STEM Education in Scotland

A thought piece by Universities Scotland

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STEM graduates are in demand. In 2013, STEM graduates were some of the most highly sought-after with 42% of employers preferring STEM-qualified graduates. However, 22% of employers said that they had found difficulty recruiting staff with STEM expertise. The demand is high – and growing – and schools and universities must work together to close this gap and provide the skills and experience the Scottish economy and employers require.

This report is intended to outline some of the background to STEM education in universities in Scotland, to identify progress and development and to pose challenges to the university and school sectors. This report is written by Universities Scotland Officers informed by, but not approved by, Universities Scotland members. It is intended to inspire discussion and debate. As such, the report will pose questions as well as potential solutions.

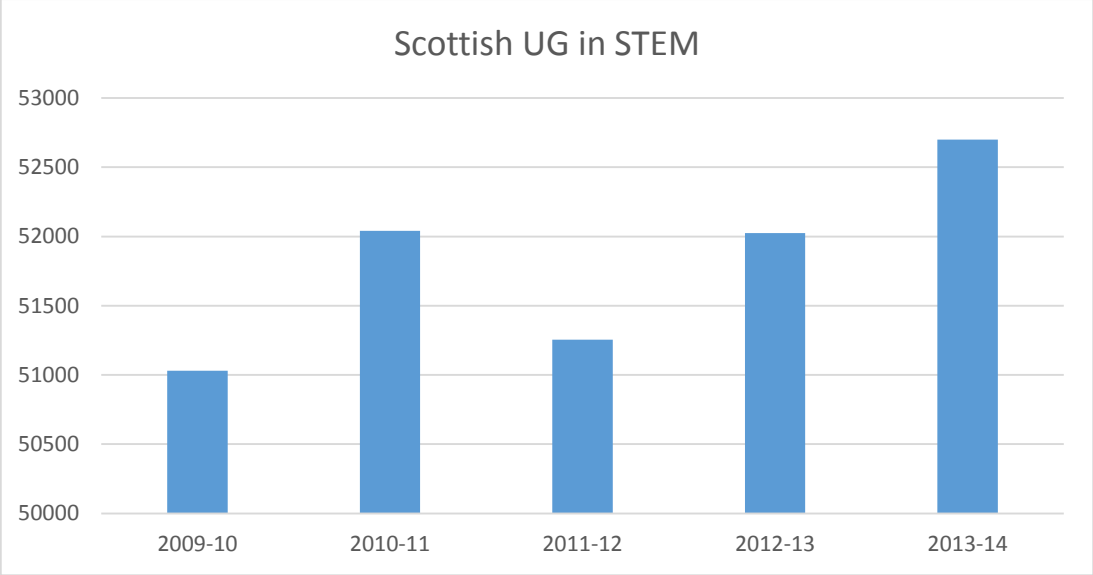
This report will consider:

- An overview of higher education STEM
- University engagement with STEM in schools
- The impact of Curriculum for Excellence
- The role of universities in training and supporting teachers in STEM
- Gender balance in STEM

An overview of higher education STEM

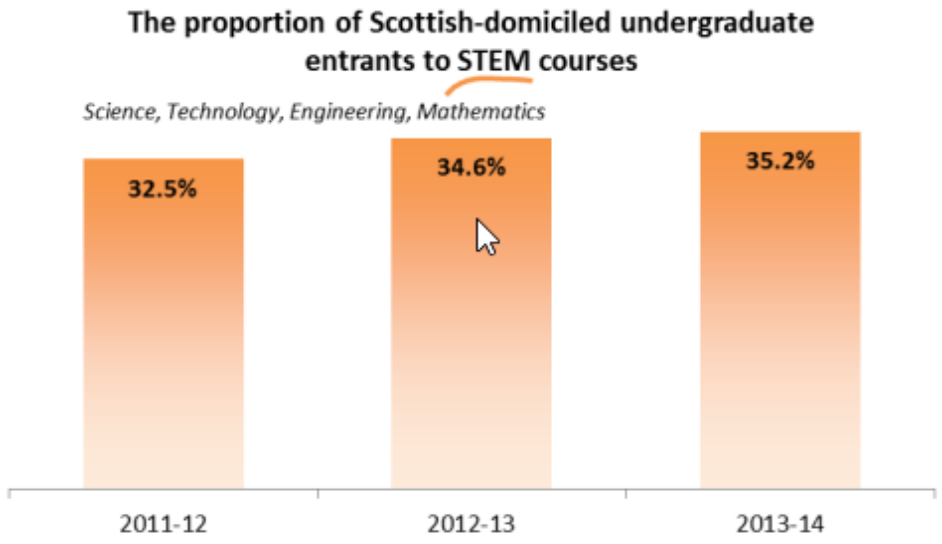
STEM education at higher education level is big business. In 2013-14 there were over 52,000 Scottish students studying undergraduate programmes in science, technology, engineering and mathematics at Scottish universities.[1] There has been a gradual increase in STEM undergraduates over the past five years – an increase of over 3% from 2009-10 to 2013-14.

[1] Please note this does not include STEM students studying at the Open University.



This increase has partly been assisted by focussed support and funding for STEM from the Scottish Funding Council.

As noted by the SFC, "Scottish-domiciled undergraduate entrants (SDUE) to STEM courses in universities have increased from 10,352 to 12,102, [2009-10 to 2013-14] enabled by the additional 300 places released to the sector by SFC in 2012-13. For example, SDUE numbers in Biology have grown from 745 in 2009-10 to 810 in 2013-14, an increase of 9%; and SDUEs in Physics have gone up from 350 in 2009-10 to 425 in 2013-14, an increase of 21%."[2]



Source: HESA

The commitment by SFC to 1200 funded places in STEM subjects over four years from 2012-13 will continue to support the increased demand from employers for STEM graduates. A commitment to continuing this funding from 2016 from the SFC is crucial.

[2] SFC Outcome Agreement Summary 2015: http://www.sfc.ac.uk/web/FILES/Funding_Outcome_Agreements_2015-16/Universities_Progress_and_Ambitions_Summary_2015-16.pdf

STEM is also a key area of focus, in line with requests from the then Cabinet Secretary for Education and Lifelong Learning, to review gender imbalance across university provision. In STEM, male and female students are both over-represented and under-represented. This will be discussed in further detail below.

University engagement with STEM in Schools

Universities engage with schools in a myriad of ways. This engagement has, perhaps, been strengthened further by the introduction of Curriculum for Excellence and the requirement for universities to better understand the school curriculum and its impact on university entrants.

The nature of the engagement has ranged from direct delivery of STEM education to school pupils by universities, co-delivery and supported delivery of STEM education and advice and guidance on STEM education by university academics. Current positive practice with scalable opportunity includes:

- University of Strathclyde Engineering Educational Enhancement Project: In the summer of 2013 the Faculty of Engineering led an Educational Enhancement summer project investigating and developing approaches to enhance successful STEM transition from school to university within the context of the Curriculum for Excellence. The output from this was the co-development by university students and staff of a new optional 10 credit module for students within the Faculty of Engineering at Strathclyde. This module allows 3rd, 4th and 5th year students to engage with local schools over a single semester in STEM activities. Students work in mixed engineering discipline pairs (and where possible mixed-gender) with their allocated school to develop a programme of STEM activities that meets the needs of the school and is reflective of the students' skills set. Typical activities include design, build and test workshops, homework clubs, visits and engagement in STEM activities within the University, Careers and Information events. This module was piloted in 2013/14 with 5 students and two schools - Govan High School, and John Paul Academy, Summerston. In 2014/15, the module was widened to 14 students and six schools - Govan High School, John Paul Academy, Bannerman High School, Clydebank Academy, Vale of Leven Academy and Dumbarton Academy. The faculty would like to expand the programme further this coming academic year.
- Chemistry at Work – a partnership project: The Chemistry Departments of the University of Strathclyde, Glasgow and West of Scotland invites school groups in to do fun lab sessions, and also delivers Chemistry at Work on a 3 year rolling basis where S3 and S4 students come in to see chemistry used in its wider applications. This direct delivery also contributes to students understanding of real-life work place impacts of academic learning.
- Stamp Science Days (University of Stirling): In February 2015, the School of Natural Science at the University of Stirling hosted their 'STAMP' Science Days. Students from local high schools, around 400-500 of them, were driven through an exploration of the ideas and experiments that are relevant for the research carried out by the School Divisions. Each talk attempted to highlight how a scientific approach can improve and drive understanding of such apparently simple things while possibly overlooking their inner complexity. This challenged young people's perceptions of science as intangible or theoretical.
- CREST at University of the Highlands and Islands: UHI have been successful in securing funding to develop and deliver a CREST Programme to schools in the Highland Council area. CREST is a nationally recognised and well regarded structured awards based programme for

both primary and secondary schools. With a large geographical coverage it can be difficult to support very remote schools. This is not only due to the remoteness from main centres but also due to lack of sufficient school staff and resources to accommodate external activities. However, this has been addressed to an extent by the use of video conference technology and increased attempts to recruit more STEM Ambassadors in rural locations.

- Science Connects STEMNET's STEM Ambassador Programme: The University of Glasgow holds the West of Scotland STEMNET contract (operated by Science Connects). There are 2000 Ambassadors in the West of Scotland - a mixture of undergraduates, postgrads, PhD students and staff. This programme has been running since 2001. Ambassadors have their own engagement with schools e.g. Advanced Higher Physics investigation help, Parasitology workshops, Chemistry at Work Days or else respond to Science Connects' requests for help on a monthly basis. 80% of Ambassadors undertake at least one activity a year and 94% of the regions 151 secondary schools have had at least one Ambassador engagement in 12 months. The provision of ambassadorial support is not, however, without challenges - Ambassadors visit schools in 12 local authorities, ranging from North Lanarkshire down to Dumfries and Galloway. Dumfries and Galloway is the most challenging area due to distance from the institution and requirement to engage with relevant, local industry.

Underpinning virtually all of the good practice activities in STEM engagement is the principle of partnership. Schools recognise and wish to utilise the expertise in universities to benefits young person's education. This also allows universities access to schools and school pupils to support educational attainment and build aspiration for access to university STEM programmes.

In order to gain value from further expanding work between universities and schools there are three key factors:

- Quality of engagement
- Sustainability of the partnership and programme
- Greater formalisation and systematising of relationships

In order for the outreach work and support for delivery to be effective – for schools, universities and ultimately students – it is necessary that the engagement is meaningful and of a high quality. The ability to deliver quality programmes is largely dependent on the financial sustainability of the programmes and the ability to commit to delivering a partnership over a sustained period of time – this allows for development of effective relationships between staff and the informed development of the programme over time in response to participants feedback and requirements of the partners. Increased sustainability also facilitates longer-term effectiveness review – to determine the impact of these programmes and build evidence of demonstrable benefit from the financial and time investment of the schools or universities.

Partnerships between universities and schools are multi-layered and multi-faceted. While this has benefits (e.g. a range of school and university staff engaging on various topics of interest) schools can be overwhelmed by offers of engagement or can struggle to identify a route into partnership with universities. There would be benefit in developing more formalised partnerships and identified points-of-contacts in schools and universities to facilitate this engagement more effectively. Given the diverse nature of universities and the myriad of requirements schools will have, there may be value in exploring routes for greater partnership amongst schools (e.g. through clusters or at local authority-level) to then partner with universities. In addition to providing greater stability, these broader partnerships may allow for the development of additional support – the Young Engineers

and Science Clubs Scotland[3] are a good example of the exponential benefits of broader partnerships, facilitating support for students, teachers and engagement with industry to build excitement for and skills in STEM at primary and secondary school level.

Many of the requests from schools to universities for support were in response to school's lack of confidence in their ability to deliver the revised Curriculum for Excellence STEM curricula. Where universities were able to assist this has likely delivered additional benefits but feedback suggests these partnerships tend to be locally-based and dependent upon individuals in both the university and the school to establish and maintain. This presents numerous challenges: schools without local universities delivering STEM education are less likely to access support, successful relationships can break down due to staffing changes in schools or universities and universities lack a clear oversight of all the STEM engagement in schools within their area as responsibility often sits with individuals below management levels.

Universities are already exploring ways to overcome some of these challenges. Professional Learning and Networking in Computing (PLAN C) was a project funded by Scottish Government to provide computing science-specific professional learning. Fifty lead teachers were trained nationally and are leading around twenty five local teacher 'hubs' covering around 28 of the 32 local authorities in Scotland. The local hubs meet monthly, physically. Around half of all Scottish computing science teachers have had direct engagement of some form in the project. PLAN C local hubs have had difficulty running in some areas. It is hard for Argyll and Bute, Eilean Siar and Orkney and Shetland teachers to come together physically. To overcome, or mitigate this, challenge Perth UHI are providing their video conferencing technology to teachers in Orkney, so that the teachers can join in with the strong North Perthshire local hub. This is proving to be successful and it will likely be rolled out in other areas as well. In addition, it is intended for all PLAN C materials to be made available in a self-study format so that teachers who cannot make the physical meetings, considered to be the gold standard for supporting a network of this kind, are able to pick up on the crucial professional development available.

Universities identified a number of challenges to further engagement. A number of these challenges were of a practical nature – the difficulty of finding sufficient flexibility in school timetables, restrictions of time and financial resources for both schools and universities to utilise all opportunities. One university identified limitations of hardware, software and equipment in schools that necessitated school pupils attending a university to engage in the STEM education. While this can be beneficial for school pupils to experience learning on a university campus, this added further barriers for schools (logistical challenges of travel, expense of travel, additional time for travel encroaching on timetable and, for schools without a local university, a fundamental barrier.) While it was acknowledge that prohibitive cost would prevent schools from purchasing specialist hardware or equipment, there was frustration with the barriers from school IT systems when universities tried to share software with schools.

Potential actions (and existing activity to build upon):

- Universities should undertake a mapping of existing STEM engagement in schools to better understand their own current contributions
- Deans of Science and Engineering Group should work with School Leaders Scotland to identify gaps in support (including rural exclusion) and share innovative methods to provide support

[3] http://www.yecscotland.co.uk/index.html

- Consideration of formalisation of partnerships between universities and school clusters or local authorities
- Consideration of programmes/projects which clearly bring benefits to both parties (i.e. university and school) such as providing opportunities for higher education students to develop teaching experience
- Review of school timetabling to identify opportunities for flexibility to support outreach activities
- Review of school IT systems to make software sharing easier

The impact of Curriculum for Excellence

The higher education sector is supportive of the introduction of the Curriculum for Excellence. Scottish institutions have been heavily engaged in the support for the introduction of the curriculum and in ensuring admissions processes take account of the revised structure of Curriculum for Excellence. The true impact of Curriculum for Excellence on university entrants has not yet been felt as the phased implementation of the Senior Phase of Curriculum for Excellence means CfE graduates will not enter HE until 2015 or 2016. By the 2017 intake, all Scottish-domiciled school leavers will be entering university on the basis of the Senior Phase of Curriculum for Excellence.

A core tenet of Curriculum for Excellence is increased interdisciplinary learning in the curriculum – a trend and expectation replicated in higher education. There are mixed views as to the success of this development in Curriculum for Excellence thus far. There are broadly two views:

- Schools have successfully developed interdisciplinary learning experiences
- Schools have successfully adopted the language of interdisciplinary learning

The structure and approach to Curriculum for Excellence supports interdisciplinary learning. The multi-layered, skills-focussed approach is intended to develop learners' abilities to engage across learning boundaries – this sits well with the developing ethos of interdisciplinarity and development of knowledge and of practical implementation of said knowledge in HE.

The sector is strongly of the view, however, that a strong grounding in disciplines and subject knowledge is essential for the development of a higher-level of education and for effective interdisciplinary learning. It is reassuring, therefore, to note commitments from teachers such as:

> "Where schools or authorities are taking a creative and innovative approach to the curriculum to teach skills they are not doing so at the expense of the traditional curriculum or knowledge, but in a way that enhances subject areas."[4]

The HE sector will be closely monitoring the capabilities and competencies of undergraduate entrants as CfE graduates enter HE.

It is generally viewed that schools have the willing to engage in interdisciplinary learning but, where it has been less well implemented, this has been due to lack of tools (personal experience, support for teachers etc.) to do so. In some circumstances this manifests itself as multidisciplinary learning – a situation where multiple disciplines are considered alongside each other but without the final step to truly reflective synthesis, analysis and knowledge creation achieved with interdisciplinartity.

[4] Building our Curriculum Self-Help Group (BOCSHG), Interdisciplinary Learning, Improving Pupils' Achievements through Curriculum for Excellence, January 2015

There is broad agreement, however, that school students are aware of and expectant of receiving and engaging in interdisciplinary learning (even if their understanding of it is flawed.) In light of this, universities are monitoring and reviewing curriculum in order to meet the expectations of incoming students.

This does, however, pose a number of questions:

- Are universities, with a tendency to 'faculty entry' and selection of a range of subjects in the initial years of a higher education programme, engaging in interdisciplinary learning or offering learning opportunities in multiple disciplines?
- How will we know when Schools/Universities are achieving interdisciplinary learning? And will it improve attainment?

The role of universities in training and supporting teachers in STEM

There are two major ways higher education supports teachers in STEM: as providers of teacher training and as providers of continuing professional development.

It is notable that entry requirements for teacher training programmes (primarily BA, MA, BEd provision) do not typically include a requirement for a science qualification at Higher (in the way that Higher English is usually a requirement). From data collated by the GTCS[5], only around 55% of entrants to teaching qualification programmes in 2014-15 had a science qualification at SCQF level 6 or above (higher). It is considered that this has a direct impact on the challenges outlined above in confidence that teachers have in delivery of STEM. The sector is divided as to whether this should be changed and, if it were to be changed, how best to change it. There are broadly three views:

- Adding a Higher Sciences requirement would restrict the applicant pool
- Adding a Higher Sciences requirement would increase confidence in STEM education for entrants and any limitation of the applicant pool would be minimal
- Adding a Higher Sciences requirement would increase competence in one science subject but not necessarily STEM education more generally – adding a requirement for at least two sciences studied at National 5 level would broaden science experience and increase broad confidence

There is a risk in option 1 of further embedding gender imbalance. As noted below, female students are far less likely to continue study of STEM subjects to Higher level which may, if this were implemented, restrict access for female students into teaching. Arguably, the efforts to improve gender balance need to be undertaken before this step can be considered – currently it could have the opposite impact of its intent.

Option 3, however, has practical appeal. The broader STEM engagement through multiple sciences would increase experience of, and confidence in, STEM education, it would not have such a significant gender-impact as a higher level requirement and would allow for the concept of interdisciplinary science education to be ingrained in the next generation of teachers.

[5] This data set was not comprehensive so should be considered to be indicative. The data was based on breakdowns of qualification prior to entry to undergraduate and postgraduate teaching to seven Scottish universities.

Teacher training itself has been amended over previous years, partly in response to developing pedagogy and research and partly due to the implementation of Curriculum for Excellence. The changes to programmes have not, however, been uniform. There have been two, potentially contradictory, trends:

- Increased subject-specific focus
- Increased pedagogy and practice focus

One institution has broadened the BA Education programme to allow students to study subjects out with the Education discipline in first and second year – encouraging advanced subject level learning in an academic discipline which may be of interest of relevance. This discipline may be STEM-related (though this is not a requirement – students may select any discipline). The alternative approach – to increase the focus on pedagogy – is more in-line with the Curriculum for Excellence philosophy and in response to the Donaldson Report. As noted by one institution "Due to the reduction in time being allocated to the study of subject areas, students learn about themes and concepts rather than focussing in detail on experiences and outcomes. They are expected to work on their understanding of how theory links to practice and can work on linking theory to experiences and outcomes during their school placements."

As these developments have taken place over the past few years most restructured programmes have not yet been through a full-cycle and graduated any students – so the effectiveness of altered approaches has not yet been measured. This will be a key area for monitoring.

Institutions are developing innovative practices within teacher training provision to improve STEM education. One example is the intended development of a 'Science Clinic' at the University of Strathclyde, to build on their previously successful 'Literacy Clinic'[6]. This model involves teacher training students receiving initial training in aspects of science and then going to various primary schools to offer additional activities to children in areas of deprivation. The project is designed to build student teachers' fluency in real-time teaching responses in ways that provide a strong emotional and social dimension to their learning and, crucially, to improve both the student teacher and young person's confidence and knowledge in STEM-related subjects.

An analysis of students studying for a Postgraduate Certificate in Education or Professional Graduate Diploma in Education at Scottish universities in 2013-14 shows that the various discipline strands are also heavily gendered. Overall, almost 75% of PGCE/PGDE students are female. Most subjects – even those typically imbalanced towards male students at Higher-level and undergraduate degree entrants – have a majority of female students. The only two strands which are heavily imbalanced towards men (e.g. fewer than 35% of one gender) are Computing and PE (84% and 67% respectively). Almost all other strands are heavily imbalanced towards female students.

Universities are heavily engaged with CPD delivery – often in partnership with Scottish Government, Education Scotland or local authorities. There is, again, a divergence across the sector in approach to this with some universities focussing CPD for teachers in the School/Department of Education with others delivering through relevant academic disciplines.

One institution described the change in approach to CPD provision for teachers: "There has been a shift from 'top tips for teachers' to developing a more critical approach to effective pedagogy. The approach now is more about developing pre-service and in-service teachers' understanding of: key concepts; how to develop appropriate challenge of children's understanding of their world and how

[6] http://www.strath.ac.uk/humanities/schoolofeducation/education_projects/literacy_clinic/

STEM subjects can explain, develop and impact on their world; how to ensure the key principles of curriculum design are embedded in teachers' planning; promote STEM as contexts for developing literacy, numeracy and health and wellbeing; promoting the importance of STEM for society both culturally and economically."

There appears to be the highest demand for physical sciences CPD, with this being identified as the area causing most anxiety for teachers.

This leads us to a number of questions:

- Given increased focus on pedagogy and skills development in Curriculum for Excellence and a number of teacher training programmes, should there be a greater shift to delivery of CPD through discipline-related departments (e.g. Physics Department) instead of university Education departments? This could increase the knowledge-focus for CPD to combat the perceived STEM-confidence deficit.
- Can anxiety around physical sciences be reduced by amending entry requirements (e.g. Nat 5 requirements as suggested above), through altering teacher training programmes…or does it require increased resources to deliver more comprehensive CPD support?

Gender balance in STEM

Universities Scotland is committed to fair access irrespective of gender – and identifies activity already undertaken by institutions to support this. Underpinning this desire for partnership working and progress is the existing commitment of institutions to equality and diversity and to ensuring that processes and practices are free from discrimination and that potential applicants, applicants, students and graduates are treated fairly and equally regardless of gender.

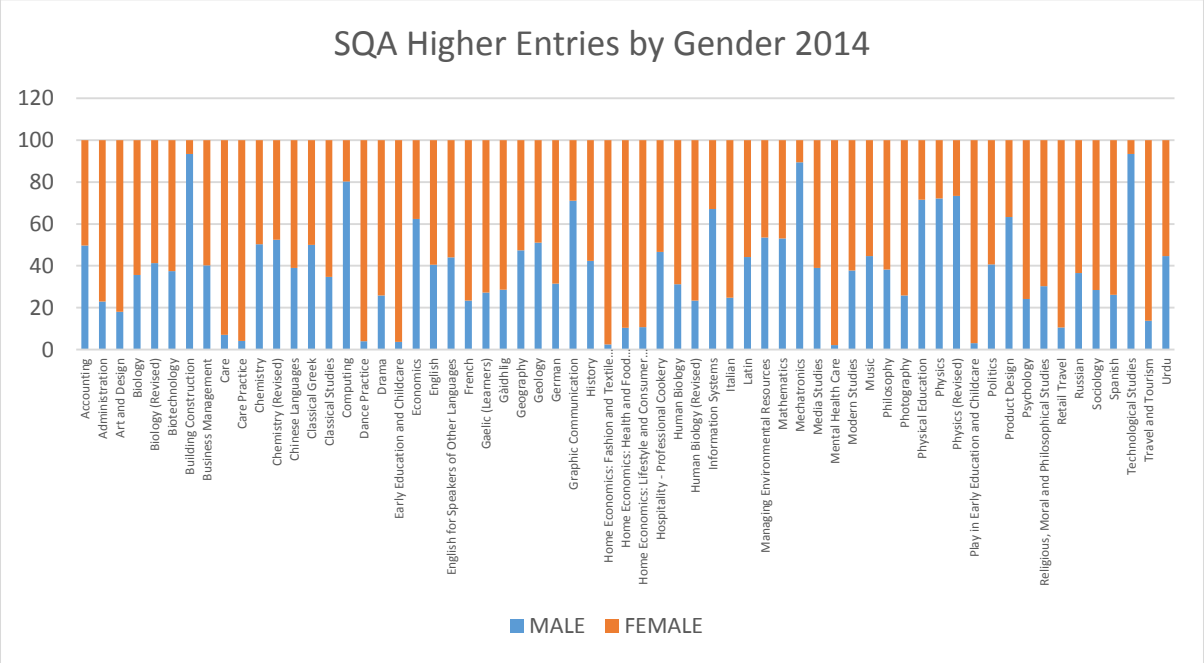
Universities Scotland has analysed publicly available data on school attainment, school leavers and UCAS applications to provide further insight into this complex area.

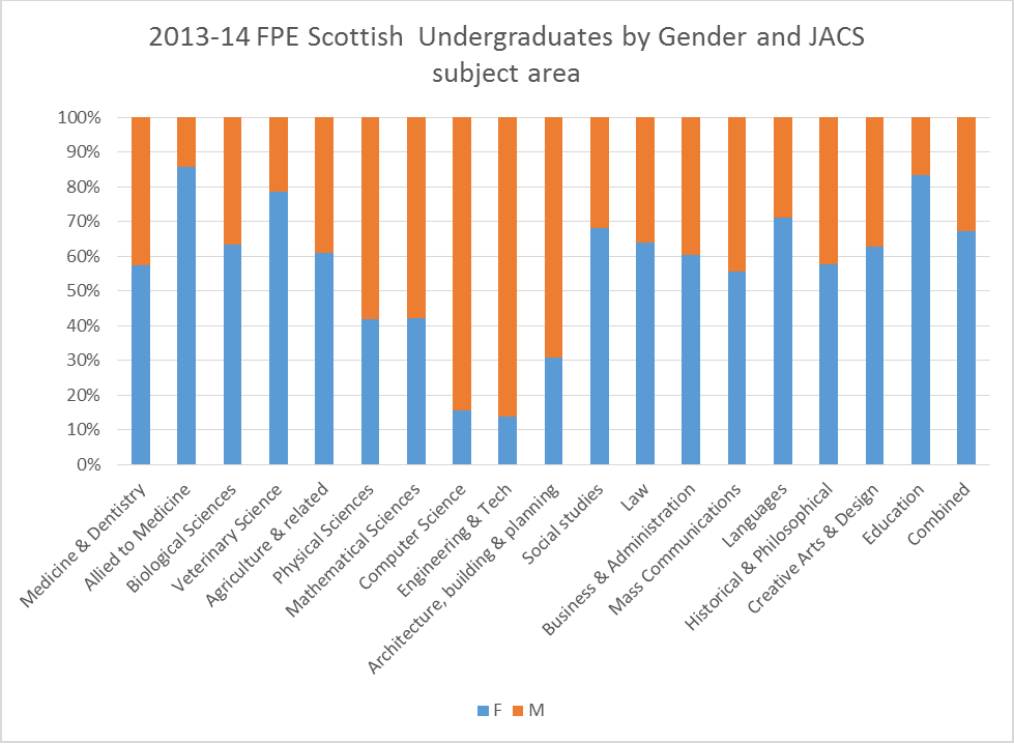
There is much that could be done with this data. Key conclusions at this stage appear to be:

- fewer male pupils take Highers than Standard Grades (although we are looking at different cohorts);
- male pupils are less likely to achieve high grades at both Standard Grade and Higher;
- some subjects at Standard Grade, Higher and HN level are more likely to be taken by one gender than another and this patterns to continue to university applications;
- a higher percentage of the female S4 role complete S6 than the male S4 role, though this gap has narrowed slightly since 2009-10; and
- female pupils are more likely to have attained relevant qualifications for university entrance, except at 3+ qualifications at SCQF level 7 (e.g. Advanced Higher), where more male pupils obtain this level (although the numbers are small for both sexes).
- Scottish Females are generally overrepresented at every SCQF level within Scottish Universities from undergraduate through to PhD however, by academic subject, females are only substantially underrepresented in: engineering; IT; and architecture, building and planning – a roughly 20:80 ratio. Males are under-represented in subjects allied to medicine, education, social studies, arts, business, biology, agriculture, law and medicine.

- Gender inequality overall is reduced vastly for graduate employment: The employment rate as a whole for males in Scotland in 2013 was 74.5%. This falls to 67.6% for females[7]. No such gap is apparent in Scottish domiciled graduates leaving higher education. In 2012/13 DLHE 92% of female and 90% of male leavers reported being in employment or further study.

There are clear correlations between gender imbalance in school qualifications and the inevitable impact this has on ability to recruit to university programmes.





[7] Scottish Government Annual Population Survey 2013

These tables show that gender imbalances are inculcated at early ages and, to some extent, perpetuated. They show fewer than 35% of female students studying for higher computing and physics and this replicated in physics, engineering and computing in university. Equally, male students are less-likely (under 35%) to study psychology or biology at higher and are under-represented in medicine, veterinary medicine and biology at university.

There are a range of activities undertaken by universities to overcome these attainment and gender challenges. The following are a few examples:

- Heriot-Watt University's Dragonfly project which seeks to motivate girls to be interested in STEM subjects: HeadStart is a well-established education programme whose aim is to encourage students interested in mathematics or science to consider technology-based careers. It provides an opportunity for those in Year 12/S5 to spend up to a week at university prior to making their UCAS application. Dragonfly Days are specifically designed for females going into Year 13/S6 to develop basic project management skills further by working with others
- CoderDojo - CoderDojo is a global movement of free, volunteer-led, community based programming clubs for young people. At a Dojo, young people, between 7 and 17, learn how to code, develop websites, apps, programs, games and explore technology in an informal and creative environment. Initiatives such as the CoderDojo are avenues out with the formal education process which can encourage girls into computing science.
- The University of Dundee's Women in Science Festival that seeks to celebrate and encourage women in STEM and is open to the public. This festival is organised in conjunction with other partners including the University of Abertay Dundee and the University of St Andrews.
- The University of the Highlands and Islands have held 'Institute of Physics Ashfield Music Festivals' to encourage engagement in STEM - Ashfield Music Festival is one day off-timetable activity in which students develop skills in enterprise and learn how physics applies in the context of setting up a music festival by taking on one of six roles: project manager, health and safety advisor, construction manager, electrical engineer, sound engineer or lighting engineer. They are supported by real-life scientists – referred to as "experts" – and must use a mixture of physics-based knowledge, creativity and skills associated with enterprise in order to win the contract to build the main stage.
- Royal Conservatoire for Scotland's run Entry to the Creative Industries (Production and Performance) Project on behalf of FOCUS West and offers tailored support to S5 and S6 pupils, irrespective of gender, who are interested in progressing in the performing or production arts. This programme works with pupils from the 37 FOCUS West schools with an interest in progressing to college, university or higher education institutions with specific interests in music, drama, dance, film, television, technical and production arts.
- The University of St Andrews, in partnership with Equate Scotland, has developed an Unconscious Bias workshop for staff involved in student recruitment which will be delivered in November 2014. The workshop will reflect on research that shows that unconscious bias can have a dramatic effect on our judgements and will discuss how unconscious bias can have a negative impact on women in the workplace and student admissions. The workshop is part of a broader set of work including the development of the University's 'Inclusive Curriculum Toolkit' which was implemented in 2013.

Many outreach activities are valuable and effective but difficult to scale up. Universities are, inevitably, at one end of a pipeline and thus outreach activities are attempting to resolve an imbalance or a challenge inculcated early on in young people's lives. The more fruitful approach, therefore, is to team these activities with action undertaken in schools and early year's education. A number of the approaches suggested above should contribute to improved gender balance including:

- Increased partnership working between schools, colleges and universities to support STEM education in Schools through increasing teacher's confidence in STEM subjects
- Direct delivery of STEM education by universities (both staff and students) in schools and in extra-curricular activities aimed at young people to challenge the stereotypical view of STEM subjects

Future developments

Reassuringly, there is no shortage of willingness to engage or a lack of commitment to enhancing STEM education in Scotland and in fact there are many example above of significant work being undertaken to improve and increase STEM education. Crucial to this success will be building on partnership. However, there are three key questions which need to be answered in order to realise the necessary step-change:

- How do you measure the impact of activities in a short-term (e.g. outreach programmes) and longitudinal approach (e.g. impact of Curriculum for Excellence in science-discipline attainment)?
- Who has responsibility for driving forward actions which span educational sectors?
- Who funds activities which often span educational sectors and, in times of reduced funding or increased expectations, will come under increased pressure and scrutiny?

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