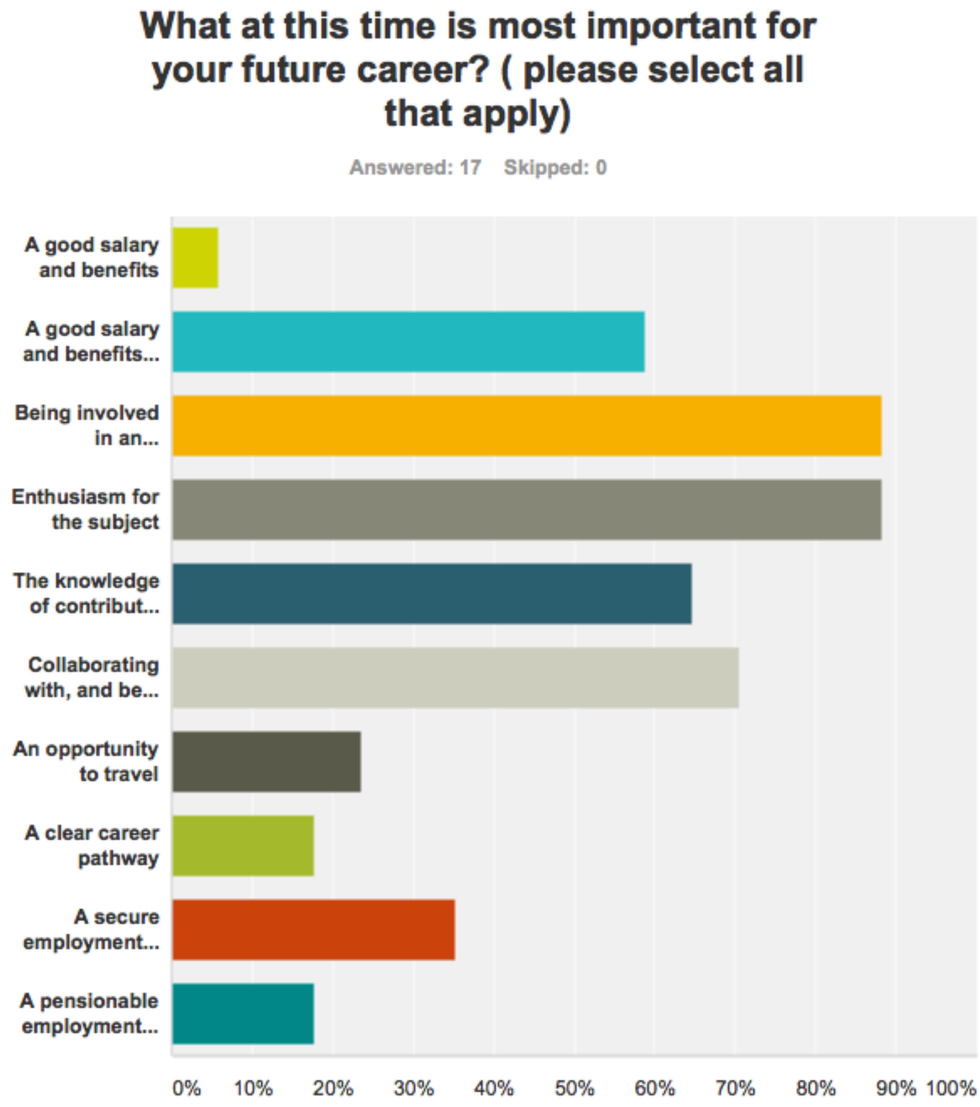
Figure B.46: Survey 5, Question 6



Answer Choices	Responses	
A lengthy study period needed for some subjects (beyond the first undergraduate degree)	41.67%	5
College and university fees	41.67%	5
Leaving home to go to university	0.00%	0
Leaving university with a large debt	33.33%	4
Concern about lack of earning potential while you study	33.33%	4
Concerns about subject difficulty and reaching the required academic standard	16.67%	2
Uncertainty about the supply and demand for skills in my preferred field	41.67%	5
Total Respondents: 12		

Comments (2)

Figure B.47: Survey 5, Question 7



Answer Choices	Responses	
A good salary and benefits	5.88%	1
A good salary and benefits are important but not enough in themselves	58.82%	10
Being involved in an interesting job	88.24%	15
Enthusiasm for the subject	88.24%	15
The knowledge of contributing to something worthwhile	64.71%	11
Collaborating with, and being in the company of other like-minded people	70.59%	12
An opportunity to travel	23.53%	4
A clear career pathway	17.65%	3
A secure employment position	35.29%	6
A pensionable employment position	17.65%	3
Total Respondents: 17		

Figure B.48: Survey 5, Question 8

B.10 Survey 5. Student comments on the LIYSF experience.

1. LIYSF was an amazing opportunity to learn about scientific research, see scientific establishments and make great friends. It has also helped me settle on what I wanted to study at university.

- Age 18
- Gender Female
- Home country Poland

2. It would have been interesting to have more rigorous mathematics-based lectures, related and unrelated to Physics.

- Age 18
- Gender Male
- Home country Bulgaria

3. The LIYSF experience was one of a kind. Even though it was focused on learning it wasnt just about science. Through that experience i learnt so much more about people of my age, different cultures and countries that iv'e never heard before, university life, london, and interestingly about myself. It was a unique experience that successfully balanced scientific learning (often through inconventional and innovative methods) and social interaction.

- Age 17
- Gender Male
- Home country Cyprus

4. To me my visit to LIYSF was a nurturing experience of feeling just remotely normal. Personally, I would have liked a more practical, hands on approach to science. Rather than lectures and demonstrations, which I find to be a poor representation of the real world of science, I would prefer projects. Projects of real science, experiments and trial and error, beyond that singing/dancing/artistic nonsense.

- Age 16

- Gender Male
- Home country Norway

5. would like to become a chemist and then follow pharmaceutical sciences field . I am really enjoying working in the lab and its my dream to learn how to make medicines for people who need help. LIYSF was the best experience in my life! Everything was perfect, I really enjoyed the specialized lectures and visits. Now, after the LIYSF I feel more confident and sure for what I want to study, it really helped me!

- Age 17
- Gender Female
- Home country Cyprus

6. I loved it. I met people that were enthusiastic in science, and who also left me enthusiastic about science. I wasnt sure before i attended whether science was the career i really wanted to pursue, but after LIYSF I think science is the best option for me.

- Age 16
- Gender Female
- Home country Czech Republic

7. During Liysf I made incredible friends from all over the world as well as attended exciting lectures and met inspiring proffessors who were enthusiastic about their subject. LIYSF was the first time where i felt that I perfectly fit in with this very large group of people in contrast to school were very very few people feel as passionate about science and especially biology as I do. Perhaps the only thing that i eould change at liysf was the lectures to more of those concepts that were entierly new and i never knew existed such as the boron hydrides lecture this year

- Age 18
- Gender Female
- Home country Cyprus

8. LIYSF was, to me, an eye opening experience and I wouldn't be exaggerating if I described it as the best experience of my life. During LIYSF I obtained many skills including opening to others even more than before, being opened to other ideas that

might or might not contradict with mine, and taught me loads about responsibility and self-descipline. If I could go back in time and get asked to go to LIYSF again I wouldn't hesitate for a second.

- Age 18
- Gender Female
- Home country Isreal

9, more in depth engineering experiences

- Age 18
- Gender Male
- Home country New Zealand

B.11 LIYSF Pre-event Questionnaire

Pre-event Questionnaire: 2015 London International Youth Science Forum

Dear Participants,
I'm Carol White, a researcher from the University of Sussex. Please spare a few minutes to tick the answer to 4 questions. There is no obligation, but if you can- thank you very much!

I am attending LIYSF because I think it will help me to make study and career choices

O	O	O	O	O
strongly agree	agree	neither agree nor disagree	disagree	strongly disagree

I don't yet know enough about a career in science to make a decision about my study and career decisions

O	O	O	O	O
strongly agree	agree	neither agree nor disagree	disagree	strongly disagree

Meeting like-minded people my own age interested in science is not always easy in my day- to- day life

O	O	O	O	O
strongly agree	agree	neither agree nor disagree	disagree	strongly disagree

I like science but I don't think I want to make it my career

O	O	O	O	O
strongly agree	agree	neither agree nor disagree	disagree	strongly disagree

Any further comments?

If you are you willing for me to contact you please leave your email address:

Your Email

LIYSF Questionnaire
Thank you very much for contributing to research.
If you would like to contact me, **please tear off this strip,** my email address is
C.R.White@sussex.ac.uk **or crw24@sussex.ac.uk**

Figure B.49: LIYSF 2015 Pre-event Questionnaire