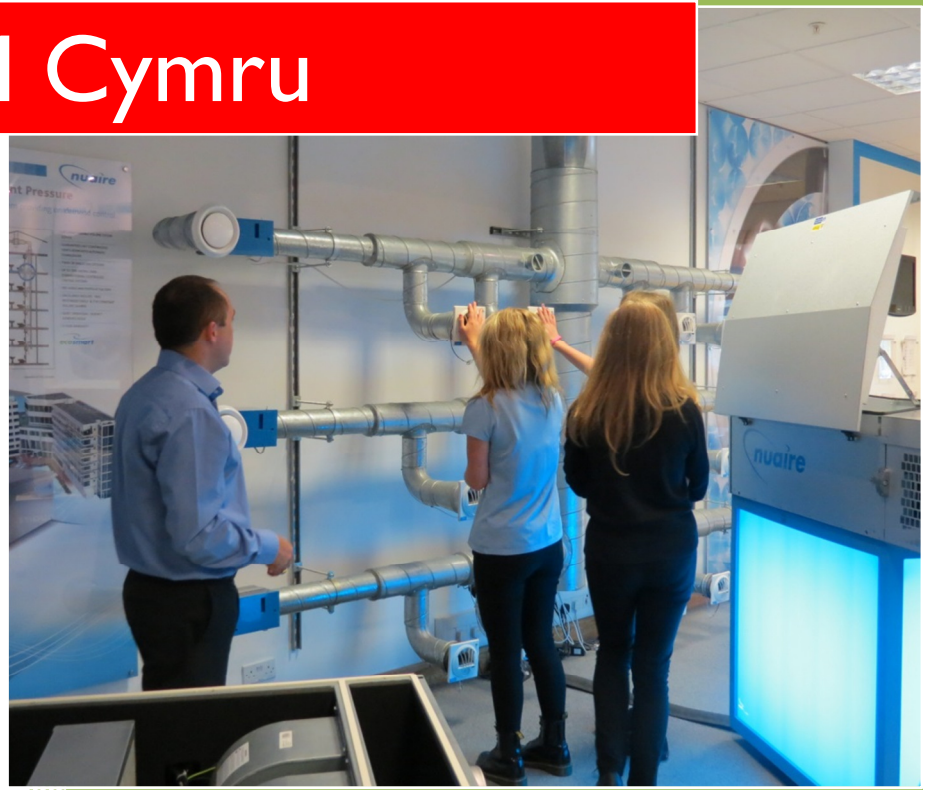
Hoshin

Final Evaluation of STEM Cymru



ESF
Ewrop & Chymru Buddsoddi yn eich Dyfodol
Europe & Wales: Investing in your Future
European Social Fund
EESW
STEM Cymru

Contents

Executive Summary

STEM Cymru is funded through the European Social Fund (ESF) Raising Skills and Aspirations Theme. STEM Cymru's aim is to encourage young people to participate in interesting technological and engineering activities to contextualise and improve skills in science, technology, engineering and maths (STEM). It is anticipated that this will raise aspiration and attainment levels in STEM, thereby increasing the numbers of students entering further and higher education in STEM subjects. It is also designed to encourage students to consider careers in STEM based occupations and particularly engineering.

STEM Cymru is delivered in association with colleges, universities and companies, managed by a non-profit educational charity, The Engineering Education Scheme Wales Ltd (EESW). STEM Cymru is delivered to 11-19 year olds in the Convergence Area, through a series of progressive strands. These strands are designed to engage and re-engage young people in STEM and the support their interest in a STEM-based career. Activities funded through STEM Cymru are delivered alongside, and as a part of, EESW's projects covering the rest of Wales.

STEM Cymru caters for all learning styles, providing activities outside the classroom in workshops and at employers' premises.

These are then reinforced in the classroom, completing the experiential learning cycle.

By exposing young people to the world of work, STEM Cymru increases their career maturity. STEM Cymru impacts on young people's career aspirations in a variety of subtle ways and is most effective when young people can see other young people (like themselves) pursuing STEM education and careers. For the majority, this confirms their interest in STEM-based careers, especially engineering.

STEM Cymru has a major indirect impact on the STEM agenda in Wales, improving STEM teaching and understanding and increasing employer engagement in STEM. Indeed, the awards events have grown to become one of Wales' major occasions, having a tremendous effect on Welsh policy and employer commitment. This represents the Strategic Added Value of STEM Cymru and can be measured by assessing the Welsh Government's policies towards STEM and spend on STEM-related activities.

The impact of STEM Cymru is through its targeted 6,805 participants of whom 47.8% should be female and 110 employers participating. There is also a target of 1,759 other positive outcomes.

However, STEM Cymru is exceeding all of its targets, having achieved 6,677 interventions of which 51.3% are with females, and 1,582 other positive outcomes (the remainder being on track for completion prior to the end of the project) and 123 employers participating. Translating this to economic impact we calculate a total impact of £8.7m, or a return on investment (ROI) of 300%. Whilst EESW is to be congratulated in delivering 8,259 interventions in total, this is only the tip of the iceberg in terms of what it could achieve for the Convergence Area, if more investment could be leveraged, as proven by the impressive ROI.

In addition, there are a number of softer targets and objectives that feed into the Welsh Government's STEM strategy and overall European Social Fund objectives for the Convergence Area. In particular, STEM Cymru contributes towards a number of cross-cutting themes, including promoting gender equality.

The business plan for STEM Cymru outlines a number of objectives. The degree, to which these have been met have been rated on a scale of 1 to 5 (see page 13). This therefore, provides a useful summary of EESW achievements through STEM Cymru. It is very encouraging to find that the average is 4.5, showing that EESW has been very effective in delivering the business plan.

Perhaps, the greatest contribution of STEM Cymru is in underpinning the Welsh Government's STEM strategy by providing a cadré of enthusiastic young people who will become the engineers, role models, advocates and teachers of STEM to future generations in the Convergence Area. Only through this long term commitment can the area's policy makers address the gaps which exist in the application of science and technology across its industries.

Unfortunately, a high proportion of the Convergence Area's most able young people leave it for higher education and never return. Promoting Welsh universities (through strands like Headstart Cymru) and the take-up of apprenticeships in the area decreases this leakage of young people from the Convergence Area. In fact, supporting the area to re-engage retain its assets has a more sustainable economic impact than, developing new assets.

STEM Cymru ROI = 300%

Background to the Project

Convergence Funding

The Convergence Objective covers Europe's poorest regions, those whose gross domestic product (GDP) per capita is less than three-quarters of the EU average. The Convergence Programmes for West Wales and the Valleys comprises funding from two separate European Structural Funds: the European Regional Development Fund (ERDF) and the European Social Fund (ESF). Priority 1 Theme 2 is 'Raising Skills and Aspirations'.

The ultimate impact of Convergence Funding is to increase the area's GDP so that it converges with the EU average; an impact that one North Wales female applicant to Headstart Cymru identified most eloquently:

"I would like to think that I can contribute to the economy of Wales in a positive way. This statement does sound a bit presumptuous, but history tells us that individuals can make giant strides to help mankind, especially in relation to my future area of study e.g. Fleming's discovery of penicillin or when Bevan set up the NHS."

STEM Cymru

STEM is the acronym for science, technology, engineering and maths. The government's STEM programme aims to increase young people's STEM skills in order to provide employers with the skills needed for a 21st century workforce and ensure Wales' place as a leader in science-based research and development. The Welsh Government (2012b) recognises the importance of this and the degree to which Wales is being overtaken by its international competitors:

"We need to address a decline in GCSE take-up of STEM subjects, and the fact that take-up at A-level has not increased in line with overall A-level entries."

As do the Science Advisory Council for Wales (2013):

"Evidence suggests that Welsh students are falling behind their UK and European counterparts in terms of the number of students choosing STEM subjects at a higher level – particularly in the areas of physical sciences and engineering. In addition, a lack of supporting infrastructure for the continuing professional development (CPD) of science teachers and poor resources in schools are preventing the delivery of high-quality teaching."

ESF's Raising Skills and Aspirations Theme funds STEM Cymru. It aims to encourage young people to participate in innovative technological and engineering activities to contextualise and improve skills in STEM. These raise aspiration and attainment levels in STEM, increasing the numbers of students entering employment and further and higher education in these area.

STEM Cymru is managed by The Engineering Education Scheme Wales Ltd (EESW), a non-profit educational charity, but delivered in association with partners such as colleges, universities and companies. Activities provided by STEM Cymru are delivered alongside and as a part of EESW's projects covering all of Wales, ensuring the continuity and longevity of STEM Cymru. Nevertheless one impact of STEM Cymru funding is that there is a higher level of school engagement within the Convergence Area than in the rest of Wales.

The Evaluation

Data in this Report

Due to some changes in audit requirements from WEFO, the end of December 2014 provided a natural cut off point for the data contained in this report. Where a this is not the case it is clearly identified.

Evaluation Aims

1. To provide EESW with an independent evaluation of the STEM Cymru project which meet Welsh European Funding Office's (WEFO) requirements.

Evaluation Objectives

By the end of the evaluation, Hoshin will have assessed:

1. the programme against its objectives in the business plan and WEFO's cross cutting themes;
2. the outputs against the business plan and targets;
3. the effectiveness of outputs of the individual delivery strands;
4. the effectiveness of the outputs in terms of female participation;
5. the effectiveness of the cross cutting themes (environmental sustainability, equal opportunities and use the Welsh language) in relation to the strands, project and project material (printed and online);
6. the effectiveness of the catchment of other soft targets and reporting; and
7. commented on the effectiveness of partnership working with employers, schools, colleges and universities;
8. drawn conclusions and made recommendations.

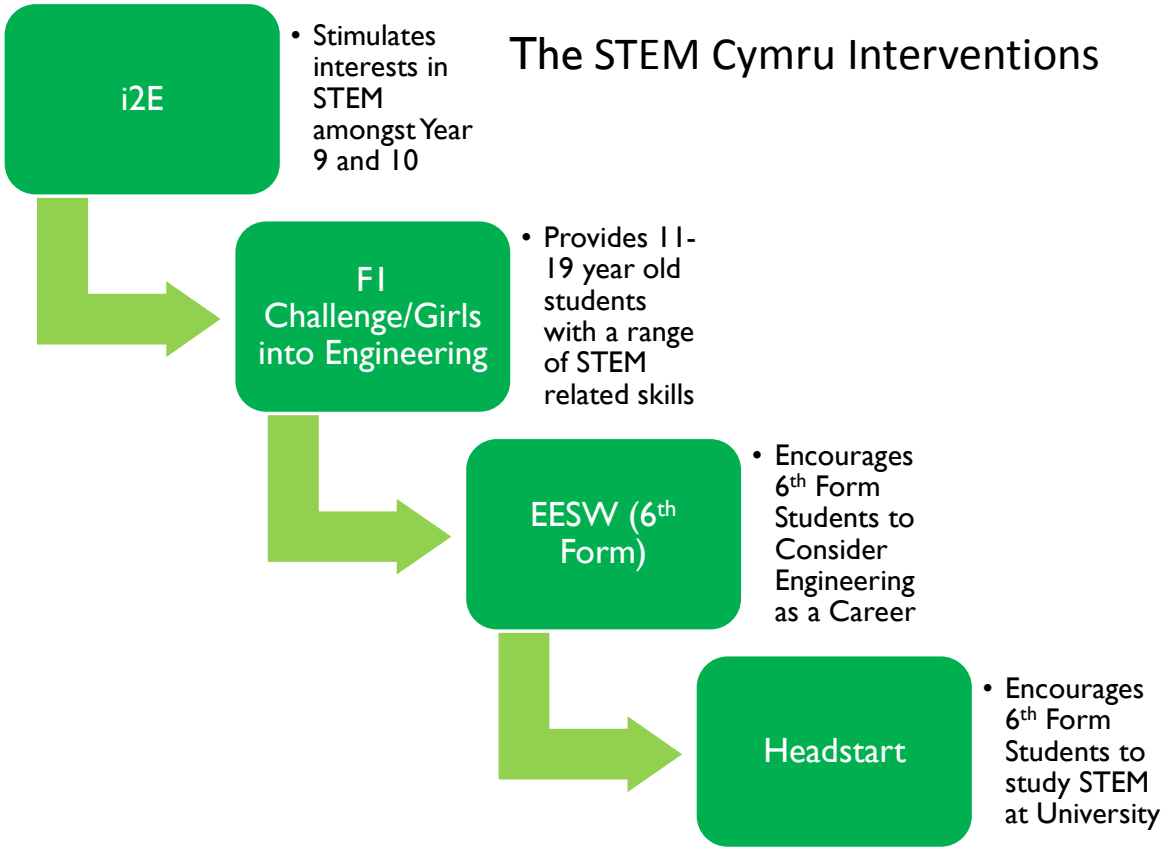
The Theory of Change

STEM Cymru leads students through a series of progressive interventions and also provides opportunities to prevent 11-19 year olds from disengaging from STEM, as they progress through their secondary (and tertiary) education. This is an important feature of STEM Cymru which contributes towards its overall success.

Whilst some strands could be seen as less intensive, involving interventions of less than 10 hours, the majority of interventions are intensive involving 100 hours plus of learning. This mix enables EESW to target specific groups and issues and lead them into more intensive and higher-impact strands.

Since policy makers in industrialised countries started to take an interest in STEM and developed STEM interventions, there has been a preoccupation with identifying 'what is the best intervention?' and 'at which point in a student's development should it take place?' The reality is that different interventions are more suited to some students than others and that students disengage and reengage at different times in their schooling. Although we know that times of change, such as moving to secondary school and moving into the VI form, are crucial times in forming attitudes, the reality of the examination calendar is such that interventions must take place long before these critical times. Of course, educators instinctively know that there is no simple solution to engaging young people. But equally we do know that some interventions appear to be more successful (in terms of their satisfaction levels, impact and the numbers they recruit) than others.

Nevertheless, there is a widely held view that it is important to introduce students to the excitement and opportunities offered by STEM as early as possible:



"Early exposure to STEM initiatives positively impacts on primary pupils' dispositions towards STEM …" Enterprise and Business Committee (2014)

Although almost tautologically true, this misses the important issue of re-engaging the disengaged, which can occur to even the most previously engaged students. There is also a widespread belief that there is a need

to convince students that STEM subjects are not more difficult than other subjects, when traditionally exam marking has been more rigorous and they have been taught less creatively.

"One of the barriers to developing learner confidence in STEM, is the view shared by many learners that STEM subjects are more difficult than other subjects in the curriculum. Teachers in schools and colleges work hard to dispel this myth. Good curriculum choices, support for learners to understand career paths and appropriate early, unbiased career advice, is essential to help learners overcome this negative perception and to understand the nature and excitement of STEM careers." Welsh Government (2012a)

STEM subjects tend to be highly cumulative and sequential

When progressing through the education system, students are required to specialise in some subjects which results in disengagement from others. When disengaging from STEM it is often more difficult than other subjects to catch up, reflecting the nature of STEM subjects:

- STEM subjects tend to be highly cumulative and sequential;
- STEM knowledge is specialised;
- STEM knowledge is rapidly changing:
  - STEM-trained individuals have alternative, high-paying career options;
  - STEM is not always familiar and accessible to the public and education leaders.

It is this disengagement which leads to persistent skill shortages across many STEM professions (as identified by Careers Wales), negatively affecting the economy of the Convergence Area. Addressing this is therefore central to the longer-term impact of STEM Cymru.

"Our primary benefit is in the support of the pipeline of talent into the STEM area in South Wales." South Wales employer

The Learning Cycle

The STEM Cymru strands provide students with the opportunity to learn outside the classroom.

"It showed application rather than learning out of a book." South West Wales university student

They also appeal across learning styles, something that more didactic teaching rarely manages.

"It really cemented the belief that I wanted to do something with my hands." South Wales employer and former EESW (6th Form) participant

"Very good solution with REAL and PRACTICAL engineering solutions which would actually work in industry, unlike many things taught at school." South Wales employer

This learning is then reinforced in the classroom, providing a complete cycle of experiential learning, by giving students with time to reflect on what they have learned (Gibbs,1988). This is an important feature of STEM Cymru's delivery, as the evaluators have frequently found a lack of co-ordination between STEM interventions and classroom practice in England. This is also an element of Kolb's (1984) learning cycle, reinforcing the learning that is taking place. The importance of which was highlighted in NFER's (2009) evaluation of the Bloodhound Educational Programme:

"Some interviewees expressed enthusiasm regarding the BEP providing a 'hook' on which a variety of lessons and exercises could be developed and delivered."

Indeed, this is the reason why we believe STEM Cymru has such a profound impact. It provides educators with a unique opportunity to reinforce the learning cycle within the classroom, time and time again, even though this may only be implicit in STEM Cymru's delivery.

"You can see the practical aspects of what you do in class." North Wales EESW (6th Form) student
"EESW scheme is a good initiative to bring students closer to real working environment and solving real problems that occur every day." Employer

The success of these strands is very much in evidence as is the way they combine to provide students with a progression from STEM subjects to STEM occupations.

"Because of F1 in Schools I would like to do F1 engineering." Female South Wales

Of course, STEM Cymru and in particular the project in the EESW (6th Form) strand provides participants with something to put on their CV's (63% of students do this) which is almost always picked up on and discussed during university and job interviews (experienced by 39% of former students).

"At my interview for my job I talked about my EESW project." South Wales employee

The Welsh Government has recognised the importance of workplace connections with learning and in Donaldson's (2015) recommendations regarding careers and the world of work.

"If organisations such as ours are to fill future engineering and construction roles then it's vital we do what we can to recruit young people now and it is through projects like EESW that we can do just that." North Wales employer

Strategic Added Value

Perhaps the most significant impact of STEM Cymru is in promoting STEM to policy makers, improving STEM education in schools and colleges and in engaging employers in the STEM agenda.

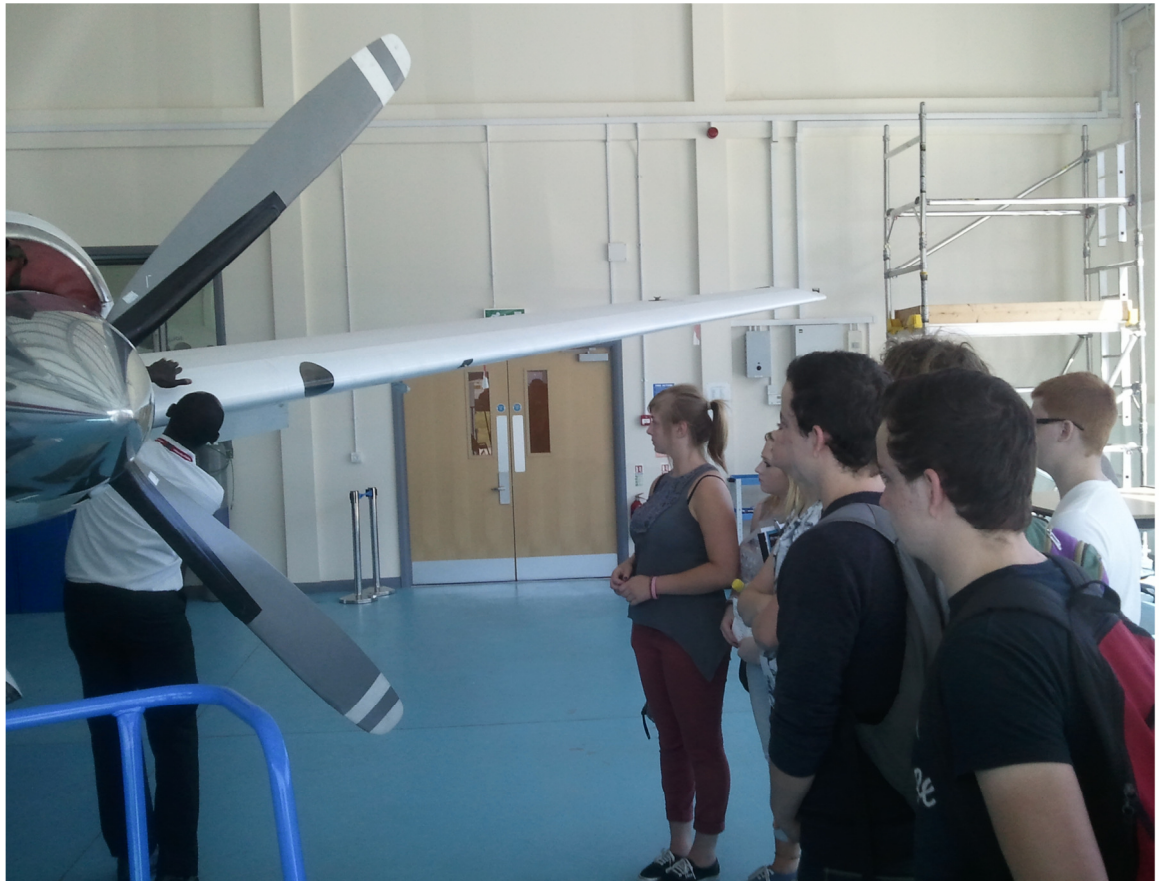
"I got back from the Celtic Manor and my headteacher said, 'right, how much money do you want for engineering next year?'" South Wales teacher

This is because, unlike STEM delivery in some parts of England, EESW work with schools, colleges and employers, enhancing existing delivery rather than competing with it. The high level of Strategic Added Value is also a reflection of the high public and political profile, quality and increasing impact of the awards events.

"I have seen this event grow and grow..." Carwyn Jones First Minister AM speaking at the Celtic Manor awards event

Indeed, the awards events have grown to become as important as individual strands and are could only have done so with the co-operation and support of their partners, highlighting the 'goodwill' created by EESW's collaborative approach. All this creates tremendous leverage for STEM in the Convergence Area, by increasing spend on STEM in Wales, which we can be sure is far in excess of the matched funding element of the project, which is £766,728.

The most significant impact is in promoting STEM to policy makers



Project Management

The Management of STEM Cymru

STEM Cymru is managed by EESW, an organisation with over a quarter of a century's experience of managing STEM projects within the Welsh education sector. In the main, the strands that make up STEM Cymru are tried and tested strands. This means that STEM Cymru are able to provide an experienced management structure for the project, knowing what works and what does not.

"An excellent day that was well organised and gave pupils a good insight into engineering studies and careers and gave them an idea of college life." Mid Wales teacher

EESW's main strength is the continued personal contact between schools, colleges and businesses through its area staff. Unlike, some other WEFO funded projects there is continuity in EESW's delivery and continuity in its staffing, this is so important in leveraging continued support.

EESW have embraced social media, which is starting to become major communications method, not simply between EESW and students, but also with other STEM management and delivery organisations. It is therefore, helping to overcome some of the confusion within the marketplace as to which organisation is responsible for what in Wales.

During the five years of the project the evaluator only uncovered very minor criticism of the project and its management; this was always followed up on immediately by the management team. Indeed, students, teachers and employers were always full of praise for the project and the project management.

Administration and Data Collection

EESW have embedded highly efficient administration and data collection into the STEM Cymru project, flowing naturally from their mainstream delivery. This means that much of the data for the quantitative elements of this report was available from EESW. Indeed, the evaluators felt there was no need to add to this quantitative body of evidence and focused on augmenting this with more qualitative research. As previously stated this data is for the whole project until the end of 2014 unless explicitly stated in this report.

Customer Satisfaction

Overall STEM Cymru attains a very high level of satisfaction amongst students, teachers and employers.

"Excellent scheme that should be continued into the future." Employer

A large sample of female students taking part in Girls into Engineering and i2E, suggested that on balance (taking the negative responses from the positive) some 64.6% would like to take part in similar activities prior to the event, but this rose to an impressive 74.2% following the event. For i2E as a whole the figures are 64.6% and 70.9% respectively.

"I would like to take part in more things." West Wales student

Students on EESW (6th Form) were asked if they had enjoyed taking part. 92% claim to have enjoyed it.

Headstart Cymru students were asked to rate a number of elements of the course, which produced an overall mean of 3.5 (on a scale of 1 to 4, where 1 equalled poor and 4 equalled excellent, so the midpoint is 2.5). For the overall event the mean rose to 3.7. They were also asked to rate their enjoyment of different features of the strand which produced a mean rating of 4.1 (on a scale of 1 to 5, where 1 equalled strongly disagree and 5 equalled strongly agree, so the midpoint is 3) and 4.4 for the student experience. Indeed, one North Wales' student commented:

"Great experience. All staff were very helpful and a pleasure to work with and learn from."

Whilst a South Wales student simply claimed that it was 'awesome'.

Teacher feedback from events showed that 88.8% would recommend the activity for other pupils in the age group and a further 74.2% felt that pupils of other age groups should be offered the experience. One South Wales' teacher commented:

"Very informative. Not only do the students learn from the experience but I learned about a variety of professions on offer and the qualifications required which I can share with all my students."

"It was awesome."

In the main, employers taking part in EESW (6th Form) had their expectations exceeded. Indeed a high 85% of participating employers intend to participate in the scheme in the following year.

"An excellent initiative that really does benefit everyone involved. The time that I have dedicated to the project has been low and easily manageable around my day to day work which proves that the team I had were able to work with little guidance and assistance. An enjoyable experience." Employer

Converting all available data on satisfaction (including information from students, teachers and companies) to a common scale and percentage (a statistical process which means multiplying the numerator and denominator of each set of observations so that they can be compared) we find the overall rating to be 88.1%. Unfortunately, using a common percentage means that these statistics may not be as comparable as those quoted for individual strands (which are more accurate as they have not been subjected to a statistical manipulation).

Outputs and Demographics

EESW is funded through STEM Cymru to deliver interventions to 6,085 young people aged 11-19 (its target group) and 1,759 other positive outcomes, over the five year contract. Other targets include working with 110 employers, a project using soft outcomes measurement systems, a project integrating sustainable development and a 46.5% female participation rate.

To date 6,677 interventions have been delivered. So far, 51.3% of all participants have been female, above the targeted 46.5% participation rate and reflecting EESW's commitment to addressing what is a particularly difficult issue of under-representation of females in STEM study and careers. Some 1,582 other positive outcomes have been achieved by students completing CREST awards courses over the project. Finally 123 employers have participated in STEM Cymru.

The greatest numbers of students by strand are for i2E (32%), Girls into Engineering (28%) and EESW (6th Form) (22%). An analysis by strand by year reflects the effects of the recession on employer placements and changing operational issues between the strands. Nevertheless, this does show how effective EESW has been in developing a response to these changing circumstances.

Broadly reflecting the ethnic composition of the area 96.1% of students claim white ethnicity, 1.1% are Asian (of which a third are Indian), 0.4% are black and 1.5% cent of mixed origins.

The cultural diversification that is beginning to occur even in some of the remoter parts of Wales is evident in students' preferred language. Although some 83.7% stated a preference for English and a further 14.4% for Welsh (despite some 44% speaking Welsh and 53% understanding Welsh), the other languages are truly global.

Progress towards Objectives

1. Adopt a Common Strategy to Address the Take-up of STEM Activity

As all strands within STEM Cymru are arranged and organised by EESW, there exists a common strategy at the heart of delivery. The strands provide a seamless mechanism for engaging and re-engaging students in STEM and promote the take-up of STEM activity. However, there is some variability across partners, which hardly impacts on the common strategy (providing an overall assessment of 4 out of 5).

2. Agree Common Strands of Support to Raise Levels of Awareness in STEM Activity

As with the previous objective common strands are at the heart of delivery and these certainly raise awareness of STEM activity. Therefore, we can consider this objective to have been fully met.

3. Provide Intensive Personal Support for Young People between the Ages of 11 to 19 in STEM Activities

Some of the strands, such as F1 in Schools Challenge and EESW (6th Form) are indeed intensive. However, EESW is challenged in fully achieving this objective due to the inability of a small proportion of schools and teachers to release students for STEM activities. As this hardly impacts on the project and STEM Cymru does provide the opportunity for intensive personal support they still warrant 4 out of 5 for this objective.

4. Provide Additional Essential Skills Support as Required

Essential Skills include:

1. Communication;
2. Application of Number;
3. Information Communication Technology.

These were very much in evidence in strands like F1 in Schools Challenge and EESW (6th Form). However, in other strands whilst implied they may not have been made explicitly and may not have always been reinforced (producing a rating of 4 out of 5). To a large extent this is one of the great benefits of STEM Cymru: that it addresses these essential skills in a manner that is natural and makes them fun. Indeed, the fact that we can only say that this objective is partially met is more a reflection on the objective's lack of suitability (or at least a lack of clarity in terms of its strategic fit with the project) than EESW's performance.

5. Provide Themed Strands to Continue to Improve Levels of Understanding, Intelligence, Self-Confidence and Self–Esteem in STEM Skills in A Practical Way That Will Capture the Imagination of Young People

The reason why the previous objective only scores a four is because this objective has been met fully. By offering such holistic delivery, STEM Cymru very much addresses issues like self-confidence, but this may be at the expense of explicitly addressing some other issues. All strands are highly practical and capture the imagination of young people by engaging them in activities that are far removed from their day-to-day schooling.

6. Link Young People With Industry and FE and HE Institutions through Team Activity That Will Deliver Measurable Time Based Outputs

The importance of links to industry were highlighted by the Enterprise and Learning Committee (2011) who stated that 'We look forward to Estyn's report on engineering in post-16 education, which is expected in spring 2011, and recommend that Welsh Ministers should act on its findings, including developing measures to improve the link between industry and education institutions.' The strands within STEM Cymru certainly provide team activities which deliver measurable time based outputs. They also link young people to industry, further and higher education, such as in the way that Girls into Engineering has linked young people to industry and universities. Although STEM Cymru more than met its target on employer participation, the recession has affected its ability to connect more fully with the wider employer community (therefore we have rated this at 4 out of 5). Nevertheless, employers have contributed towards all strands, particularly EESW (6th Form).

7. Encourage Young People to Consider Pathways in Science Technology Engineering and Mathematics (STEM)

Two-thirds of young people taking part in EESW (6th Form) would consider further education, or careers, in STEM. We can therefore rate this objective at 4 out of 5. EESW have embraced social media, which is starting to become major communications method, in promoting STEM to students.

8. Improve Rates of Entry to Apprenticeships and Further and Higher Education in STEM Subjects

Two-thirds of young people taking part in EESW (6th Form) (who would consider an apprenticeship or training and the only strand for which we have data) now want to train in STEM subjects, as a result of taking part, we therefore consider this objective to be fully met.

9. Increase Percentages of Young People Likely To Consider STEM as a Career Choice

As a result of taking part in STEM Cymru, 24.9% of young people (taking part in EESW [6th Form], the only strand we have data for in terms of future careers in STEM) would now consider a STEM career (and 66.4% overall), so again we rate this at 4 out of 5.

10. Increase the Number of Young Women Participating In STEM Activities, Qualifications and Career Pathway Choices

STEM Cymru achieved a high 51.3% of female participants, and whilst their attitudes towards STEM are still a little behind those of the male participants, STEM Cymru has certainly increased the numbers studying STEM and intending to pursue a STEM career (as is evidenced from our observations and discussions with female students). We therefore consider this objective to have been fully met.

As CREST is now treated as another positive outcome the qualifications element of this objective is now redundant.

11. Raising Awareness of Young People about Sustainability and the Need for Environmentally Friendly Innovation through Presentations, Hands On Science Activities and Working with Industry and FE and HE Institutions

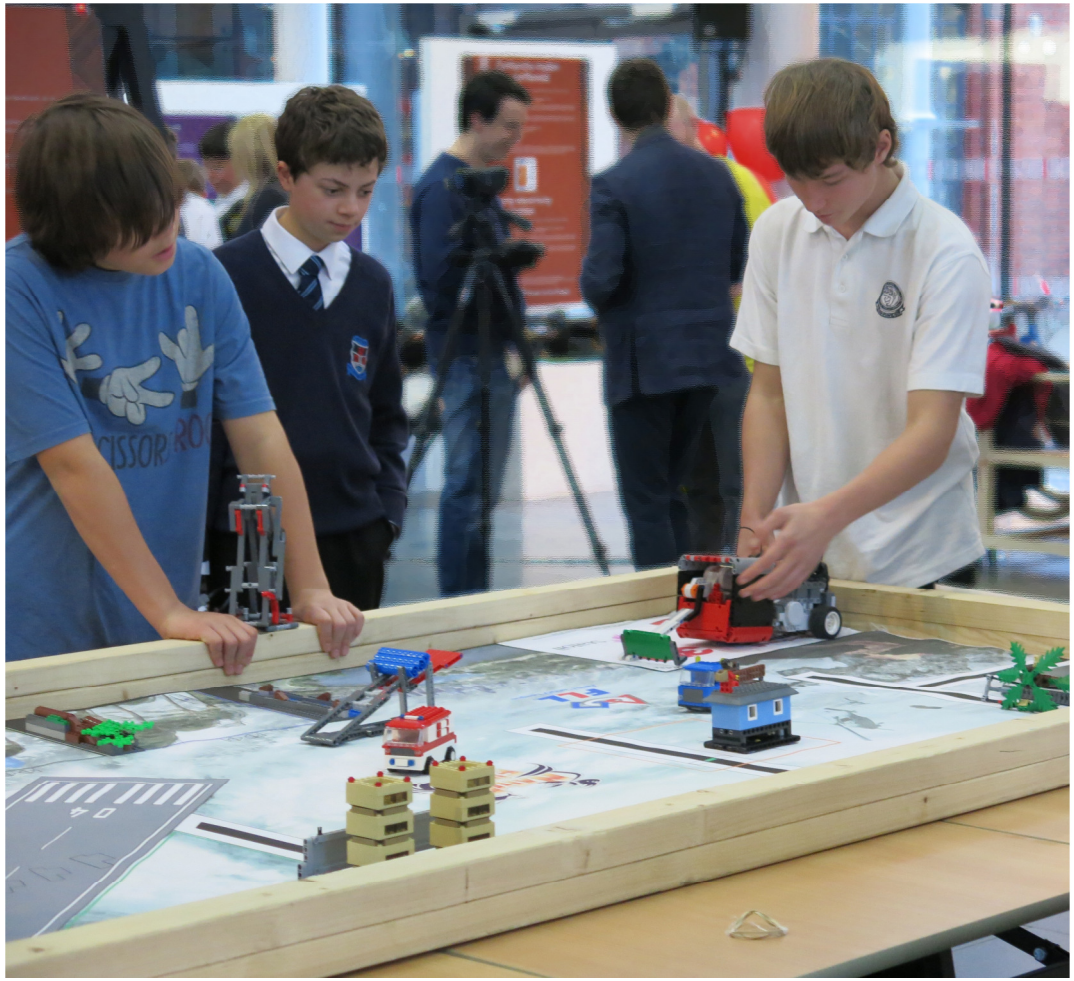
This objective is a little like the essential skills objective. There is much evidence of sustainability and environmentally friendly innovations throughout STEM Cymru and particularly as a part of Go4SET, i2E and EESW (6th Form); however, it was not always explicit. Again, to make it explicit would probably dilute the power of messages contained within entertaining activities and is therefore not recommended. Nevertheless, there has been a discernible effort to increase projects with explicit reference to sustainability since last year's interim evaluation (such as the introduction talk on sustainability given to all EESW [6th Form] students).

"We will research sustainable energy in class." i2E student

We therefore rate this objective at 5 out of 5.

12. Build a Continuum of Learning Opportunities for Young People throughout the Key Stages of Their Development to Increase Skills and Take-Up of STEM Subjects

The strands themselves represent a continuum of learning activities and therefore this objective is fully met. The funding mechanisms reward EESW for student numbers and not this continuum, despite some students taking advantage of the continuum; if it were possible to relax these mechanisms, STEM Cymru would be more effective.



13. Establish a Data Monitoring System to Allow Evaluation of the Impact of the Project against Set Targets and the Dissemination of Results to Interested Parties

EESW are to be congratulated in developing sophisticated data monitoring and analysis tools and reports. This system provides quarterly reports and thematic reports on issues such as cross-cutting themes to the Welsh European Funding Office. This objective is therefore, fully met.

Introduction to Engineering (i2E)

i2E is targeted at Year 9 and 10 pupils and is designed to stimulate their interest in STEM subjects by providing a task set in an enjoyable and real context. The tasks in i2E afford students the opportunity to apply concepts that they had been taught in lessons. Applying theory, and using a variety of senses in doing so, reinforces the theory and ensures that the concepts are learnt.

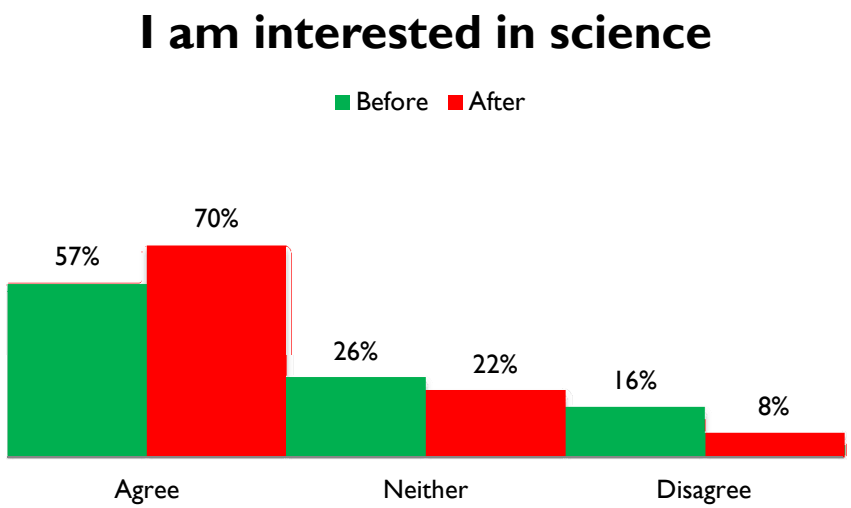
One project involves teams of up to three pupils assembling and testing models of wind turbines to demonstrate how energy is transferred. Each turbine can be adapted in terms of gear layout, blade design, number and size of blades. The turbines can then be used to inspire further design or scientific investigations.

"I have enjoyed designing and building the casing for the wind powered turbine. It was difficult to get all the parts to fit the first time we cut them out on the laser machine. This made me more determined to draw them more accurate [sic] before the second cut. I really enjoyed seeing the turbine turn when it was completed as I had a real sense of accomplishment." North Wales i2E student

Overall, students taking part are clearly enthusiastic about the activities and there is obvious science learning taking place.

"I enjoyed making the actual turbine, because I got to learn how it generates electricity and you got to test different types of blades." i2E student

Whilst the enthusiasm is not always translated into an interest in science careers, the strand probably does as much as it can to promote STEM to students of this age. Indeed, some there is a 22% increase in those interested in science as a result of taking part and some 23% now know what engineering is.



Go4 SET

Go4SET is an activity within the i2E strand which allows pupils to work in small groups on a civil engineering project to design and create a model of a venue that meets local needs, such as a sports venue or visitor centre. Students consider the main factors that a professional civil engineer would take into account when undertaking similar projects, particularly environmental, social and sustainability issues. The teams will display their work to a panel of assessors at a presentation day. The winners are presented with an award.

Overall, students taking part in GO4SET see mathematicians as smart (10.5%, unprompted, hence low numbers); although so too are scientists (6.9%) and engineers (2.3%). In addition, a further 5.4% thought

mathematicians to be brainy as did 3.0% and 0.9% for scientists and engineers respectively. Rather positively the percentages for interesting are 1.2%, 4.2% and 1.9% and 0.9%, 2.1% and 2.4% respectively. However, nearly as many found these professions boring. Nevertheless, there are encouraging signs that the strand is beginning to alter opinions even of students in this rather cynical age group.

Progress and Outcomes

As with so many of the strands team working, time management and communications skills were very much in evidence. These are important skills that students need to develop both for further study of science and careers in STEM based occupations. i2E is therefore, an excellent vehicle for promoting these important life skills.

"I have learnt how to work in a group very well and how to express my confidence." i2E student

Those taking part certainly felt that the activity was engaging and commented that it was 'interesting' which is illustrated by the following quote:

"Made me more interested in engineering."

Furthermore, i2E appears to have been effective in dispelling the myth that 'science is for boys', with a 22%age point positive change as a result of taking part in i2E. It would therefore appear to be a useful mechanism for promoting gender equality at what is a critical stage in the opinions formed by young people.

F1 in Schools Challenge

The F1 in Schools Challenge is a well-established international project that includes students of all ages. It involves designing and manufacturing CO_2-powered balsa racing cars using sophisticated computer aided designing and manufacturing (CAD/CAM) skills.

The competition has been very successful and the benefits to students have been evident to all involved. The competition has three distinct categories: Key Stage 3, Key Stage 4 and VI form. The learning style of the Challenge is an ideal model for learning as students develop a range of skills in a motivating and exciting context.

Teams within each category compete against one another at regional finals to represent Wales at the national final and, if successful, go onto the international finals. Winners of the regional finals also attend the awards and presentation day event, where they are able to display their car and explain how they created it.

Both South and North Wales finals are extremely well attended; indeed the North Wales event has some years been the largest regional F1 event in the UK.

"The quality of the work [in North Wales] is excellent." F1 in Schools Challenge event organiser

The reason for such high attendances is that teachers are very aware of the impact of F1 in Schools Challenge on students and how it feeds directly into the curriculum, enlivening the pedagogy in the classroom.

"It was hard work, but I really want to do it again." North Wales trainee teacher

With many schools entering teams year after year, as it becomes integrated into their STEM curriculum. Indeed, F1 is seen by many teachers as one of their most important tools in maintaining students enthusiasm for STEM,

F1 in Schools Challenge is organised just like a real F1 competition, with teachers taking the competition very seriously. Indeed, when the first car raced the room fell completely silent.

"I don't think there is a bad thing about it." South Wales student

Judges took great care to moderate their scores, as though they were marking formal qualifications. Given that there are a number of awards given for different aspects of F1 in Schools Challenge, such attention to detail is to be commended, but also has a marked effect on students' experience and what they get out of the day. Indeed, the evaluator frequently witnessed the change in students' attitudes when they became aware of the seriousness of the judges. To many this was perhaps the first time they had experienced a business-like approach to projects.

In the F1strand, more so than any strand, the development of essential skills and employability skills, such as team working, leadership and time management are most in evident.

Progress and Outcomes

Perhaps, the greatest contribution of the project was the degree of confidence that it had clearly created across many of the teams. Most approached the evaluator to describe the project to him and were happy to discuss what they had learnt from it. Indeed, it would be hard to over emphasise the impact of F1 in Schools Challenge on teams, particularly those that take part in international competitions. The marketing for the project claims that it is 'a life changing experience' and this certainly appeared to be the case.

"Being here [the NEC] steps it up to another level." Student at National Finals
"We can see the change in her." Parents at National Finals

A number of students taking part in F1 in Schools Challenge described how, as a result of the competition, they now want a career in engineering.

"*We are thinking of a career in engineering."* South Wales student
"Earlier in my school career I took part in the Formula 1 in Schools scheme. I found that being part of this scheme was really useful and interesting because it involved researching, designing and making model cars from balsa wood to race down a 20m track powered only by compressed CO_2." Extract from student UCAS personal statement

Students are also very much aware of how taking part has contributed towards their academic and career futures.

"I was the team manager and I was responsible for managing the team and getting the work done on time." Student

Case Study

Jonathan Wyn Roberts
Design and Technology Teacher
Repton International School in Dubai

Jon was studying to become a teacher at the University of Wales Bangor, when he was assigned to a local school (on Ynys Môn) to assist them in the 2011-2012 F1 in Schools Challenge. At this point Jon was totally unaware of what was to come and where it would lead to.

"The more I thought about it and reverberated the name Formula 1 in my head, being the massive (massive understatement) fan that I am of the sport, it started to rain on me that this would actually be quite interesting and right up my street. As I very often do with the unfamiliar (perhaps too much sometimes) I started researching F1 in Schools and as I delved deeper into this fascinating initiative, it became clear that my outlook and commitment to this posting was about to change."

This was only the start of his affiliation with F1 in Schools Challenge and he moved to Ysgol Uwchradd Glan Clwyd who advanced to the 2012 Bloodhound UK National Final. The team 'Speedy Sixes' were awarded the coveted fastest car award as well as second place overall in the competition.

"It is fair to say that at this point I was beginning to think to myself that I was becoming a bit of an expert and perhaps a 'big kid' in all of this."

After graduating from Bangor University with honours, Jon was lucky enough to secure a position as Design and Technology teacher at Repton International School in Dubai. This was a pretty big deal for someone who had lived at home with his parents in North Wales. It wasn't however totally unknown as his Formula 1 in Schools achievements and experiences were the cornerstone of his appointment. He was tasked with developing

the programme at Repton School in Dubai at a time when the competition was really taking off in the region.

Away from the direct competition he works very closely with F1 in Schools Challenge at Yas Marina Circuit, Abu Dhabi, who own the competition franchise throughout the Middle East. This work sees him provide training to schools and teachers in the region, write resources and support material, and also co-ordinate the Dubai machining and support centre, which is based at Repton School in Dubai.

"Without the opportunity afforded to me at the University of Wales Bangor and the support that EESW gives to F1 in Schools, the experiences I have had to date would not have been possible. I continue to support both the initiative and organisation back home wherever I can and hope that I can continue to do so in the future. For now though, my sights are firmly set on achieving the dream of guiding a team to compete at the 2014 World Finals in Abu Dhabi."

"I don't think there is a bad thing about it."

Girls into Engineering

STEM Cymru helps to achieve greater gender equality by supporting a number of specific activities. As well as having female engineers to work with girls on projects that link with industry and the F1 in Schools Challenge, EESW organises special visits and activities to show girls the opportunities that exist for them in the STEM world of work. They are shown how the knowledge gained in maths and science can be applied in meaningful contexts to exciting and rewarding careers.

The vast majority of students taking part felt that the strand was very different to their normal school activities. Indeed, it elicited some very positive responses regarding the impact including:

"By taking part in this project, I have learnt that engineering is not only about the work done in factories or in dense industrial environments, but also in many other areas such as biological and medical. I have also learnt that engineering comes into many areas where a problem is needed to be solved. By doing this project I have improved many scientific and technical knowledge skills, especially in the practical field by carrying out extra-curricular experiments and doing personal research which allowed me to gain a greater understanding of the areas within science that I had not experienced before." Student

Students' comments illustrated just how different this was from the school-based curriculum in summing up what they had enjoyed about the event:

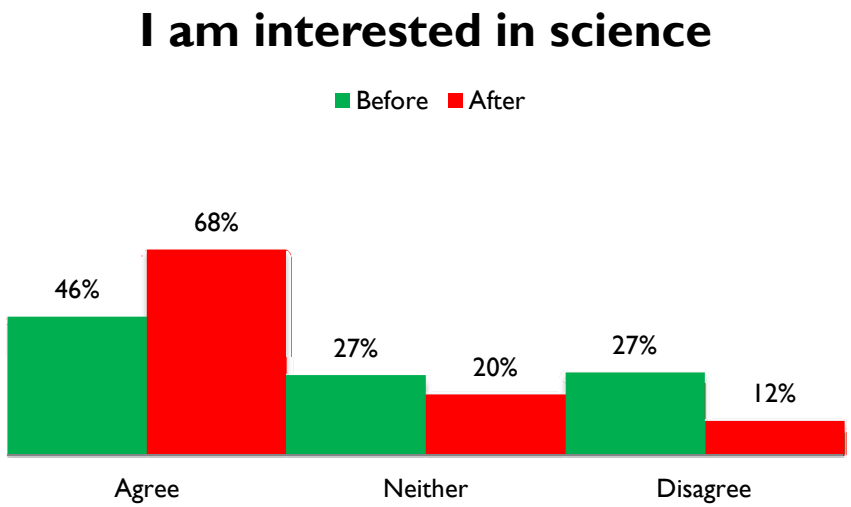
"It was just AMAZING." West Wales student

The strand very effectively challenged the myth that engineering is for boys as this perception decreased by 73%age points following participation in the strand.

"The girls thoroughly enjoyed! So much so they have already been to see me today to ask if they can develop and improve their cars and have a 'round 2' in school. What more can I say?! Girls wanting to learn more about STEM subjects- in their spare time!! Mission accomplished!" South Wales Teacher
"Realising I have more potential than I thought." South Wales Student

Progress and Outcomes

Overall, Girls into Engineering is having a very positive effect on girls' attitudes towards STEM. In particular, it is informing them about engineering and the types of engineering (64%age point change in those believing that there are a lot of different types of engineers) and providing them with an interest in science. Indeed, as a result of the strand girls are now significantly more likely to be interested in science (a change of 48%age points).



"I have learnt that engineering is a career that I would like to pursue in the future as I have enjoyed completing this project very much and have found it extremely interesting. Also, I have learnt how most engineers go about a new project and how they cope with it i.e. how they find out costs and who guides them. Within this experience I have developed my communication, ICT and technical knowledge skills. My communication and ICT skills were improved by set activities such as discussions regarding the project and using CAD to draw the design." Student
"It has inspired me to be an engineer." South Wales student

Whilst a South Wales student summed up the effect that it had had on so many of the girls taking part:

"I really want to go to university."

Indeed, following Girls into Engineering four-fifths of females now want to go to University compared with only three-fifths of boys attending STEM Awareness Events.

The Girls into Engineering strand has proved so popular that its remit has been extended to a full day's event and to include non-engineering companies, such as the National Botanical Gardens of Wales, by rebranding the strand Girls into STEM. The initial response to this has been overwhelmingly positive.

"It has inspired me to be an engineer."

EESW (6th Form)

EESW (6th Form) encourages Year 12 students to consider engineering as a career. A professional engineer, from a link company, works with a team of up to six high ability Year 12 students and their teacher for 5-6 months on a real engineering problem. Back at school the teams refine their solutions before submitting a formal report, mounting an exhibition of their work and presenting their findings to a panel of professional engineers at the awards and presentation day. The reports are evaluated by assessors and winners are chosen for the various award categories including best innovative or adapted design and best overall team performance.

An important element within the pedagogy of EESW (6th Form) is that it represents real life problems of engineers for students to solve. Young people learn by seeing what engineers do in their daily working lives and how they become involved in problem solving.

Equally important is that the projects take students outside the day-to-day school environment and seem to them to be something special. Indeed, the visit to the sponsoring companies is what many students value the most.

"Going to the factory was just amazing." Female South Wales student

In the main, this combination of factors means that most students really approach the project with enthusiasm (all agreed that they enjoyed EESW [6th Form] at the end of the workshops). During the induction days the evaluator observed students beginning to look for solutions to their problems immediately after they were set.

"If that pipe is fixed to that and that to that, surely they will spin independently?" North Wales student

This enthusiasm was confirmed by teachers (especially during the workshops) who understood how this translated into real learning outcomes.

"Every day after school we have been in the workshops for the last three weeks." North Wales student

On balance (taking the negative responses from the positive responses) 77.7% of students would recommend the workshops to fellow students next year.

Progress and Outcomes

The majority of students taking part in EESW (6th Form) are committed to further study in STEM and a STEM based career. Indeed prior to the strand a high 59% want to go to University to study a STEM based subject, as a result of the strand this rises to 65%. A high proportion of students appear to be natural scientists who have never considered a career in anything other than STEM. This opens the strand to the criticism of containing too much deadweight, in that most of the outcomes would have occurred anyway. However, EESW (6th Form) does challenge and refine students career choice, by exposing them to the opportunities within engineering.

"It was extremely rewarding. With all the projects coming together I thought yes I definitely want to do engineering and at the Celtic Manor I was convinced that I wanted to do Materials." South West Wales university student
"EESW was definitely why I did engineering." South West Wales university student

Nevertheless, the impact of EESW (6th Form) can be so profound that even those who are maybe unsure about a science based career, begin to consider engineering, which they see as more practical and enjoyable.

"I wasn't sure of career possibilities in Art, so I took science, but now I am struggling a little with my sciences... I didn't consider engineering as a choice but I enjoyed this so much, now I am confused." South West Wales student

During the workshops the evaluator witnessed two engineers working with students on a problem. Whilst discussing components they consulted an online catalogue. It was obvious that this had a resonance with students, as it was similar to leisure activities (such as looking at online music and clothing sites) they would undertake. Included in the parts description was a scientific equation; reinforcing that seemingly theoretical concepts have a very practical application.

A part of the reason why some students become committed to a career in engineering following EESW (6th Form) is that for the first time many of them realise that they can use their skills in a way that will earn them a living.

"You can see a job at the end; you can see a career path." South West Wales employee and former participant

"Doing EESW showed me how many apprenticeships and companies are out there." South West Wales employee

In particular, they enjoy visiting workplaces, solving real industrial problems and mixing with engineers at the awards events.

"I was really impressed that we could do it." North Wales student

Of course the experience of EESW (6th Form) provides participants with an incredible confidence boast, not least because of the realisation that they can solve real problems and engage on an equal footing with people earning a living from engineering.

"Honestly at the start I was a bit sceptical. It was overwhelming and then I thought I can actually do this." South West Wales Student

"I really like the fact that we went to the site, so you're interacting with engineering professionals." South West Wales university student

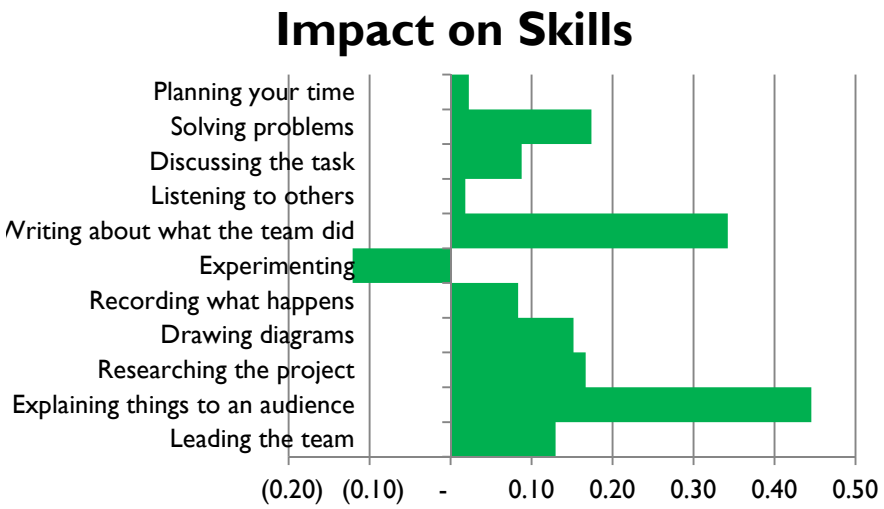
The reports and presentations clearly stretched some students (despite there being an excellent introduction to them at the workshops), but also had a massive effect on increasing their confidence and confirming their interest in engineering. Of course, such skills are critically important in securing good jobs and are equally important in ensuring that participants achieve as engineers.

"I wasn't sure what I wanted to apply for at University. Going to the Celtic Manor (awards event) and speaking pushed me into the right direction." South West Wales student

Indeed, some former participants stressed the importance of the non-technical skills they developed during the project, including team working, communications, problem solving and organisational skills.

"EESW gives you a chance to use your employability skills." South West Wales employee

Students were asked to rate their skills in these important areas on a scale of 1 to 5 with 1 being not at all well and 5 being very well, both before and after the strand (so the maximum change in score is 4). Overall, the change was a positive 0.14, the highest changes being in the important employability skills of explaining things to an audience (0.45) and writing about what the team did (0.38). The only negative change was for experimenting (-0.12).



These are the employability skills that are so frequently mentioned by employers when asked about the sort of skills they are looking for.

Indeed, all too often these skills are missing form a young person's education, even if they have attended university.

A number of former participants spoke of how much they enjoyed the autodidactic nature of the project and how this had encouraged them to study further in their chosen academic subjects. This included one female student at Swansea University who wants to complete a PhD at the University and pursue a career as a research engineer. Another male from North Wales described how his status, as Welsh Engineering Student of the Year, was specifically discussed during his interview at Cambridge University.

Prior to beginning the strand some 41.5% wanted to pursue a STEM based career, this rose to 66.4% as a result of taking part. Furthermore for engineering alone this rose from 17.0% to 27.3%. So we can conclude that the strand is having a very positive impact on the young people who take part in it.

Case Studies

Dr Dyfyr Davies
Engineering Manager
Weartech International Ltd

Dyfyr attended Ysgol Maes Garmon in Mold, where he studied physics and pure and applied maths at A Level, largely because these were the subjects he enjoyed the most. Along with other physics students he was given the opportunity to join a project working with BA Airbus in Broughton, managed by EESW. It proved to be a fundamental moment in shaping Dyfyr's career aspirations:

"The project was an introduction into what engineering was (and in part that engineering existed). I know schools offer courses titled engineering more often these days, but I find they are courses aimed at training technicians or crafts rather than engineers. Participating on the scheme and particularly the

interaction my team members and I had with the engineers at BA Airbus was a very big if not the main influence on my decision to study engineering at university. I knew I could go to university and study one of my A-Level subjects, but for me personally mathematics or physics courses didn't have enough real life connection - more theory based perhaps, and I wanted a more practical side that as a result of the EESW project I knew engineering could offer."

Dyfyr then studied engineering at Lancaster and completed a doctorate in Engineering at Corus Steel awarded by Cardiff and Swansea Universities.

After this he joined Weartech in Baglan, first as a Development Engineer and has been promoted to Engineering Manager. This affords him the opportunity to support scheme like EESW and share his experience with young people.

"Children know what a doctor is, they may well know what a lawyer is, but they know an engineer came to fix their leaking washing machine or did the service on their parents' car, and as a university course they often don't know what they would then become in their working lives. Without schemes like the EESW there would without a doubt be far fewer students choosing to study engineering at university, and manufacturing in the UK would slowly become unsustainable as a result."

Lloyd Godwin
Project Manager
Airvolution Energy

Lloyd attended Ysgol Brynteg in Bridgend, where he took A' Levels in computer science, D&T and sports science as he 'chose those' he 'wanted to take'. As a result of studying D&T Lloyd was given the opportunity to join EESW (6th Form). He worked in a team of just four developing a solution for metal ceiling tile waste for local company SAS International. They spotted that the waste was relatively dense and developed a washing machine counterweight for Hoover. Lloyd claims that he:

"Enjoyed problem solving [and] being a bit hands on."

As a result he decided to study engineering at University ('EESW opened my mind to Engineering') and having been inspired by 'Extreme Engineers; and 'Mega Structures' he decided on Civil Engineering at Cardiff. Lloyd's first job was with Lang O'Rorke, but the opportunities were limited as a result of the recession. He then moved to Raymond Brown in Bridgend as a Project Manager on renewable energy projects.

Lloyd is about to start as a Project Manager with Airvolution Energy a developer of wind farms. This will involve moving from the Convergence Area to London as he 'always wanted to live in London'.

Daniel Nicholas
Engineering and NBD Operations Manager
Spectrum Technologies

Daniel attended Cynffig Comprehensive School in Bridgend, where he studied A-level Maths, Physics and Geography. Through EESW Daniel had the opportunity to become the Project Manager/Project Lead on a project for Tarmac. The brief was to design and build a machine capable of monitoring the water content of the road sub-base material and, if the moisture content was too low, to add the required amount of water. Prior to this project he:

"… had no management experience or any real engineering experience with an industrial environment."

The project exposed the team to the following:

1. Electrical/Electronic Engineering
2. Software Programming
3. Mechanical Engineering

4. Project Management.

The experience had a fundamental impact on Daniel's career maturity.

"The key decisions behind my career choices can be traced back to the EESW project…. I found I enjoyed both the Electrical / Electronic Engineering and Project Management… The project was the first time I really assumed any true responsibility e.g. ensure the project was completed to the required standard within the time and cost designated by Tarmac, this was something which I really enjoyed and still do, however with time the responsibility has significantly increased…. Upon completion of the project I decided that going forward I wanted to become a Project Manager."

When he left school after completing his A-Levels he took up an apprenticeship with the Ministry of Defence (MoD) and trained as an Electrical /Avionics Engineer working on military aircraft. But after working for five years in the MoD having gained significant experience in the field of electrical and electronic engineering and a significant number of qualifications, he decide to leave to pursue his ambition to become a Project Manager. So he joined Spectrum Technologies Plc, in Bridgend, as an Electrical Design Engineering to further develop his experience, focusing on new product development. During this period he completed his degree in Electrical and Electronic Engineering. After two years at Spectrum he was promoted to Project Manager a role which he held for 3 years until being promoted again to the Engineering and NBD Manager, although he still manages certain projects.

Richard Passmore
Steel and Slab – Plant Engineer
Tata Steel Strip Products UK

Richard attended Morriston Comprehensive School, where he studied A-Level geography, business studies and information technology. He participated in EESW during his 6th Form. He had never previously taken any interest in engineering as it was not a subject offered at this school. Participating in the scheme was very enjoyable, the team were supported by INA Bearings and tasked with finding a solution to lifting 25kg baskets of tappets due to the increase in accidental injuries and back strains being caused to the operators during manual handling of the baskets. They completed the project and came up with a solution which was implemented by the company and won the award for Health and Safety at the presentation day at Celtic Manor.

"Since being involved with the scheme, it is an experience that I have highlighted at every engineering interview I have participated in. For me it shows where my passion for engineering began. The process of identifying a problem, creating a solution and implementing that solution was incredibly satisfying at such a young age. I feel that without my involvement in this scheme, I would not have pursued the career path I am currently on."

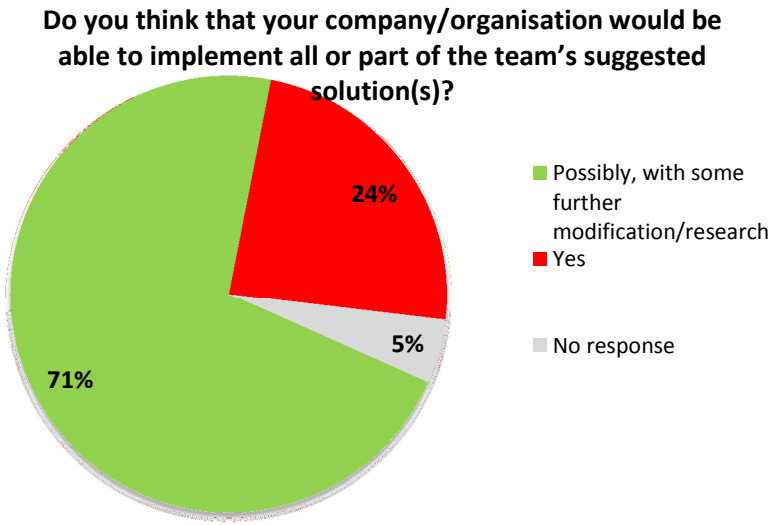
He got an apprenticeship at Tata Steel Strip Products UK and as a result he then attended Bridgend College where he studied for a BTEC National Certificate in Mechanical Engineering. Following this he completed a Higher National Certificate (HNC) in Mechanical and Manufacturing Systems at the University of Wales, Newport. He then went on to complete a BSc (Hons) in Mechanical and Manufacturing Engineering at the University of Glamorgan.

"The impact of EESW was fundamental in my career path choice, shortly after the scheme I joined Corus as a mechanical engineering apprentice and set myself the target of becoming a chartered engineer by age 30. I am currently 28, and into my 3rd of 4 years on the iMechE professional development scheme aiming to complete chartership by March 2016. I feel my exposure to engineering through the EESW was a first step on what has now become my career path!"

He has been promoted from a Caster Mechanical Craft-Fitter, Mechanical Engineer and now works as a Plant Engineer.

Benefits to Business

Perhaps, the most important feature of the strand is when students realise that their solutions may actually be implemented by their sponsoring companies. In 2012-13 EESW began to track implementation of projects by companies and found that 11.3% had already implemented them and 17.0% had implemented or were investigating them. Overall, some 24% of companies said that they would implement the solution and a further 71% might do so with some modification.



The Welsh Government (2012a) suggests that '*most STEM employers recognise the importance of engaging with schools and colleges'*. Although some employers do see a direct relationship between EESW (6th Form) and recruitment, many get involved because they believe that they have a responsibility to promote STEM.

"We work closely with local schools and encourage our employees to attend and speak with pupils about their careers. A project like this really brings engineering to life for the pupils and having a work placed mentor on hand to encourage and guide is a bonus that schools don't often get." South Wales employer

Nevertheless, there is growing evidence of employers actually implementing student projects, possibly as a result of the increasing use of return on investment calculations by the teams.

"Our solution will offer great cost benefit to our link company. It will allow current construction to under-go much faster, using less workers and working hours, lowering labouring costs. It will also mean the project will be completed quicker so profits can be made in shorter time scales allowing room for more profits." EESW (6th Form) student

"The final solution has by far exceeded the expectations. Its viability is still to be proven, but the amount of detail put into the final prototype was extremely professional." Employer

To a large extent this is at the heart of engineering and must provide many students with the motivation to further develop their interest in engineering.

In addition, it is clear that, as the labour market begins to firm up once more, employers are recognising the importance of the projects to future recruitment, either directly of participants, or indirectly as a result of their reputation.

"We hope that members of the teams will consider (company name) as a potential employer in future and apply for our apprentice/graduate schemes." Employer

Headstart Cymru

Headstart Cymru provides an opportunity for those in Year 12, to spend three days at university prior to making their UCAS application. Headstart Cymru is a residential summer school; students stay in typical undergraduate accommodation at the university and attend broad-based courses looking at a range of engineering disciplines. It is designed to give students in Year 12 a real taste of what it is like to study at university and of university social life.

"Insight to university life and courses available." South Wales student
"The opportunities I acquired to experience different fields and engineering, Headstart has been an invaluable background and are something that has given me a clear direction as to a future in engineering." North Wales student

The strand is very much in line with a recommendation from the Enterprise and Skills Committee (2011):

"We recommend that higher education institutions and individual academics in Wales should be challenged to lever their academic STEM success into economic and educational areas through collaborative working with businesses and schools…"

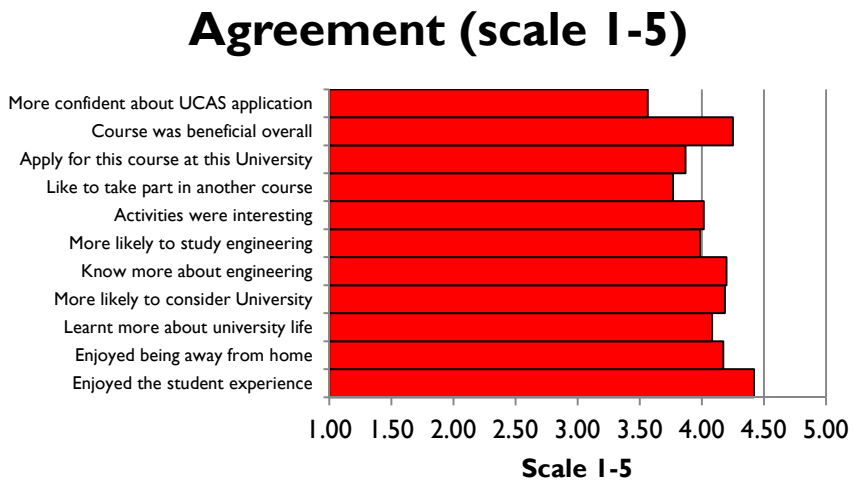
Headstart Cymru provides the opportunity to work closely with lecturers and postgraduates from several engineering departments. There is an opportunity to attend hands-on laboratory sessions to explore practical principles in engineering, as well as participating in group-based design, build and test projects. The universities also provide a programme of company visits to local engineering companies.

Students were asked to rate their satisfaction with the strand on a scale of 1 to 4 (with 1 equalling poor and 4 equalling excellent). The highest rated aspects were lecturer/student ambassador support (3.8), organisation, event overall and the evening activities (all 3.7). The lowest levels of satisfaction where recorded for the company visit (2.7, but above the mid-point of 2.5) and the campus tour (2.8).

Progress and Outcomes

Headstart Cymru provides students, probably for their first time, with an excellent insight into the different disciplines within engineering, enabling them to begin the process of deciding which course to study at university. When asked what they had gained from Headstart Cymru, one South Wales student summed up that they had learnt about… *' different types of engineering."*

Nevertheless, on a scale of 1 to 5 with 1 being strongly disagree and 5 being strongly agree (therefore the mid-point is 3) the mean score for I am more likely to consider going to University as a result of Headstart was 4.19. Furthermore, the average for being more likely to study engineering was 3.99 and an impressive 3.89 for I am more likely to apply to this University (highlighting that the effects mentioned previously are those of a minority). Indeed, of the 267 responses we have from students only 6 (2.2%) stated that they wanted to go to University to study a non-STEM based subject.



It is apparent that Headstart Cymru has a very positive effect on student's career maturity, but this may not always in ways that will directly benefit the host university. As interestingly, the small proportion of students that are dissuaded from studying engineering at university are well aware that understanding that they don't want to study at a university, or on a particular course, is a positive outcome from Headstart Cymru.

"After today I don't want to do materials science, but that's good as I now have a better idea." South Wales student
"[I am now]… more confident in electrical engineering as a career." North Wales student

In conclusion, Headstart is doing an excellent job at promoting the study of STEM subjects and engineering in particular, at a Welsh University. This is central to our arguments on the economic impact of STEM Cymru.

Headstart Cymru provides students with an insight into the different disciplines within engineering

The Awards Events

With Big Bang being integrated into the awards events, they now provide a full range of activities for young people, making them a strand with outcomes in their own right. Indeed around 3,000 young people attend these events including visitors, and are profoundly affected by them, but this is not captured by EESW as an outcome for STEM Cymru due to WEFO indicators.

All sessions attended were of high quality and utilised inspiring speakers. Also, during the awards events the Institute of Civil Engineers were building real suspension bridges with the students, who when they have finished actually walked across the bridge, in hardhats. Such a blend of learning styles and practical experimentation in solving engineering problems must have had a profound impact on the young people taking part, probably one that they will never forget. During the awards event at Venue Cymru the evaluator attended the Tomorrow's Engineers lectures, during which the three laws of motion were introduced. The audience was transfixed and all hands went up when questions were asked. A similar reaction was witnessed at the Celtic Manor when Dr Mark Lewney explained string theory applied to a guitar, to an audience of students.

When employers participating in EESW (6th Form) were asked to rate the awards event nearly three quarters said that it exceeded their expectations, with the remainder saying that it met them. This really does highlight the massive impact that the event is now having on Welsh industry and policy makers.

"This is a wonderful well organised event, very impressive." South Wales employer at Celtic Manor

Such is the prestige of the awards event that when IMechE wrote to their members asking them to assess EESW (6th Form) and they were inundated with the response, especially from former participants.

"… and we were turning people away… more and more people are actually saying, oh yes I remember doing that."

Gender Equality

The Enterprise and Business Committee (2014) commented that:

"The issue of gender differentials and progressions in STEM related subjects remains a priority of the Welsh Government."

This is enshrined in the guidance issued to schools and colleges by the Welsh Government (2014b):

"The guidance supports delivery of actions in 'Science for Wales' – including aiming to challenge gender stereotyping and address negative perceptions about STEM subjects."

Indeed, Chwarae Teg show that, in Wales, whilst 28.1% of males have a senior STEM job only 15.2% of females do so. Such issues were discussed by the Enterprise and Learning Committee (2011) who recommended that 'the Chief Scientific Adviser, through the National Science Academy, should evaluate initiatives aimed at addressing negative perceptions and gender stereotypes of STEM subjects and should promote good practice within the school system, starting at the earliest possible age.'

Whyte (2010) estimated that the economic impact of the loss of women in science to the UK economy is £2bn annually (based on the loss of female earnings associated with the economic inactivity of STEM graduates). With shortages of professional engineers in the Convergence Area, it is important to promote equality and diversity through STEM Cymru, to ensure that all those with an interest in engineering are provided with the opportunity to realise their potential.

"We need more female engineers." South Wales female student and winner of the UK Engineer of the Year

Unfortunately, many girls have expressed a dislike for STEM subjects (especially maths: Wang 2012:1) and a strong preference for art and English. Such attitudes manifest themselves as females move from primary to secondary school and whilst they are in secondary, tertiary and higher education (the National Grid 2009, found that 39% of boys in the UK were interested in an engineering career compared with 4% of girls). Hendley et al (1995) found significant differences in attitudes towards STEM between girls and boys in South Wales at Key Stage 3.

Based on feedback from the STEM awareness events, girls' least favourite subject on balance (taking those who dislike from those who like) is maths, followed by Welsh and French. The most popular subjects with girls are art, PE and history.

Research conducted in Cardiff (Watermeyer and Stevenson, 2010) suggested that negative attitudes can be challenged and changed. In addition, research across all STEM Cyrmu strands appears to contradict so

much of the research on girls' attitudes towards STEM. Indeed, some 76% of girls stated that science and single science is their favourite subject. Although 11% stated that maths was their least favourite subject, some 24% said it was their favourite. This evidence does seem to suggest that attitudes towards STEM are nothing like as strongly held as so much of the literature suggests, or at least they are rapidly becoming more positive.

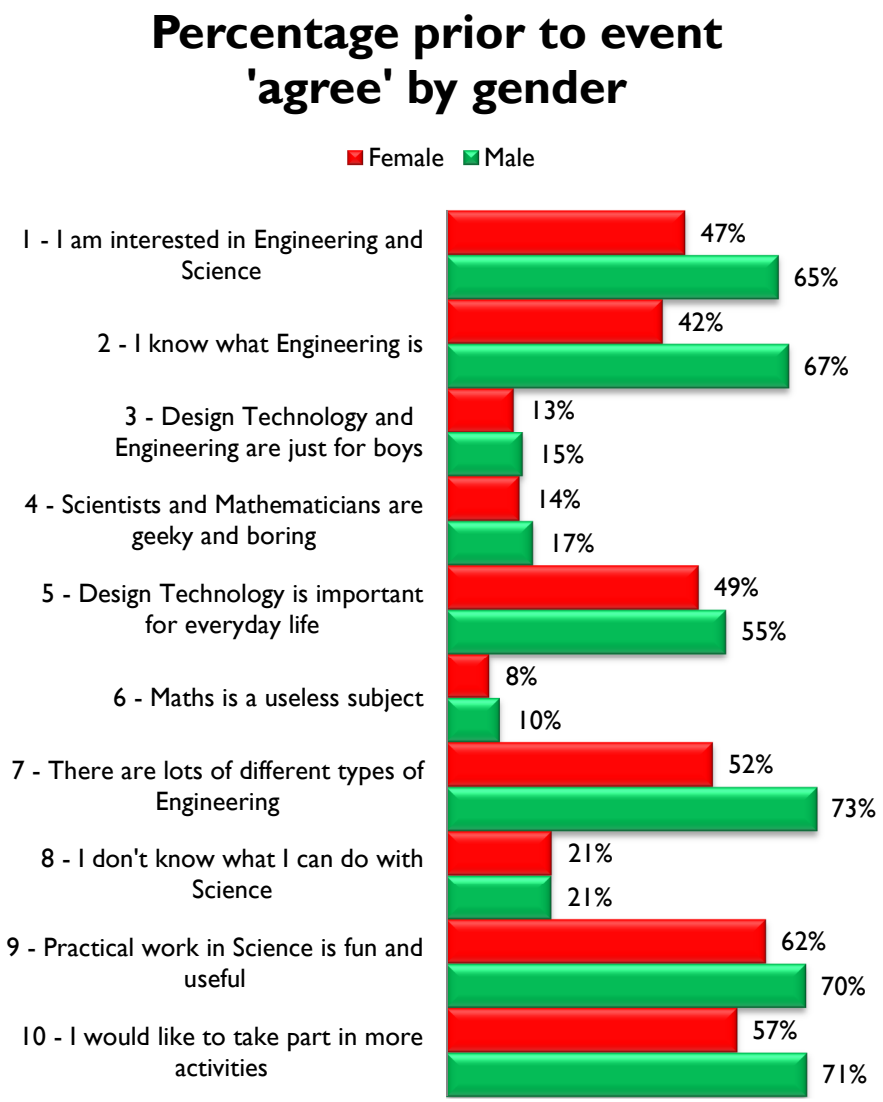
"The boys don't like us beating them." North Wales F1 all female team member
"I'm much more open to the idea of female engineers." Female student

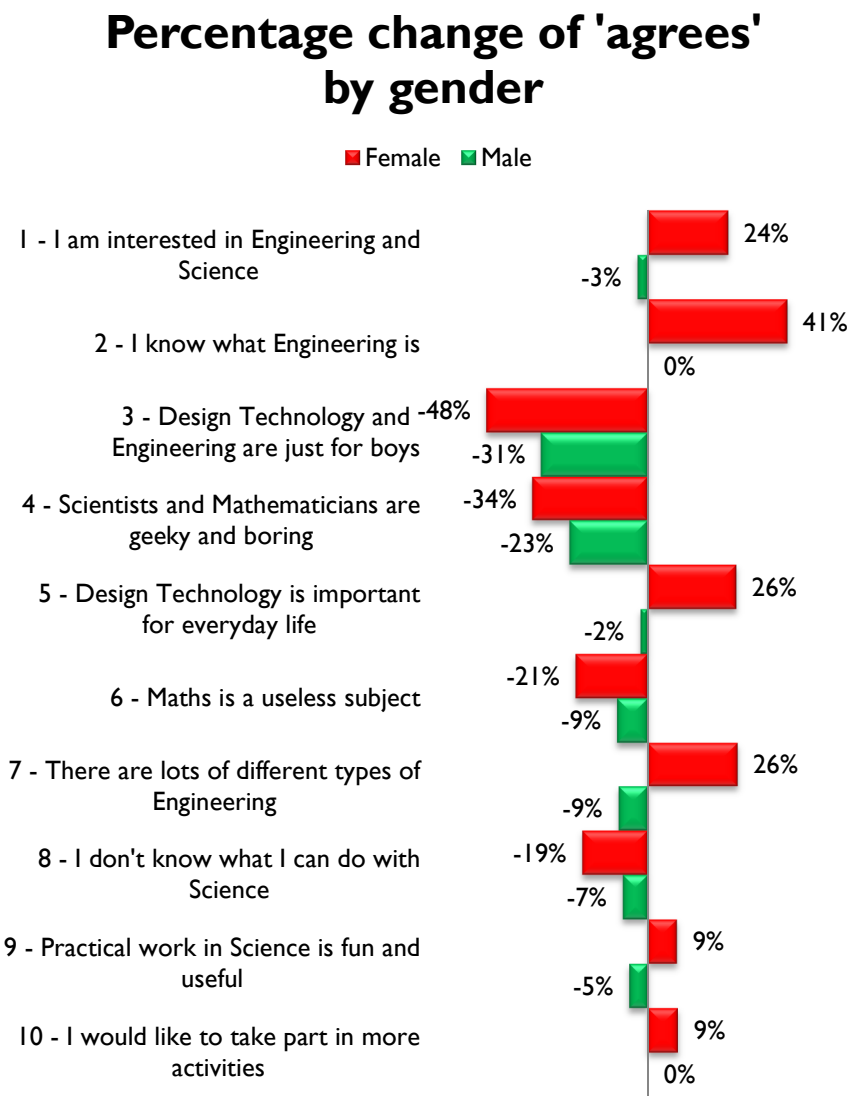
Of course, an alternative conclusion is that STEM Cymru is having a profound effect on females, which we certainly have witnessed. Indeed, evidence from the STEM Awareness Days does highlight the profound effects that STEM Cymru is having on females, by looking at the attitudes by gender prior to the event and the change in attitudes before and after the event.

Furthermore, comparing feedback from STEM Awareness Events some four-fifths of females want to study at University compared with just three-fifths of boys.

Despite this overwhelming evidence on the impact of STEM Cymru we still on balance conclude that attitudes are changing anyway, particularly amongst younger age groups.

This is borne out by analysis of the two following graphics which show that prior to an event males have more positive attitudes than girls. But that the events are having a greater impact on females (as shown in the second graphic). Naturally, if females have more negative attitudes prior to the event then there is a higher propensity to create positive change. Nevertheless, that the change is so strong reinforces just what a positive effect EESW is having on females that participate across their strands and in particular in Girls into Engineering.





Evidence from the US (Ellis and Andam, 2004) also identifies the high level of disengagement amongst females and points to the following problems with females leaving STEM educational programmes:

- *"Half of all women leaving engineering programs cited dissatisfaction with the programs at their schools, including grades, teaching, workload, and pace.*
- *One-third mentioned negative aspects of their school's climate: competition, lack of support, and discouraging faculty and peers.*
- *One-half said they left because they were not interested in engineering."*

STEM Cymru does much to encourage female students to participate in its project against the background of overall gender equality in Wales. Indeed, when engaging in teamwork across the various strands, it was noticeable how often female students took the lead. To an extent the success of these females has provided positive role models for future cohorts. In addition, it supports teachers in encouraging females into STEM, a critical factor noted by Chevin (2011):

"But by far the main issue seems to be the need for inspirational teaching."

Role models appear to have a greater impact on girls than boys, especially female role models (Lockwood, 2006). This suggests that initiatives like STEM Cymru can have a very positive impact on gender equality. In particular, STEM Cymru has been very active in providing female role models, which will help to break down the negative aspects of career salience.

"It is a way to specially motivate pupils, so much so that it is my goal to encourage more pupils from the coming school year and the next year." South Wales teacher describing Girls into Engineering

Regrettably, there are many negative factors (especially post schooling) which are beyond the control and influence of EESW, meaning that their interventions have to have a strong and, as much as possible, lasting impact.

Ethnicity

Whilst around 4.0% of the Welsh population are from a BME background this declines to only 3.2% in the Convergence Area, with the highest proportion residing in Swansea (4.7%) and the lowest in Blaenau Gwent (1.1%). In the main, these consist of people with origins in Asia, including Chinese, Indian, Pakistani and Bangladeshi and mixed ethnicity, especially amongst the young (and who often define themselves as Welsh, rather than through their minority ethnic background). As BME groups have a youthful age profile these percentages do increase for the target group, they nevertheless remain relatively small.

Teachers with BME students suggested that culturally they were more likely to favour STEM based careers.

"When you ask them [BME students] what they want to do, they say civil engineer or doctor." South Wales teacher

Indeed, Chinese and Indian students are overrepresented in STEM education compared to their white UK counterparts, whilst Caribbean and Bangladeshi students are under-represented in STEM education (Wynarczyk and Hale, 2009).

Recent research from the US (Goonatilake and Bachnak, 2012) suggests that summer schools like Headstart Cymru, can dramatically increase BME student's interest in STEM; in fact the evaluator witnessed the very positive impact of being taught by a BME lecturer on the motivation of BME students at a Headstart Cymru campus (a similar outcome to using female role models to support gender equality).

The Welsh Language

Although EESW does much to promote the Welsh language, some North Wales students believe that even more could be done by partners within the Welsh medium (although were certainly not criticising EESW on this point). In spite, of EESW offering translation services to all partners, some non-translated material will inevitably appear, especially at functions like the awards event. This is particularly important for activities taking place in Gwynedd (and especially the Llyn Peninsula and Bala areas). Nevertheless, there is a national problem highlighted by the Enterprise and Business Committee (2014):

"… in 2012 an average of 4 applicants per secondary posts for Welsh-medium [STEM] teaching, compared with 12 for English-medium."

In spite of the findings of the Enterprise and Business Committee (2014) there is evidence of the interest in STEM amongst Welsh speakers. Indeed, the STEM pavilion has been the most popular at the National Eisteddfod for the last five years.

Sustainability

i2E specifically requires students to work on an environmentally themed project. In fact, environmental issues are very popular with young people, and developing projects to address environmental issues really helps to motivate them. This feature was evident in the increasing numbers of environmental activities and projects the evaluators witnessed occurring within STEM Cymru. Pecan et al (2012) argue that renewable energy is an excellent tool for promoting STEM in rural areas, which may not have a tradition of employment in engineering.

"I have enjoyed designing and building the casting for the wind powered turbine… I really enjoyed seeing the turbine turn when it was completed as I had a sense of accomplishment." North Wales student

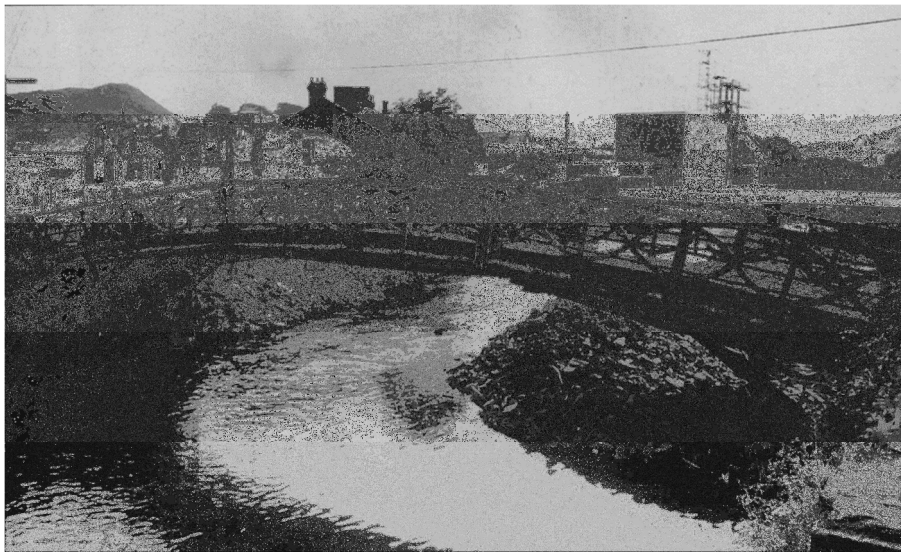
Many student projects in EESW (6th Form) had a strong environmental focus, and some of them could be developed to provide solutions to environmental problems, or new environmental products. Indeed, all those taking part receive a presentation and hand-out on sustainability issues. This is reflected in the large number of projects now with a strong environmental focus, especially renewable energy and waste reduction.

This is illustrated by one student who clearly has developed a strong appreciation of energy conservation and its potential societal impact.

"The environmental implications this system has is that it uses a lot less energy than it used to use making it an energy saving system because it is using less energy than using a lot less pressure which results in using a lot less water helping reducing the amount of water we are wasting. The social and commercial impact it has is that it could work in any type of car which would then make it more environmental friendly. [sic]" Student

A particularly interesting EESW (6th Form) project involved the reconstruction of the world's second iron bridge over the Taf Trail. This has created significant interest from conservationists and the local authority who will implement the students design.

Unfortunately, the reductionist nature of calculating economic benefits largely ignores the tremendous contribution STEM Cymru may have in promoting environmental sustainability. This is a long-term and largely unintended consequence, which nevertheless could be STEM Cymru's most profound impact over the years.



Economic Impact

Outputs and Outcomes

Outputs are the numbers of students who have received benefits from STEM Cymru, how this has impacted on them becomes the outcome (we are assuming that the final outcome for STEM Cymru is earning a living as a STEM professional). Attributing outcomes to outputs can be fraught with difficulty over the long-term, not least as students will have received a variety of interventions, which are often impossible to disaggregate (it is from this reason that most evaluation models identify intermediate outcomes and apply a benchmark to them to estimate the final outcome). At the heart of the issue is to what degree can we attribute an intervention at school to the career history of an individual, no matter how important that intervention may have been?

Such considerations are somewhat academic when there is such a body of evidence of the tremendous impact of STEM Cymru on students career paths and therefore, on the economy of the Convergence Area.

"Science, technology, mathematics and engineering are the bedrock for innovation in business and industry and the Welsh Government will continue to push forward links between these and education – helping young people get a real grasp of the real world of work." Carwyn Jones, First Minister (March, 2012 in Welsh Government 2014a)

"I think EESW was the key factor that I wanted to definitely do engineering, because when we first got the project, it felt and looked and sounded like the hardest thing I'd ever have to do… and it actually came out to be one of those rewarding things…" EESW (6th Form) student

For example, one young employer (with 4 employees and who is about to increase this to 10) attributed his decision to do something hands on to STEM Cymru, which cumulated in him starting his business in the Convergence Area, but with income from across the UK. We also know that four-fifths of students use their experience in the UCAS application personal statement, 63% on their CV, over a third on job applications and near two-fifths during interviews.

We have to see attempts at evaluating the impact of STEM Cymru as an attempt in systemising and quantifying what common sense tells us to be blatantly true. Inevitably, therefore such attempts to systemise the impact calculation appears crude and open to question based on evidence from qualitative case studies.

The Evaluation Framework

Translating outcomes to economic benefits is an attempt to quantify the value of the outcomes to the Convergence Area, by assessing the return on investment (ROI) from STEM Cymru. Central to the economic case for STEM Cymru's interventions is that it is encouraging students towards higher attainment and therefore better jobs. It will be successful if it encourages young people to become engineers rather than enter lower paid occupations.

"It [EESW (6th Form)] helped me to choose to do a degree." South West Wales university student

Commenting on specific activities aimed at teachers, rather than the whole STEM Cymru programme, 91% of teachers felt that it would increase pupils' interest in STEM subjects. Interestingly 68% felt that it would improve attainment (which is central to our economic agreement) and 85% that it would increase pupils' career awareness (again central to our economic agreement). This follows a logic which was identified by the First Minister, at the Celtic Manor:

"Physics and Chemistry graduates earn 30% more than other graduates over the course of their working lives."

Reiterating the Welsh Government (2012a):

"STEM graduates offer skills and knowledge that are highly valued in the labour market. Chemistry and physics graduates will earn, on average, 30 per cent more over their working lives than graduates in other subjects. The demand for STEM graduates is likely to grow significantly over the next few years."

A number of studies suggest that the economic returns for studying the physical sciences, maths, and engineering are higher than average. Although evidence has suggested that around one third of graduates fail to get a graduate-level job (McIntosh, 2005; Chevalier and Lindley, 2007), for STEM graduates, this is much less of a problem.

The following rather dated calculations were made by the Royal Society of Chemistry and the Institute of Physics to show the return on investment from a STEM degree. Engineering UK (2015) has some more recent data on starting salaries by graduate subject and pay progression, but these are not as important as lifetime additional earnings in calculating the economic benefits.

Subject	Additional Lifetime Earnings
Engineering	£219,971
Chemistry	£186,307
Physics	£188,249
Maths	£241,749
Biological sciences	£109,845
Psychology	£100,479
All degrees	£160,061
Arts degrees	£34,494
Source: The Economic Benefit of Higher Education Qualifications produced for The Royal Society of Chemistry and the Institute of Physics by PricewaterhouseCoopers LLP, January 2005	

Furthermore, these differentials are predicted to increase because it is forecast that 80% of new jobs will require math, science, and engineering, and 50% of the technical workforce will retire soon. This is a factor which appears to have entered the consciousness of young people and is gradually being reflected in an increasing uptake of STEM subjects.

"… knowing the jobs you can get from studying science." Female North Wales Student

However, most studies do not differentiate between the occupations a STEM graduate pursues, with some of the highest wage levels being paid by corporate law firms and the City of London. That such employers seek

out STEM graduates rather than those from business, or other subjects, is an accolade for the STEM curriculum, but could also represent a degree of leakage. Albeit reductionist, we are only concerned with the salaries of STEM professionals either living or working in the Convergence Area and not the higher salaries of STEM graduates working as solicitors, financial analysts and merchant bankers in London.

Unfortunately, the Annual Survey of Hours and Earnings does not provide reliable evidence, for Wales, at SOC 4 digit (the lowest level of disaggregation within Standard Occupational Classifications, but one that is necessary for such detailed calculations) to make meaningful calculations on STEM Cymru's likely future contribution towards GDP via employment income. What is available and reliable is contained in our Appendices and forms the basis of our calculations on the impact of STEM Cymru. Engineering UK (2015) have used the same data source, but only reported on SOC 4 digit occupations where the data is reliable, meaning that a lot is missing.

A less convincing approach is to look at the Gross Value Added (GVA) by those industries most likely to employ engineers compared with those who are least likely too. This is fraught with problems, as even a hotel chain may employ some maintenance engineers, whilst the bulk of people employed in utilities are administrative and customer service personnel. Also once again data is incomplete for Wales at a level to produce meaningful results. Again, what is available and reliable is contained in our Appendices and forms the basis of our calculations on the impact of STEM Cymru.

Applying to Framework

Looking at the difference in wages between STEM professionals and associate professionals (£30,692) non-STEM professionals/associate professionals (£29,320) this amounts to £1,371 per annum. This significantly lower differentiation representing the high wages paid to STEM graduates in non-STEM occupations. Again, see Appendices for the basis of these calculations, although these appear to contradict the findings of Engineering UK (2015), they are in fact, but as previously identified they are taken from the same data source and represent averages rather than selective individual occupations.

Using the Gross Value Added (GVA) for those industries most likely to employ engineers compared with those who are least likely too, we find that the GVA per employee for mining and quarrying, manufacturing, utilities and construction is £53,687, whereas for the rest of the economy it is £31,794. This would suggest that for every employee entering these industries the Welsh economy gains £22,892 per annum. See Appendices for the basis for these calculations.

Obviously many of the industries in the rest of the economy are supporting services which the productive industries rely on; however, as there are shortages of engineers across most of the productive industries it is not unreasonable to use this as the basis of our calculations on the economic impact of STEM Cymru.

The Skills Uplift calculation is in addition to these outputs and therefore normally needs to be treated separately. However, in the case of STEM Cymru we do not believe these other outcomes to be having an impact over and above other interventions. In other words we do not believe that the gaining of a CREST Award is significant to a young person's future career in isolation to the huge impact that a strand like EESW (6th Form) will have on them. We have therefore, not added Skills Uplift to the other two methods but takien an average across them. Because we are more confident in the wage differential method we have weighted this method as twice as important as the others in calculating our averages.

Nevertheless, Engineering UK (2015) identifies the impact of students studying STEM at an FE College and of undertaking an apprenticeship. These are increasingly important outcomes from STEM Cymru that our model has not included, in order to simplify our calculations. Bevertheless, we do believe and have seen the tremendous benefits that

STEM Cymru has had on some students in exposing them to potential rewards from an engineering apprenticeship.

Based on the 6,677 students that have received an intervention via STEM Cymru and the 1,582 other positive outcomes, it would suggest total benefit to the economy in the Convergence Area of £41.8m.
However, not all of those taking part will actually go on to science and engineering occupations, so we have discounted this to 72.9%, based on our EESW's longitudinal survey, where we track the actual numbers who go to University.

This needs to be further discounted to account for the depleting of future benefits that is students being blown off their trajectory into engineering by external factors. Based on the longitudinal survey we can identify those who go to University actually study a STEM subject (this is based on a very narrow definition of STEM and does not include subjects like IT and medicine, reinforcing our conservative approach to economic impact), this is 24.7% bringing the total to £8.1m.

We also have to take account of significant project deadweight, i.e. that the project has worked with young people who would have pursued a career in engineering regardless. Of course this does not mean that the project had no effect on these young people simply that in economic terms it is difficult to quantify. Based on responses to the EESW (6th Form) satisfaction survey we believe the deadweight to be 81% for this strand (we are only counting those students for whom STEM Cymru had a great influence), this is because the strand attracts a large proportion of students already dedicated to STEM. However, in other strands the deadweight will be significantly less and we have applied an overall deadweight of 50%. This would produce an economic impact of £4.0m.

In addition, there will be leakages from the project with engineers taking up jobs outside the Convergence Area and even Wales, netted by those from outside taking up jobs in the Convergence Area. Given the depressed state of the labour market in Wales and particularly in the Convergence Area we estimate this to be a net of 70%. This produces an impact of £1.2m

"I wouldn't see any reason to move to Cardiff, if the jobs weren't there." South West Wales employee

There are a number of more minor effects and the multiplier of 1.39 to consider bringing the total back to £1.2m. Finally we need to consider the effects of persistence and decay, which are treated differently between the GVA and Skills Uplift methods but bring the net impact to £8.7m.
Given the total funding of £2,876,594 for the project the leverage created by STEM Cymru is over 1:3! In other words for every £1 spend on STEM Cymru, £3 will be added to GVA in the Convergence Area.

Whilst there are many assumptions in calculating this figure, they are all derived from the Independent Evaluation Framework Guidelines. Although we would accept that some understatement of discounts is possible (in spite of our conservative approach), it is also the case that the students taking part are likely to add more value to the economy of the Convergence Area than the average student, or even the average worker in science and engineering based industries. Indeed, educational interventions normally have a greater impact than many other interventions and STEM Cymru is so precisely targeted on economic success. Overall therefore, we are of the opinion that this figure could be an understatement of STEM Cymru's true contribution.

We are therefore, confident in stating that the net impact of STEM Cymru on the economy of the Convergence Area is £8.7m and that for every £1 spent on STEM Cymru the Area gains £3 in benefits. This highlights the incredible value for money of STEM Cymru and other well targeted educational projects. It also supports further investment in STEM Cymru and programmes like it.

	Direct Estimate of GVA	Gross Impact in Terms of GVA	Skills Uplift	Weighted Average
Base	6,677	6,677	1,582	6,677
Base Impact	21,893	1,371	34,720	14,839
Impact	146,178,093	9,156,237	2,746,384	41,809,238
Gross Impact	26,341,292	1,649,954	2,746,384	8,096,896
Less Deadweight	13,170,646	824,977	1,373,192	4,048,448
Less Leakage	3,951,194	247,493	411,958	1,214,534
Less Displacement	2,769,787	173,493	288,782	851,389
Less Substitution	2,706,082	169,502	282,140	831,807
Times Multiplier	3,761,454	235,608	392,175	1,156,211
Persistence	37,614,537	2,356,082	980,437	10,826,785
Decay	30,467,775	1,908,427	643,424	8,732,013
Total	**30,467,775**	**1,908,427**	**643,424**	**8,732,013**

Case Studies

Dr Ben Evans

Ben is currently a lecturer in aerospace engineering at the College of Engineering, Swansea University. He is also a part of the engineering design team for the Bloodhound Supersonic Car.

The most significant effect on Ben studying STEM was his physics teacher (Mr Evans) at Bishopston Comprehensive, prior to which he was an all-rounder. Bishopston Comprehensive doesn't have a VI Form so he moved to Gorseingnon College. It was here that he developed an interest in engineering.

"At 16 I was pretty clueless about what engineers did, I really wanted to become a pilot."

During his A Levels Ben took part in the EESW (6th Form), not then funded through ESF.

"I did it to look good on my cv, but I was still thinking of doing Science at Cambridge."

Ben worked with BP at Baglan solving a flow management problem, which gave rise to his interest in engineering.

"I think the process made me realise that if I did engineering it would open up more doors."

Prior to going to Cambridge, Ben took part in an EESW's Year in Industry programme working in production for Valeo. The experience of working in manufacturing made him realise that he really wanted to work in research and development.

"That year put me off anything to do with manufacturing."

EESW therefore was fundamental in Ben's choice of studying engineering and contributed to his career maturity by demonstrating to him which areas of engineering he liked best.

"I grew up an awful lot."

Overall Ben believes that it is difficult to isolate the effect of EESW from other contributors, such as teachers. Nevertheless he does believe that EESW was the biggest influence on him choosing engineering.

Prior to moving back to the Convergence Area Ben 'knew nothing about the University', but was delighted to find a Department engaged in 'world class research'.

Now Ben both lives and works in the Convergence Area, contributing towards the GVA of Swansea University. He contributes through applied research and accessing research grants, he will also contributing to the GVA of the engineering sector through commercialisation of inventions for Bloodhound. Furthermore, if Bloodhound is a success the contribution it would make to the reputation of British engineering would be immense, some of which would flow to the Convergence Area.

"Bloodhound being successful is getting a new world speed record and the rivals not beating it."
"Blood would open all sorts of doors that are quite unpredictable."

Ben has been successful in generating the following research income:

2012 Ingenious public engagement grant from the Royal Academy of Engineering (£21,760);
2010 Swansea Academy of Learning and Teaching Grant (£2,200).

In addition, he has contributed to numerous learned journals which may have some commercial application.

Ortho Clinical Diagnostics

Ortho Clinical Diagnostics provide total solutions for screening, diagnosing, monitoring and confirming diseases. They serve the transfusion medicine community and laboratories around the world. The Pencoed factory is a part of Johnson and Johnson's Medical Devices and Diagnostics Division.

Being a production facility producing high quality products critical success factors for the Pencoed factory are process control and innovation, to reduce costs and enhance the range. These are achieved through a well-educated (around 30% are graduates) and motivated workforce.

Ortho Clinical Diagnostics involvement with STEM Cymru is via the EESW (6th Form), which they normally provide prizes and projects for. Clearly in providing these projects the company is contributing to the overall impact STEM Cymru has on students in the Convergence Area.

But in the main, their involvement is for the greater good of engineering and Wales, as Kevin Doran, the Engineering Manager, said:

"There's nothing in it in the short-term for us."
"There's huge support for this amongst my team."

Certainly, they lose contact with students after the project and none have subsequently applied for jobs at the company. Although as Kevin recognises that at some point they may want to return to Wales, as he did and then they may apply to the company.

"I've worked all over the country and came back to Wales."

One potential benefit is the effect on morale of employees taking part in the project.

"Everyone who's done it sees it as a very positive experience."

In addition, the company is about to launch a Higher Apprenticeship Scheme, which EESW will be supporting. The reasons for this Scheme are twofold. Firstly the company find it difficult to recruit graduate engineers with the skills required (both technical and soft).

"Trying to compete on completion of University is difficult."

Secondly the company would prefer to inculcate young engineers with their desired behaviour and work practices prior to this being formed at university.

"There is an opportunity when they are 17-18 to pull high potential individuals from the system and develop the skills and values that we specifically need."

Magnox

Energy Solutions has contracts with the Nuclear Decommissioning Authority for the operation and management of its ten Magnox nuclear power plant sites, which are operated by Magnox. Under these contracts, they are responsible for the operation, defueling, and decommissioning of those sites. Magnox is owned by Energy Solution of the US.

The Nuclear Decommissioning Agency has a duty to minimise the socio-economic impact of decommissioning by:

- considering the socio-economic impacts of its activities ;
- give encouragement and support to the local community;
- make grants and loans within the community.

Through their service contract Energy Solutions and therefore Magnox have responsibility for implementing the socio-economic support. Furthermore, Wylfa is the site with moderate potential for a negative socio-economic impact on the immediate area. Indeed the loss of the 600 jobs at Wylfa would reduce the area'ms GVA by £77m, not considering

the multiplier effects and the losses already resulting from the closure of Anglesey Aluminium, which benefitted from cheap nuclear power.

Engagement with STEM Cymru is formally through the EESW (6th Form) of STEM Cymru and involved in many aspects of delivery. This engagement is a part of the socio-economic support and many of their activities would continue without EESW and STEM Cymru. Nevertheless, EESW's contacts with education do provide a quick means of Wylfa engaging with schools and the local community.

Although the commitment to promoting engineering within the local community is deeply felt by many at Wylfa and is more than simply as responsibility.

"There are a few of us who are supportive because we remember where we came from."

Kronospan

Kronospan is the UK's only fully integrated producer of wood based panel products, so they're able to control every detail of every part of every process. Kronospan was established in 1897 as an Austrian family company, now it is the world's largest wood-based panel manufacturer. Kronospan in Wales opened in 1970, making it the company's first overseas venture. From Wales it distributes panels to the UK and Ireland and has some exports where British architects have specified their products, for example in the Middle East.

Kronsopan are vertically integrated and even grow their trees, therefore, their critical success factor is productivity. Higher productivity is derived from process improvement and high staff morale.

Kronsopan's involvement with STEM Cymru is through its involvement in the EESW (6th Form), with schools from inside the Convergence Area.

Kronospan do work with local schools and take on apprentices, but the Engineering Scheme hasn't fed directly into this. Nevertheless engagement with STEM Cymru must have some positive effects on apprentice recruitment, if only through positive public relations.

The most recent EESW (6th Form) project has been implemented by the company. It was to develop a system to reduce change over times. Change over now takes one person two minutes instead of two people 30 minutes. Change overs occur on average twice a week so the man hours saved in a year is 97 hours (28 mins * 2 * 2 * 52).

Siemens

Siemens was established in the United Kingdom 169 years ago. The company employs around 13,000 people in the UK, including about 5,000 in the manufacturing sector. Last year's revenues were £4.4b.

Siemens Healthcare Diagnostics have 550 staff based in Llanberis. The Siemens facility in Llanberis manufactures and distributes IMMULITE reagents used on blood analysers in hospitals and clinics worldwide to aid the diagnosis of medical conditions. The reagents are consumables used in Siemens products produced in the USA, which are sold through an international sales force. Llanberis therefore, represents a manufacturing unit within the wider Siemens supply chain.

As a manufacturers of high quality products, process control and process improvement are critical to the company's success. Whilst many jobs are comparatively low skilled, all staff are trained in a wide range of continuous improvement techniques. There are, also a number of highly skilled (often PhD) level bio-medical professionals employed and five engineering professionals.

Siemens engaged with STEM Cymru through the EESW (6th Form), but this year are also involved in F1. Their reasons, like so many businesses involved, are entirely altruistic. It is unlikely that any student involved with the project will at a later date apply for employment at Siemens. As Daniel Williams the Engineering Manager put it:

"Generally it's the right thing to do."
"We're not doing this because we think we need a skill today."

Siemens believe that they have a responsibility to their local community and local schools. By providing local students with real world problem solving techniques they are aiding their career maturity.

"A part of the problem with students is that they are forced to makes choices about FE and careers, but they have no experience to base it on."

Siemens are therefore contributing an important element to the logic chain of STEM Cymru.

The project has resulted in a new production aide that Siemens will implement. It is more for preventative reasons that solving an immediate problem, but it could be argued that the aid will ensure that £'000s of wastage does not occur. Perhaps even more tenuous is that such wastage could mean a line going down and unsatisfied customers which give the role of the Llanberis factory in the global supply chain could have major monetary consequences.

General Dynamics UK

Industry

General Dynamics UK Limited is a leading prime contractor and complex systems integrator working in partnership with government, military and civil forces and private companies around the world.

General Dynamics UK has 50 years' experience in manufacturing and contract management skills to deliver C4I communications solutions, Armoured Fighting Vehicle (AFV) technology, security systems for critical national infrastructure and deployable infrastructure.

General Dynamics UK has 11 world-class facilities across the UK and internationally with over 1,650 employees of which 769 are employed in South Wales. Although they employ a spectrum of engineering professionals, the majority are systems engineers.

General Dynamics UK take part in a range of STEM Cymru activities and broader STEM activities. Indeed, a team at General Dynamics UK is dedicated to educational engagement and promoting engineering to young people. This commitment is largely altruistic and despite recruiting engineering graduates from Cardiff University there is no link to recruitment. Furthermore, General Dynamics UK is about to start an apprenticeship programme, which will inevitably link into STEM Cymru.

Nevertheless General Dynamics UK is actively involved in STEM activities, as they are committed to encouraging young people to consider engineering as a career. As a defence company, for many of roles, they are only able to employ UK nationals, and so it is important for them to do all they can to ensure we have that future pool of talent available.

Schaeffler (UK) Ltd

Industry

The Schaeffler Group with its product brands INA, FAG and LuK is a leading manufacturer of rolling bearings and linear products as well as a supplier to the automotive industry of high-precision products and systems for engines, transmissions and chassis applications. With around 74,000 employees worldwide, the Schaeffler Group is one of the largest German and European industrial companies in family ownership.

INA was incorporated in 1955; with the facility at Bynea producing INA branded tappets for the global automotive industry.

Engagement with the local community, schools and promoting engineering is very much tied in with Schaeffler's commitment to continuous improvement and indeed as winners of the Welsh Quality Award it is a requirement. As Derrick Lewis the Technology Director put it:

"The company's image is important to us in the community."

A part of their commitment also comes from being a privately owned German company and a commitment from the Plant Director to Welsh engineering.

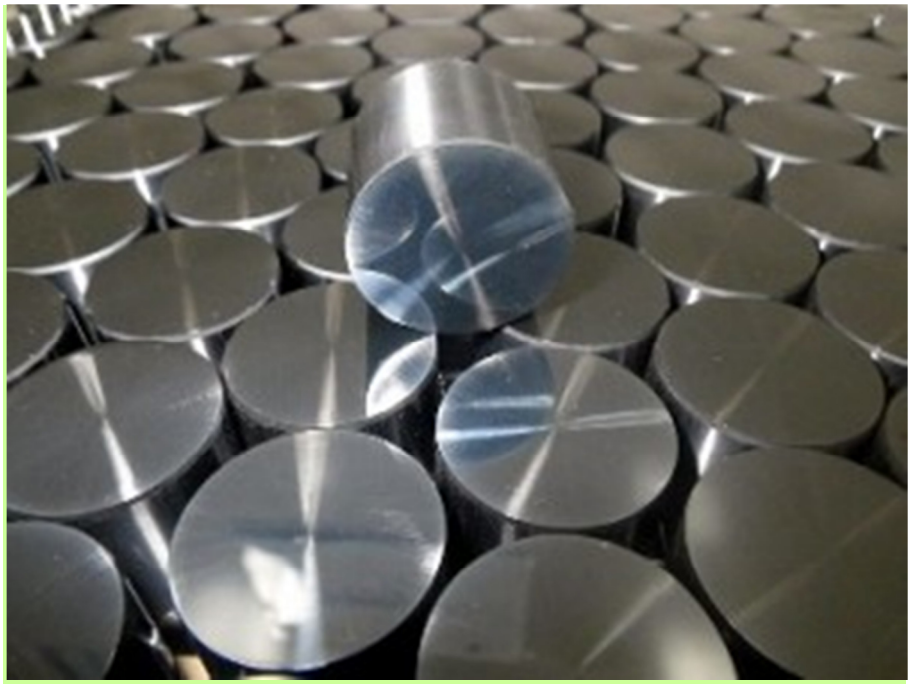
"The Plant Director is Welsh at heart and keen to do things for Wales."

In the main their involvement has been on the EESW (6th Form) and they have provided projects for a number of years. Many of the results of the projects have been implemented in the factories production.

"Throughout the years there have been a number that we have implemented."

A recent provided an innovative solution for identifying oil in the cooling towers. Although largely a preventative measure its implementation would reduce, the already miniscule, chance of an outbreak of legionella. The damage to the company's reputation for far outweighs the likely cost of fines and a court case.

The company recruits apprentices locally, although have not directly recruited anyone from STEM Cymru. However, the support EESW (6th Form) has given is in helping school engagement and in promoting Schaeffler as a good company to work for.



Appendices

Methodology

Originally designed for a three year project the methodology was adapted for the full five years. In order to maximise the value for EESW the evaluators relied heavily on naturally occurring management information, analysis of surveys conducted by EESW and informal research methods, such as semi-structured interviews taking place during the delivery of the strands. Overall the methodology can be summarised as:

- Analysis of management and other secondary information (including demographics on 6,677 participants).
    - Survey based data from 3,102 students, 66 teachers and 101 employers (where possible amalgamated into a time series dataset).
- 4 stand-alone focus groups (2 students, 1 university students who had participated whilst at school or college, 1 employer group who had participated as students themselves).
- 11 in-depth case study interviews.
- Around 2,000 semi-structured interviews with students, teachers, partners, employers and EESW employees.
- Observation and participant observation at around 100 events, incorporating a variety of informal research techniques.

Economic Evaluation Framework

The Independent Evaluation Framework (IEF) was developed to assess the economic impact of the now disbanded (English) Regional Development Agencies (it is outlined in DTI, 2006). It has been criticised for being overly prescriptive and reductionist, therefore its results are just one element of the total impact of STEM on a Region. However, as the Head of the Evaluation Unit at the EU (Mairate, 2006) observes, such a framework is preferable to ad hoc techniques. Whilst Wynarczyk and Hale (2009) point out that, in the main, STEM evaluations lack rigour:

"Limited studies, evidence and evaluation of STEM initiatives, grants and schemes that currently exist are largely based on views expressed and comments made by teachers and pupils who have participated in their initiatives and… as opposed to any serious attempts to measure and demonstrate the real impact on reducing the drop out and better achievements in STEM subjects. There has been no major survey of schools and colleges that have participated in different initiatives and schemes, let alone those which have instigated their own innovation measures and interventions. It is only through such investigations that successful interventions, initiatives, bodies and schemes can be identified and promoted."

A point also identified by the Science Advisory Council for Wales (2012):

"The National Science Academy should develop an appropriate evaluation template for use in all funded projects to collect data and monitor quality of provision. Expert or academic help may be needed to design this. The National Science Academy should consider independent assessment of higher value projects, to ensure impact and value for money, and to help steer future funding calls."

IEF provides three methods for calculating the economic impact of a project on Gross Value Added (GVA, a major component of GDP), which we can adapt for measuring the economic impact of STEM Cymru, these are:

Direct Estimate of GVA

GVA = OP + EC + De + Am

Where:

OP = Operating Profit
EC = Employee Costs
De = Depreciation
Am = Amortisation

Gross Impact in Terms of GVA

GI = GVA in last complete financial year – GVA in the last complete financial year before receiving support.

GI = Number of fulltime equivalent employee jobs at end of last complete financial year - Number of fulltime equivalent employee jobs at end of last complete financial year prior to support.

The net impact should be estimated by:

NI = GI – GI*

(Note this would need to be adjusted for leakage, displacement, substitution and multiplier effects)

Where:

GI* = Number of fulltime equivalent employee jobs at end of last complete financial year x Factor to indicate amount of these fulltime equivalent employee jobs that would have existed in last financial year without the support – Number of fulltime equivalent employee jobs at end of last complete financial year prior to support.

The next stage is to quantify these jobs in terms of GVA. This can be done using the information on GVA per worker for the relevant region.

Individual Gross GVA Impact Due to Skills Uplift

Annual individual Gross Impact in terms of wages = Level of salary/annual wage just before he/she received the training support x.

This is then adjusted to the following levels of impact:

15% – Up to NVQ Level 2

or 5% – Up to NVQ Level 3

Annual individual Gross Impact in GVA = Annual individual Gross Impact in terms of wages x Regional GVA.

The IEF and IEF+ Framework use the following conventions in calculating economic impact:

Gross outputs/ outcomes	The total outputs achieved by the intervention.
Deadweight	The proportion of total outputs/outcomes that would have been secured anyway without the intervention in question.
Leakage	The number or proportion of outputs/outcomes that benefit those outside the target area of the intervention. In this study, two target areas have been used – the sub-regional level and the regional level.
Displacement	The proportion of outputs/outcomes that are reduced elsewhere in the target area. These effects can occur in product markets (e.g. among non-assisted businesses) or in factor markets (e.g. in the labour market). In this study, only product market displacement has been quantified.
Substitution	As defined by the IEF, this effect arises where, say, a firm substitutes a jobless person to replace an existing worker to take advantage of the public sector assistance.
Multipliers	Further economic activity associated with additional income to those employed by the project (income multipliers), with local supplier purchases (supplier multipliers) and with longer term development effects (dynamic effects e.g. induced inward migration).
Unintended consequences	Consequences that were not anticipated for the targeted outputs and outcomes. The unintended effects may be on non-targeted outputs and outcomes, but may still have adverse effects on sustainable economic development.

Net Impact

The IEF introduces the concept of Net Impact which is the Additionality of Intervention less the Counterfactual/Deadweight (see BIS, 2009:1) and can be expressed as:

NI = [GI x (1L) x (1Dp) x (1S) x M] – [GI* x (1L*) x (1Dp*) x (1S*) x M*]

Where:

GI = Gross Impact
L = Leakage
Dp = Displacement
S = Substitution
M = Multiplier

* Indicates the counterfactual situation

At all times it is assumed:

L = L*
Dp = Dp*
S = S*
M = M*

Within the IEF, STEM Cymru would be classified under the People and Skills Theme and the Supporting the Development of Educational Infrastructure Sub-Theme. In BIS (2009:2) the following benchmarks were published for the Supporting Development of Educational Infrastructure Sub Theme:

IEF + Benchmark		
Variable	**%**	**+/- 95% Confidence Level**
Deadweight	38.6	21.3
Leakage	29.9	14.6
Displacement	13.8	6.8
Substitution	2.3	4.8
Multiplier	139	13.4
Net Additionally	46.0	18.0

The guidance suggests that these benchmarks can be used when there is insufficient evidence from the project itself to calculate them.

In addition, for Supporting the Development of Educational Infrastructure it is assumed that benefits last for ten years, but decay at a rate of 10% per annum.

Calculating the Impact

In calculating the Economic Impact we have used the following assumptions:

STEM Cymru	Assumption	Source	Rationale
Gross outputs/ outcomes	82.0%	Management Information and Longitudinal Survey	72.9% Going to University * 24.7% Studying STEM
Deadweight	50.0% overall (based on 81.00% for EESW 6th Form)	Longitudinal Survey	Only those stating STEM Cymru had a great influence on their current situation are not included as deadweight
Leakage	32.2%	Longitudinal Survey	All those studying outside Wales assumed not to return to Convergence Area
Displacement	29.9%	IEF Guidance	This would include the effect of displacing Convergence Area students on Welsh STEM degrees with supported students from the Convergence Area
Substitution	2.3%	IEF Guidance	This would include those students substituting STEM subjects with STEM related subjects like medicine and ICT
Multipliers	1.39	IEF Guidance	The effects of wages being spent in Convergence Area by beneficiaries living in Convergence Area and on businesses of beneficiaries working in Convergence Area
Unintended consequences	0.0%		
Net additional outputs/outcomes of the intervention at different spatial levels.	0.0%		

Earnings by occupation for Wales are:

Table Annual pay - Gross (£) - For all employee jobs: Wales	2010					2011					2012				
Description	Number of jobs (thousand)	Median	Annual percentage change	Mean	Annual percentage change	Number of jobs (thousand)	Median	Annual percentage change	Mean	Annual percentage change	Number of jobs (thousand)	Median	Annual percentage change	Mean	Annual percentage change
WALES, PROFESSIONAL OCCUPATIONS	130	33,144	1.3	34,977	0.9	129	32,424	-2.1	34,615	-1.1	184	31,300	2.2	32,732	-1.8
Wales, Science And Technology Professionals	28	32,364	-1.8	33,701	-3.7	27	34,187	5.2	35,104	3.7	28	33,286	3.3	34,594	-2.8
Wales, Health Professionals	8			76,058	20.8	8			68,244	-10.2	57	29,387	1.2	32,452	-4
Wales, Teaching And Research Professionals	68	33,953	0.9	31,785	-0.3	66	33,894	-0.1	31,963	0.6	59	35,013	1.7	33,017	2.2
Wales, Business And Public Service Professionals	27	29,718	3.8	32,381	3.6	27	29,309	-0.1	30,883	-4.5	41	30,509	4.8	31,452	4.8
WALES, ASSOCIATE PROFESSIONAL AND TECHNICAL OCCUPATIONS	139	26,412	2.4	27,220	0.3	141	26,879	1.7	27,185	-0.3	119	25,522	2.1	27,077	3.7
Wales, Science And Technology Associate Professionals	20	24,974	0	25,330	-3.3	20	25,852	4.7	27,289	7.9	27	24,244	1.3	25,876	2.6
Wales, Health And Social Welfare Associate Professionals	58	25,700	2	26,209	2.2	58	26,575	3.4	26,325	0.5	14	21,553	2.8	21,761	0.5
Wales, Protective Service Occupations	15	36,433	2.1	35,245	0	14	36,377	1.3	35,822	3.3	16	37,208	3.4	34,454	-3.9
Wales, Culture, Media And Sports Occupations						7	20,978		20,654		6	x		20,493	-1.11
Wales, Business And Public Service Associate Professionals	39	26,004	4.2	27,119	2.7	43	25,400	-2.8	26,673	-3.2	56	25,216	4.9	27,522	6.5

Table Annual pay - Gross (£) - For all employee jobs: Wales	2013					2014					Average				
Description	Number of jobs (thousand)	Median	Annual percentage change	Mean	Annual percentage change	Number of jobs (thousand)	Median	Annual percentage change	Mean	Annual percentage change	Number of jobs (thousand)	Median	Annual percentage change	Mean	Annual percentage change
WALES, PROFESSIONAL OCCUPATIONS	201	31,678	1.2	33,333	1.8	206	32,072	1,3	33,584	0.8	170	32,124	0.7	33,848	0.1
Wales, Science And Technology Professionals	31	34,154	2.6	34,521	-0.2	34	35,465	3.8	35,704	3.4	30	33,891	2.6	34,725	0.1
Wales, Health Professionals	65	29,598	0.7	34,450	6.2	62	29,787	0.4	34,354	-0.4	40	29,591	0.8	49,112	2.5
Wales, Teaching And Research Professionals	61	34,204	-2.3	32,698	-1.0	62	35,482	3.8	33,505	2.7	63	34,509	0.8	32,594	0.8
Wales, Business And Public Service Professionals	44	31,110	2.0	31,725	0.9	48	30,407	-2.2	31,156	-1.6	37	30,211	1.7	31,519	0.6
WALES, ASSOCIATE PROFESSIONAL AND TECHNICAL OCCUPATIONS	124	25,746	0.9	27,607	2.0	126	26,633	3.7	28,019	1.4	130	26,238	2.2	27,422	1.4
Wales, Science And Technology Associate Professionals	28	25,320	4.4	26,483	2.3	27	27,562	8.5	28,463	6.8	24	25,590	3.8	26,688	3.3
Wales, Health And Social Welfare Associate Professionals	15	22,384	3.9	22,836	4.9	15	21,746	-2.8	21,983	-3.4	32	23,592	1.9	23,823	0.9
Wales, Protective Service Occupations	16	36,854	-1.0	35,226	2.2	17	33,351	-9.4	32,962	-6.3	16	36,045	-0.7	34,742	-0.9
Wales, Culture, Media And Sports Occupations	8	0		18,537	-9.5	6	20,637		20,647	11.6	7	20,808		20,083	0.3
Wales, Business And Public Service Associate Professionals	58	25,472	1.0	28,516	3.6	62	26,422	3.7	28,595	0.2	52	25,703	2.2	27,685	2.0

Whilst the GVA by industry in Wales is as follows:

Wales	2010			2011			2012		
	Employees	GVA £m	GVA/ Employee £	Employees	GVA £m	GVA/ Employee £	Employees	GVA £m	GVA/ Employee £
Agriculture, forestry and fishing	37,400	221	5,909	35,500	259	7,296	35,600	296	8,315
Mining and quarrying	1,800	83	46,111	2,400	96	40,000	2,200	115	52,273
Manufacturing	129,000	7,482	58,000	135,400	7,784	57,489	130,300	7,920	60,783
Electricity, gas, steam and air conditioning	6,400	822	128,438	7,600	916	120,526	6,600	973	147,424
Water supply	9,400	978	104,043	10,000	948	94,800	12,500	991	79,280
Construction	91,000	3,192	35,077	88,100	3,280	37,230	89,700	3,204	35,719
Wholesale and retail trade; repair of motor vehicles and motorcycles	336,800	7,524	22,340	337,000	7,892	23,418	342,000	8,515	24,898
Information and communication	27,300	1,303	47,729	25,900	1,289	49,768	25,900	1,493	57,645
Financial and insurance activities	29,300	2,078	70,922	32,800	2,019	61,555	30,900	2,169	70,194
Real estate activities	14,300	4,622	323,217	17,300	5,126	296,301	18,500	5,737	310,108
Professional, scientific and technical activities	142,600	3,284	23,029	141,300	3,199	22,640	136,400	3,610	26,466
Public administration and defence and health	409,700	11,725	28,619	418,200	12,221	29,223	417,200	13,391	32,097
Other service activities	66,600	1,211	18,183	71,300	1,419	19,902	71,500	1,818	25,427
Column Total	**1,301,600**	**44,524**	**34,207**	**1,322,900**	**46,450**	**35,112**	**1,319,300**	**50,233**	**38,075**

Migration Advisory Committee Skill Shortages that have Appeared for Four Years or More		
Job title	**SOC 2010 occupation**	
Geophysical specialist	2113	Physical scientists
Geophysicist		
Geoscientist		
Hydrogeologist		
Geomechanical engineer	2121	Civil engineers
Geotechnical design engineer		
Geotechnical specialist		
Engineer, petroleum		
Engineer, reservoir, panel		
Engineer, rock mechanics		
Engineer, soil mechanics		
Engineer, tunnelling		
Engineer, chemical	2127	Production and process engineers
Engineer, plastic		
Consultant within: genitourinary medicine, haematology, neurology, occupational medicine	2211	Medical practitioners
Consultant within: forensic psychiatry, general psychiatry, learning disabilities psychiatry, old age psychiatry		
Specialist nurse working in operating theatres	2231	Nurses

Careers Wales STEM Skills in Demand in Wales		
Health	24% of health establishments in Wales report skills gaps, particularly for:	
		Consultants in certain specialities
		Pharmacists
		Dental Practitioners
		Specialist Nurses and Therapists
The Life Sciences		Chemistry
		Pharmacology
		Toxicology
The Energy, Low Carbon and Utilities sector		Skills in low carbon energy generation
		Design roles e.g. Systems Design Engineer (QCFW levels 6-7)
		Technical roles e.g. Engineering Craft Technician (level 3)
		Coordination and control roles e.g. Project Controller (QCFW level 3) and Construction Site Manager (QCFW level 4)
		Sub-sea roles (Wind & Marine) e.g. Sub- Sea Structures Design Engineer (levels 6-7)
The Nuclear industry	New technologies and increasing regulation will result in skills gaps. The possible development of new nuclear sites, will create job opportunities in advanced manufacturing, engineering construction and construction trades, regulation, nuclear operations, power generation and plant maintenance. These opportunities will be for graduates, postgraduates and apprentices. The decommissioning of old nuclear power stations will mean increased demand for specialist decommissioning skills.	
ICT and Telecommunication	Systems Design and Development Professionals are the most in demand. The technical skills most in demand by employers are:	
		SQL
		.NET
		C#, SQL Server
		ASP
		JavaScript
		Java
		PHP
		HTTP
		Visual Basic
The Creative and Cultural Sector		Broadcasting Engineering

		Visual Effects (VFX)
		Graphic Design in advertising and design business
		Skilled Archaeologists
		Design and Textile Technology
Source: http://www.careerswales.com/en/tools-and-resources/job-trends/science-technology-engineering-maths		

Bibliography

Allison, C. and Cossette, M. (2007) **Three Theories of Career Development and Choice 1 (Literature Review) Proven Practices for Recruiting Women To STEM Careers in ATE Programs, Lynnwood**, WA, Edmonds Community College.

Beard, L., Ciesielski, P. and Hijazi, F (2010) Leaving their Legacy: A research experience and teaching module to maximize STEM learning for students, **The Science Teacher,** April/May.

Beede, D., Julian, T., Langdon, D., McKittrick, G., Khan, B., and Doms, M. (2011) **Women in STEM: A Gender Gap to Innovation,** Washington, DC, U.S. Department of Commerce, Economics and Statistics Administration.

British Educational Research Association (2011) **Ethical Guidelines for Educational Research,** London, BERA.

Business Higher Education Forum (2010) **Increasing the Number of STEM Graduates: Insights from the U.S. STEM Education & Modeling Project,** Washington, DC, Business Higher Education Forum.

Butt, S., Clery, E., Abeywardana, V., and Phillips, M. (2010) **Wellcome Trust Monitor 1.** London: Wellcome Trust.

Chevin, D. (2011) 'STEM - Minority report', **Times Educational Supplement** (20 May, 2011).

Christenson, S., Reschly, A. Wylie, C. (eds.) (2012) **Handbook of Research on Student Engagement,** New York, Springer.

Department of Business Innovation and Skills (2009:1) **RDA Evaluation: Practical Guidance on Implementing the Impact Evaluation Framework,** London, BIS.

Department of Business Innovation and Skills (2009:2) **BIS Occasional Paper No. 1: Research to improve the assessment of additionality,** London, BIS

Department for Trade and Industry (DTI) (2006) **Evaluating the Impact of England's Regional Development Agencies: Developing a Methodology and Evaluation Framework,** London, DTI.

Donaldson, G (2015) **Successful Futures: Independent Review of Curriculum Assessment Arrangements in Wales,** Cardiff, Welsh Government.

Ellis, G. and Andam, B. (2004) 'Designing the Engineering Classroom for Women', in **American Association for the Advancement of Science Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education**, 79-84, Washington, DC. American Association for the Advancement of Science.

Engineering UK (2015) The State of Engineering, London, Engineering UK.

Enterprise and Business Committee National Assembly for Wales (2014) **Follow-up Inquiry into Science, Technology, Engineering and Mathematics (STEM) Skills,** Cardiff, Welsh Government.

Gibbs, G. (1988) **Learning by Doing: A Guide to Teaching and Learning Methods,** Oxford Polytechnic, Further Education Unit.

Goonatilake, R. and Bachnak, R. (2012) Promoting Engineering Education Among High School and Middle School Students, **Journal of STEM Education,** 13, 1.

Hawthorn, R., Kidd, J., Killeen, J., Law, B., and. Watts, A. (eds) (1996) **Rethinking Careers Education and Guidance: Theory, Policy and Practice,** London, Routeledge.

Hendley, D., Parkinson, J., Stables, A. and Tanner, H. (1995) Gender Differences in Pupil Attitudes to the National Curriculum Foundation Subjects of English, Mathematics, Science and Technology in Key Stage 3 in **South Wales, Educational Studies,** 2, 1.

Hora, M. (2010) Factors influencing change initiatives to improve K–20 STEM education at California State University, Dominguez Hills: **Final case study of SCALE activities** (WCER Working Paper No. 2010-6).
http://www.wcer.wisc.edu/publications/workingPapers/index.php

Howard-Brown, B. and Martinez, D. (2012) **Engaging Diverse Learners Through the Provision of STEM Education Opportunities,** New Orleans, LA, Southeast Comprehensive Center.

Hurtado, S. (2010) **National STEM Data – A Broad Perspective to Reading SACNAS Mission,** ttp://heri.ucla.edu/nih/downloads/SACNAS 2010 - Hurtado - **National STEM Data - A Broad Perspective to Reaching SACNAS'** Missing.pptx (accessed 21/11/12).

Institute of Physics in Wales (2010) **Science, Technology, Engineering and Mathematics (STEM) skills: submission to an inquiry by the Enterprise and Learning Committee of the National Assembly for Wales.** London, Institute of Physics in Wales.

Kerr, S., and Kerr, W. (2013) Immigration and Employer Transitions for STEM Workers, San Diego, CA , **The Allied Social Science Associations Conference,** January 4-6.

Kolb D. (1984) **Experiential Learning: Experience as the Source of Learning and Development.** Englewood Cliffs, NJ, Prentice Hall.

Leeuw, F. and Vaessen, J. (2009) Impact Evaluations and Development Nonie Guidance on Impact Evaluation, Washington DC, **The Network of Networks on Impact Evaluation,** World Bank.

Mairate, A. (2006) **Developing evaluation capacity in the Member States: the case of Structural Funds,** Brussels, European Union.

Migration Advisory Committee (2013) **Skilled, Shortage, Sensible: Full review of the recommended shortage occupation lists for the UK and Scotland, a sunset clause and the creative occupations,** London, The Home Office.

Moya, M., Expósito, F. and Ruiz, J. (2000) **Close Relationships, Gender, and Career Salience, Sex Roles,** 42, 9/10.

Nath, C. and Collins, S. (2011)' Informal STEM Education'**, Post Note,** 382, London, Houses of Parliament.
Enterprise and Learning Committee (2011) **The science, technology, engineering and mathematics. (STEM) agenda Cardiff,** National Assembly for Wales.
National Grid (c2009**) Engineering Our Future: Inspiring and attracting tomorrow's engineers,** Warwick, National Grid.
NFER (2009) **Bloodhound Educational Programme: Independent Audit of Activities,** Slough, NFER.
NFER (2011) The STEM cohesion programme: final report**, Research Report RR147,** London, Department for Education.
Peacock, L. (2010) 'School leavers 'not interested' in engineering career', **The Telegraph** (15/8/10).
Science Advisory Council for Wales (2013) **Inquiry into STEM engagement and education enrichment activity Report of the Task & Finish Group,** Cardiff, Welsh Government.
Stevens, H. (2012) E**mployer engagement in STEM Learning in the Heart of the South West,** University of Exeter, South West Observatory in Skills and Learning.
Tytler, R., Osborne, J., Williams, G., Tytler, K., Clark, J., Tomei, A., Forgasz, H. (2008) **Opening up pathways: Engagement in STEM across the Primary-Secondary school transition: A review of the literature concerning supports and barriers to Science, Technology, Engineering and Mathematics engagement at Primary-Secondary transition.** Canberra, Australian Department of Education, Employment and Workplace Relations.
UK Commission for Employment and Skills (2011**) The supply of and demand for high- level STEM skills, Wath**-upon-Dearne, UK Commission for Employment and Skills.
Van Langen, A. and Dekkers, H. (2005) Cross-National Differences in Participating in Tertiary Science, Technology, Engineering, and Mathematics Education, **Comparative Education,** 41, 3.
Wang, X. (2012:1) Modeling Entrance Into STEM Fields of Study Among Students Beginning at Community Colleges and Four-Year Institutions, **Paper at the AIR Forum,** New Orleans LA.
Wang, X. (2012:2) Modeling Student Choice of STEM Fields of Study: Testing a Conceptual Framework of Motivation, High School Learning, and Postsecondary Context of Support, **Working Paper,** University of Wisconsin, Department of Educational Leadership and Policy Analysis, Wisconsin Center for the Advancement of Postsecondary Education.
Watermeyer, R. and Stevenson, V. (2010) Discovering Women in STEM: girls in **Science, Technology, Engineering and Maths, International Journal of Gender, Science and Technology,** 2, 1.
Welsh Government (2012a) **Science, Technology, Engineering and Mathematics (STEM): Guidance for schools and colleges in Wales,** Cardiff, Welsh Government,
Welsh Government (2012b) **Science for Wales: A strategic agenda for science and innovation in Wales,** Cardiff, Welsh Government.
Welsh Government (2014a) **Science, Technology, Engineering and Mathematics (STEM) Guidance for schools and colleges in Wales**, Cardiff, Welsh Government.
Welsh Government (2014b) **Science, Technology, Engineering and Mathematics (STEM) Guidance - Equality Impact Assessment**, Cardiff, Welsh Government
Whyte, R. (2010) **Women in Science and Engineering Research Project. Edinburgh,** Scottish Government Social Research.
Wynarczyk, P. and Hale, S. (2009) **Improving Take up of Science and Technology Subjects in Schools and Colleges: A Synthesis Review Report prepared for the Economic and Social Research Council (ESRC) "Science in Society" Team and the Department for Children, Schools and Families** (DCSF), Newcastle University Business School.