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| STEMEC Report |
| Science, Technology, Engineering and Mathematics Education Committee |
| 2016 |

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# 1. Chair’s Letter to the Minister

Dear

It is with pleasure that we present to you the third, and final, in a series of Reports dealing with STEM education in Scotland. Our first was the Excellence in Science Teaching report, delivered in 2011, and the second, the Science and Engineering Education Group (SEEAG) Report, was delivered in 2012.

Our recommendations, based on cited research and wide scale consultation, combined with other recent reports that are germane to our nation’s education, lay a basis for continuing implementation that we consider vital to Scotland’s future.

Although there is considerable and necessary detail it provides also strategic, practical objectives to be achieved over a five to ten year period aimed at supporting the professionalism of Scotland’s teachers. In doing so we hope that we have not lost sight of the purpose of education, to contribute to the full development of a rounded person, the historic and still essential approach of Scottish Education.

We should like to place on record our thanks to all the people and organisations that submitted evidence, responded to requests for information, hosted our visits in Scotland and Finland and engaged in many useful discussions, these being the central contributions to the Report.

We look forward to receiving your detailed responses to each of our recommendations and to continuing to work with you and your officers, together with many others, to contribute to the continuing improvement of Scottish STEM education

 Yours sincerely


Professor Ian Wall
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# 2. Executive Summary

Our brief was in respect of STEM and that lies at the heart of our work. It became clear to us, nevertheless, that the needs of a high quality STEM education cannot be abstracted from wider needs within Scottish education together with STEM businesses and organisations.

For this Executive Summary we have, therefore, made a division between those matters that are primarily or mainly for STEM education and those necessary for successful STEM education that are wider in their coverage.

We have, as a country, been here before. In 2003, the Scottish Science Advisory Committee’s *Why Science Education Matters* made many recommendations similar to those made in the SEEAG Report of 2012, which we are repeating in this Report in 2016.

Central to all the recommendations is the Administration of Education. Much of the focus on educational improvement is on teachers, but they are only able to flourish professionally if they are provided with the resources, structures and the support required. Thus we recommend a rolling five year national education plan with clear specific responsibilities for all organisations that contribute to education so that transparent, accountable systemic development takes place, underpinned by a focused research programme.

## STEM

In Initial Teacher Education (ITE) building the pedagogical and knowledge base of primary school teachers is essential. Increasing the tariff for students on entry (or qualification) to a science at SCQF Level 5 and after five years to Mathematics and a Science at SCQF Level 6, an internal review of the science component of ITE courses and, for the 36 week long PDGE course, providing structured STEM support to primary school teachers for at least the first two years of practice will assist this.

For existing primary school teachers there should be a national programme of financial and practical support to assist a minimum of ten percent of all primary teachers to obtain a Masters in Primary Science and Pedagogy.

The Science Curriculum, Learning, Teaching, Assessment and Support Forum (CLTA) proposed in 2014, when it is established, should simplify the 56 science ‘Experiences and Outcomes’ as a priority.

For secondary teachers the immediate priority is to recruit to meet the shortage of teachers in a number of STEM disciplines, this being an urgent part of establishing a rolling five year programme of targets for teacher recruitment in all disciplines, providing confidence to individuals and institutions in planning and implementation. For current secondary school teachers a national strategy to support the creation of a Masters led profession should be established, encouraged and supported with courses recognising the development of pedagogical content knowledge in STEM subjects.

Practical skills are essential to scientific and technological study and work. It is therefore essential that the capitation levels for laboratory materials and the technician support for teachers and pupils are at a level that provides a full range of hands-on experimental techniques in all disciplines so that students are confident and engaged in their practical work. Education Scotland’s inspectors should review and comment on this when carrying out inspections.

The loss of qualified female technologists and scientists at every level from SCQF Level 5 onwards is a waste for society and for the women themselves. Within schools and colleges more can be done in support and advice that avoids stereotyping, particularly in careers advice.

The Curriculum for Excellence (CfE) has increased the freedom of teachers to adapt the curriculum to meet the needs of their pupils but other aspects of the Scottish education system have not yet been transformed to best allow teachers to make the most of this new found freedom. Central to the success of CfE will be the growth of teachers’ professional capital so that curriculum development, as is intended, becomes teacher led.

Within this there is a particular need for science teachers to ensure that they are updating their knowledge of the developing sciences and the pedagogy associated with it for which the GTCS Professional Update process can be the framework and catalyst. A key role is played by professional learning communities across disciplines e.g. Synapse, and by effective use of clusters.

Effective operation of clusters is critical for transition and professional development. Careful evaluation of their operation needs to be carried out by the Education Scotland’s inspectorate. With the regionalisation of colleges each school should have a direct relationship with a college and a similar relationship needs to be created with a university so that from a primary school through to universities and colleges there is a cluster of mutual support and endeavour.

On our visit to Finland we visited a LUMA Centre. These are based in universities across the country and provide a well fitted multi-science laboratory area used by the university to engage with school pupils, by teachers for teaching their classes and for teacher Professional Learning activities. Such centres in Scotland would engage with the schools and colleges in their ‘cluster’ and could be established over the next five years in collaboration between local authorities and universities, supported by the Scottish Government, using existing or modified facilities.

Nationally the role of SSERC is vital and extremely valuable. Its work developing clusters and its support of primary and secondary teachers together with technicians needs to be extended and given a longer time scale to operate within rather than the current annual funding.

External support to schools and teachers remains important. The growth of YESC in secondary and primary schools with a target of 100% by 2022 is highly commendable with evidence showing that much of the material is adapted for use in the curriculum. The continued role of STEM Ambassadors together with the outreach activities of Science Festivals and Science Centres should continue to receive public support.

The evidence submitted to SEEAG by the Deans of Science and Engineering led to key recommendations regarding Interdisciplinary learning (IDL). In view of its centrality to CfE, in partnership with the Learned Societies Group, hosted by the RSE, STEMEC established the IDL National Action Group (NAG). The research and work carried out in furtherance of its programme has been very valuable to date and is reflected in our Report. The completion of the embedding of IDL within Scottish education is being led by NAG and is expected to be completed within a further three years as long as it continues to receive committed support from its members and the Scottish Government.

SQA assessments of units and courses in the senior years should be more holistic and more formative in nature whilst simplified to reduce the assessment burden on candidates and the administrative burden on teachers. The introduction of any national assessment should be monitored for unintended consequences that detract from the aims of the Curriculum for Excellence.

## Setting for STEM

The Teacher Workforce Planning Group, chaired by the Scottish Government, should take responsibility through its membership for leading and coordinating a five year rolling delivery programme of teachers in all disciplines. This responsibility should include building upon the preliminary work already commenced and attracting a suitable quantity and quality of applicants to ITE institutions and schools. Such a programme should seek, amongst others, to attract more graduates in STEM subjects, degree qualified teachers from overseas and from industry. This annually updated programme will provide confidence to individuals and institutions in planning and implementing their work.

The Donaldson Report has had a major impact upon teacher education and it is appropriate to review progress.

The development of a national strategy led by the Scottish Government for building teacher and leadership social capital is essential. This should provide teachers with sufficient time to collaborate, undertake career long professional development and lead the delivery of CfE.

There are concerns that schools are often running on minimum staffing levels. This prevents the fulfilment of the CfE objectives particularly in providing a rich and rounded experience that makes learners fit to participate in all aspects of society. It also makes difficult the drive towards a Masters led profession, the practice of clusters and the implementation of Interdisciplinary Learning (IDL) amongst other matters.

The solution to this may be an increase in the number of teachers overall, as the Scottish Government has already been attempting to do for some years, but it requires a deeper consideration that takes into account teacher/pupil contact time and administrative tasks as well as teacher numbers. This is not a trivial task and requires a review of research followed by a national discussion and then the adoption of a practical process whose objective is to bring the full flowering of the CfE. Without such rethinking of the allocation of resources it will be difficult for Scottish education to improve in general or help to close the attainment gap.

Of all issues gender discrimination requires systemic change. Evidence indicates that clear leads from the top, identification of practical programmes with clear targets and consistent engagement by senior management are essential if change is to be made in schools and other institutions.

In 2012 the Royal Society of Edinburgh (RSE) published its report ‘Tapping All our Talents’. In response the Scottish Government established three separate but related groups, in part to take forward the recommendations applying to itself and to provide national leadership on this issue. It is appropriate now for one of those groups, the Strategic Group on Women and Work to review progress on implementing the report’s recommendations. In doing so it should identify numerical targets and timescales for achievement together with encouraging and monitoring progress.

Although our work on IDL was prompted by our experience of the sciences its principles and practice are essential to all disciplines. It is one of the four contexts for learning within CfE and universities, colleges and industry have expressed their desire for IDL skills which have relevance to creativity, innovation and employment in the 21st century workplace. In consequence the work of the National Action Group to embed IDL in Scottish education practice is very important, requiring the continued strong support of government and the leaders of the (20 +) organisations involved.

In particular its benefits in engaging disengaged learners and in aiding the closing of the attainment gap need to be more widely recognised and developed as a key element within the strategy for implementation of the National Improvement Framework.

The commitment of SQA to establishing a working Group to develop IDL assessment methods is welcome and needs to be supported by greater articulation, exemplification and implementation of IDL by NAG members going forward. Universities in particular can play a key role in this implementation.

IDL is an area in which research would be very welcome but Scottish education as a whole needs a stronger research base upon which to base and assess its education practice. A national programme of educational research should be identified by Education Scotland, in partnership with others, so that both researchers and funders can clearly identify research that will be valuable and have a practical impact.

## Conclusion

Scottish STEM education stands on a strong base and has much to be proud of but it needs further support and development. Central to that is transparent, accountable education administration delivering linked, national strategies that focusses on the support of a teacher led profession that integrates all aspects from research to assessment but at all times aimed at providing pupils with a rounded education that allows them to both gain from and contribute to society.

# 3. Summary of Recommendations

## Administration of Education

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| Recommendation 1 | Once a year a national meeting of bodies responsible for education should adopt a five year implementation plan, transparent to all, with agreed objectives, responsibilities and timetables, annually to be revised and extended a further year. |
| Recommendation 2 | To strengthen evaluation and research, including independent knowledge creation, every two years Education Scotland, in wide consultation, including teachers and universities, should support and organise a national meeting of education bodies, to identify a wide programme of research that will be valuable to Scottish Education. |
| Recommendation 3 | The Scottish Government should continue its support for the Growing Up in Scotland (GUS) Study, that GUS should be ‘refreshed’ to ensure its continuing strength and a third cohort be recruited in the near future. |

## Women in STEM

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| Recommendation 4 | The findings of the Improving Gender Balance pilot project managed by the Institute of Physics and funded by Skills Development Scotland should be disseminated and incorporated into the practice of all school clusters. |
| Recommendation 5 | SDS should publish a national action plan for Careers Advice dealing with Equalities and Education Scotland’s Inspectorate should give greater prominence to this area when conducting their Careers Advice inspections. |
| Recommendation 6 | The Scottish Government through the Strategic Group on Women and Work should prepare a report on progress on the RSE’s Tapping All our Talents Report’s recommendations. |

## Teacher Numbers

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| Recommendation 7 | The Scottish Government should extend its current policy of increasing ITE places in Scottish Universities.  |
| Recommendation 8 | The Scottish Government should lead the development of a coherent national strategy for building teacher and leadership social capital which allows teachers sufficient time to collaborate, undertake career long professional learning and lead the delivery of CfE through consideration and restructuring of teacher numbers, workload, contact time and bureaucratic demands. |

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## Initial Teacher Education

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| Recommendation 9 | The qualification requirements for applications from students wishing to study to become primary school teachers should be raised to an SCQF Level 5 in a science and that after a further five years the requirements should be increased to Level 6 in mathematics and a science. |
| Recommendation 10 | Universities should review the provision of science education within their primary ITE courses, and Local Authorities should work with Universities to provide structured support for PDGE teachers in primary science pedagogical content knowledge for newly qualified primary school teachers for at least the first two years in a teaching post. |
| Recommendation 11 | The Scottish Government, working with the GTCS, Higher Education Institutions, ITE providers, Local Authorities and Professional Bodies, should develop a five year strategy to address teacher shortages in the STEM subjects with consideration given to appropriate incentives to encourage people to gain teacher appropriate STEM teaching qualifications. |
| Recommendation 12 | Improved data on STEM, especially Technological Education, teacher qualifications and expertise, should be gathered to allow for improved teacher workforce planning.  |
| Recommendation 13 | The TWPG should publish a five year rolling programme of target numbers for teachers in all disciplines, updated annually, providing confidence to individuals and institutions in planning and implementation and ensuring that shortfalls in shortage subjects are being addressed. |
| Recommendation 14 | A short life working party comprising representatives of STEC, ADES and Scottish Government should be convened to develop and implement a long term programme of financial and practical support for primary school teachers to obtain Diplomas and Masters in Primary Science and Pedagogy. |
| Recommendation 15 | Higher Education Institutions, working in partnership with others to ensure the needs of teachers and their learners are met, should develop Masters accredited courses recognising the development of pedagogical content knowledge in the STEM subjects. |

## Primary Science

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| Recommendation 16 | There should be continued and expanded support for SSERC to ensure that all Local Authorities have access to the Primary Cluster Programme and that additional support can be provided to clusters beyond their first year of participation in the Programme. |
| Recommendation 17 | Education Scotland should continue to provide a dedicated Primary Science Development Officer Role with associated responsibility for primary science content across Education Scotland platforms.  |

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| Recommendation 18 | National surveys like the SSLN survey should include information gathering about the confidence of primary teachers to deliver the science curriculum and pupil attitudes and performances in science.  |
| Recommendation 19 | As PLCs develop, Education Scotland should consider quality assurance mechanisms based on a collaborative cluster approach to primary science. This would encourage open sharing of innovative approaches and allow primary schools to use their strengths to benefit whole clusters rather than just individual schools.  |
| Recommendation 20 | The Science Curriculum, Learning, Teaching, Assessment and Support Forum should look at ways to reduce in number and simplify the 56 Experiences and Outcomes within the primary science curriculum as a priority; subsequently providing further exemplification. |
| Recommendation 21 | Education Scotland should continue to offer guidance and support around the delivery of the Experiences and Outcomes, both in terms of science knowledge and science skills at early, first and second levels. |
| Recommendation 22 | Scottish Government and Local Authorities should work with SCDI YESC’s to support engagement with 100% of primary schools in Scotland by 2022 in order to promote the embedding of YESC activities within the curriculum and ensure an entitlement for all. |
| Recommendation 23 | Scottish Government should continue to provide funding to the Scottish Science Centre Network and Scotland’s Science Festivals while maintaining a wider programme of science engagement grants to support Scotland’s varied science engagement activities. |

## Effective Career Long Professional Development and Professional Learning Communities

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| Recommendation 24 | The GTCS Professional Update process should be used as the framework and catalyst for effective CLPL for all teachers with sufficient time for effective delivery provided. |
| Recommendation 25 | Education authority and school leaders should facilitate the participation of teachers in meaningful and effective PLCs, be it local clusters, national subject fora, professional associations or other appropriate structures which allow teachers to develop as professionals and improve the learning of the students in their care and avoid the promotion of contrived collegiality.  |
| Recommendation 26 | The Scottish Government should encourage universities, the Scottish Funding Council, colleges and science centres to develop, along with schools and local authorities, a network of STEM Centres to act as hubs and give a focus for cluster working, CLPL, pedagogical development and communication between organisations. This model can be extended to other areas of the curriculum. |
| Recommendation 27 | Scottish Government, Education Scotland and Local Authorities should ensure that there is sustained funding to both increase the capacity of SSERC that will also allow them to plan extended programmes of professional support crossing over several financial years.  |

## Interdisciplinary Learning (IDL)

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| Recommendation 28 | High priority should be given by Scottish Government, Education Scotland and SQA to empowering and resourcing schools, school networks and local authorities to take responsibility for the articulation, exemplification, implementation, development and assessment of IDL within CfE. This should be a strategically planned process that impacts all areas of the curriculum. |
| Recommendation 29 | IDL has a central role to play in engaging disengaged learners and closing the attainment gap, and should be recognised and developed as a key element within the strategy for implementation of the National Improvement Framework by Scottish Government, Education Scotland, local authorities and school leaders. |
| Recommendation 30 | The creative potential and capacities of STEM subjects need to be recognised, developed, demonstrated and encouraged through IDL by Education Scotland, SQA, local authorities, practitioners and CPD providers, and in ITE. |
| Recommendation 31 | SQA and Education Scotland should take responsibility for researching, developing and delivering methods of assessment of IDL in and across the Senior Phase and the Broad General Education, in collaboration with local authorities, practitioners and schools.  |
| Recommendation 32 | The process of implementation and development of IDL within CfE should be subject to thorough and on-going independent research if a clear understanding is to be gained of the key factors that determine what works and doesn’t work, and an evaluation of its impact. Teachers as researchers should play an important role in this process. |
| Recommendation 33 | Universities, colleges and local authorities should co-ordinate their efforts to support formal engagement and partnerships with schools, school networks and their communities (including business, industry and research institutes) to develop sustainable regional hubs, professional learning communities and related partnerships as appropriate, building around emerging effective new models of engagement. The implementation and development of IDL should be a key element of this support. This is consistent with Recommendation 26 in Section 10. |

## Additional Barriers to Success

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| Recommendation 34 | Wherever possible bi-level/course or multi-level/course classes should not be taught in the sciences as the courses were not designed to be delivered in this manner.  |
| Recommendation 35 | The uptake of STEM subjects at SCQF levels 5-7 should be monitored and action taken if a decline in uptake is manifest. |

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| Recommendation 36 | SQA assessment of units and courses in the senior phase should be simplified to reduce the assessment burden on candidates and administrative burden on teachers. Assessments should be more holistic and unit assessments more formative in nature. |
| Recommendation 37 | The purposes and nature of any national standardised assessment introduced in the BGE stages should be primarily designed to increase the depth of learning of pupils and not for the assessment of the education system, which could be achieved through a thoroughly applied sampling approach. |
| Recommendation 38 | The introduction of national standardised assessment should be continuously monitored for unintended consequences that detract from the overall aims of Curriculum for Excellence. |
| Recommendation 39 | The Scottish Government should commission further research to identify the requirements, including the appropriate funding, to enable the adequate delivery of practical science and the development by pupils of practical skills across all STEM subject areas. |
| Recommendation 40 | Education authority and school leaders should ensure that adequate resources are available in schools to allow teachers and technicians to implement practical work in schools. |
| Recommendation 41 | CPD providers should ensure that teachers have good opportunities to develop effective teaching and learning of practical skills that meet the needs of learners and of the new curriculum. |
| Recommendation 42 | Technicians play an essential role in STEM education. The Scottish Government, through the TWPG, should collect statistics on technician employment in schools, as part of its annual survey of all teachers, to allow proper planning and delivery of technician recruitment, training and CPD. |
| Recommendation 43 | Education Scotland’s Inspectorate should report on whether or not schools have sufficient resources to provide sufficient hands on work in the STEM disciplines to meet the needs of learners and the new curriculum. |

# Introduction

## STEMEC

The Science, Technology, Engineering and Mathematics Education Committee (STEMEC) was established, as a successor to SEEAG, following the publication of the Scottish Governments response[[1]](#footnote-1) to, the Science, Engineering Education Advisory Group second report *Supporting Scotland’s STEM Education and Culture[[2]](#footnote-2)* in January 2012.

STEMEC’s remit, agreed with the Scottish Government, is:

*“The STEMEC Committee remit is to support and galvanise action to improve STEM education and learning in Scotland’s schools, career advice related to STEM, and public science engagement by:*

* advising and challenging the Scottish Government and national and local partners;
* providing impetus and direction to the implementation of the SEEAG Report;
* engaging with science teachers and STEM professional bodies in, inter alia, supporting STEM focused Professional Learning Communities in schools and Local Authorities in Scotland;
* assisting in the development of links between schools and FE/HE and industry/business in supporting STEM education and delivery of careers advice;
* facilitating work to advance the reach and quality of science engagement activities;
* deepening and enriching engagement with the SEEAG report in Scotland, including stakeholders’ responses to the report and their role in implementation.”

The Committee’s membership is described in Appendix I and we benefitted from the presence of Education Scotland (ES) and the secretarial support of members of the Scottish Government (SG) Curriculum Unit.

STEMEC’s remit is firmly rooted in the STEM subjects; however several of the issues covered in this report are more generic and also apply to other curriculum areas.

## SEEAG

The SEEAG Report contained sixty four recommendations for the continued development of STEM education in Scotland providing a comprehensive set of actions that, if implemented, would lead to necessary improvement in STEM education. The continued steady implementation of those recommendations remains essential if there are to be improvements that are sought.

At the beginning of our report we noted that:

*“Plus ça change, plus c’est la même chose”*

*“In 2003 the Scottish Science Advisory Committee’s (SSAC) report Why Science Education Matters[[3]](#footnote-3) made a number of recommendations for the future improvement of science education in Scotland to meet perceived concerns and challenges. The report called for a programme of curriculum change that moved away from a cluttered, content-dominated and assessment-driven curriculum with little scope for teachers to include topical or innovative material to inspire learning.*

*It recognised that the lack of science specialists and the absence of science infrastructure and technical support in primary schools were major obstacles to sustaining the interest of young people in science across the transition into secondary education, and the need to improve the uptake of science and the standard of science educational attainment in secondary education. The report made several recommendations regarding primary school science facilities, teacher and technician support in primary schools, and continuing professional development (CPD) to tackle this problem. It recognised the deficiencies in school careers advice around pathways into science and career opportunities for science graduates, and recommended that CPD be provided to address these deficiencies. It recognised the need to reverse the decline in public confidence in science. It called for better co-ordination of science education activities and support across Scotland, and recommended the formation of local clusters of primary and secondary schools, industry, colleges, research institutes and universities to support and improve science education. Concern was expressed about the age structure of a science teaching cohort in which, in 2000, one third of science teachers were over 50 years old, and a half over 45.* ***These issues all remain priority concerns in 2011”***

We would again reiterate the need for consistent, coordinated, planned transparent delivery by the organisations responsible for the changes required to enhance and support schools and teachers in delivering the richness and quality of STEM education that Scottish learners deserve and Scottish employers value.

# Administration of Education

Much of the educational research and especially policy development and its application is aimed at schools and teachers. The role of the ‘administration of education’ is much less considered though schools and teachers operate within a complex of overlapping groups of organisations that are key resource providers and distributors, supporters and restrainers, creating both opportunities and aids but also hurdles and constraints.

The complexity of the administration within Scottish Education requires high levels of professional endeavour and coordination across many organisations. Their individual performance is critical to the success of Scottish Education and, *as important*, is their effective cooperation in a visible manner and their accountability to those they serve.

In its report the OECD Review Group [[4]](#endnote-1)identified the structural complexity of Curriculum for Excellence (CfE) and the need to strengthen what it called the “middle” of Scottish education. This involves a move away from “running” an implementation programme managed from the centre towards facilitating a system based on professional leadership and collective responsibility. However, the OECD Review Group highlights that with a strengthened and more prominent “middle” comes the need for greater transparency and processes of professional accountability. STEMEC endorses the OECD view that the “middle” of Scottish education be strengthened along with improved processes of professional responsibility and accountability to ensure that there is effective administration of Scottish education. STEMEC also endorses the definition of the “middle” in the OECD report which includes the “vertical middle” of leadership at school and local authority level between teachers and national government but also the “horizontal middle” such as networks, professional communities and groups often not visible in official charts of an education systems (OECD, p98).[[5]](#footnote-4)

The recent (2014) development initiated by the Learned Societies Group on Scottish Science Education and STEMEC to establish a National Action Group to bring about the embedding of Interdisciplinary Learning (IDL) throughout the curriculum is an example of what can be achieved when major stakeholders come together with common purpose. The IDL National Statement is available at <http://www.gov.scot/Resource/0047/00477300.docx>.

Here organisations have come together to coordinate a joint plan for which each organisation takes responsibility for its practical contribution and collectively responsibility for a successful result. It is essential that all who need to contribute to programmes are aware of ‘who is doing what to whom’ and there is appropriate transparency and accountability to each other.

#### Recommendation 1

* **Once a year a national meeting of bodies responsible for education should adopt a five year implementation plan, transparent to all, with agreed objectives, outcomes, responsibilities and timetables, annually to be revised and extended a further year.**

## Educational Research

A firm evidential base developed from a strong programme of research is essential for continuing progress and improvement in Scottish Education. This view was expressed by the RSE earlier this year in a submission to the Scottish Government:

*The Scottish education community needs a national evidence base of what works and professional development in how to use evidence. This will help practitioners differentiate proven, promising and unproven approaches and inform choices about: appropriate curriculum design, resource allocation and how to monitor and evaluate practice for impact.[[6]](#footnote-5)*

It is standard practice in STEM related organisations and industries, including medicine, to make more effective use of research and evidence to inform policy. For example, recently the Royal College of Paediatrics and Child Health called for the commissioning of ‘high quality research dedicated to interventions in order to reduce inequalities’.[[7]](#footnote-6)

In the past the Scottish Government issued an annual call for research proposals in areas of concern and interest in education to the Government. That process has ceased and has not been taken up elsewhere. More generally groups as varied as a meeting of education researchers, convened to aid the OECD review of the Curriculum for Excellence (CfE), and the Scottish Teachers Education Committee (STEC)have identified the low level of educational research in Scotland. The OECD Report recommended ‘Ensure a consolidated and evidence informed strategic approach to equity policies’ and ‘Develop metrics that do justice to the full range of CfE capacities informing a bold understanding of quality and equity’[[8]](#footnote-7), which STEMEC endorses.

In order to aid practitioners and especially the research community it would be valuable to coordinate the identification of a programme of educational research of value to Scottish education, in consultation with a wide range of bodies and practitioners, including teachers, universities and the educational research community. It would then be open to all relevant parties to commission research, confident in the knowledge that the research is needed and is related to a strategic programme. This would be of great value to Scottish education and such a programme should be updated every two years and be widely publicised.

#### Recommendation 2

To strengthen evaluation and research, including independent knowledge creation, every two years Education Scotland, in wide consultation, including teachers and universities, should support and organise a national meeting of education bodies, to identify a wide programme of research that will be valuable to Scottish Education.

Nevertheless Scotland is fortunate in that successive Governments have supported the Growing Up in Scotland (GUS) study. This is the longitudinal research study tracking the lives of thousands of children and their families from the early years through childhood and beyond. The main aim of the study is to provide new information to support policy-making in Scotland but it is also intended to provide a resource for practitioners, academics, the voluntary sector and parents. This study is of almost inestimable value not only for what it directly provides but also in providing a rigorously prepared base upon which a wide variety of other studies can be undertaken. The Study has been running for ten years and its recent report[[9]](#footnote-8) is a valuable indication of the riches it can provide.

The value of this study is its longevity and retaining its strength is vital. Inevitably there have been some losses from the two cohorts that are currently within the study and it is important that these are refreshed, particularly as many of the losses are in the disadvantaged groups. In consequence it is recommended that early refreshment of both current cohorts be undertaken.

With the first cohort of CfE students having reached the end of the BGE in 2013 it is a good time to add a third cohort. Not only will this provide a firm basis for understanding and improving education knowledge and practice but it will be very helpful in evaluating and supporting the commitments already made to early childcare.

#### Recommendation 3

* **The Scottish Government should continue its support for the Growing Up in Scotland (GUS) Study, that GUS should be ‘refreshed’ to ensure its continuing strength and a third cohort be recruited in the near future.**

# Women in STEM

With the shortage of STEM educated school, college and University leavers causing problems for industry, commerce and teaching it is necessary to consider the position of girls and women within STEM. This is not a new issue, which thus emphasises the need for a national strategy that can be related to the different practical threads of activity taken up in schools, colleges, universities and in commerce and industry.

## Background

Within STEM education and employment the general picture is repeated at all levels. This graph shows the participation of women in six sciences/technologies, firstly in school and secondly in academia:



This demonstrates an overall and almost consistent loss of STEM educated women. When it comes to *all* employment, 27% of women who graduate in STEM work in the sector they qualified in compared with 52% of men. This means that of the 56,000 female STEM graduates in Scotland just over 15,000 continue to work in the sector. If the proportion of women continuing in STEM was the same as for men then there would be an additional 14,000 STEM graduates working every year.

In vocational education, for Modern Apprenticeships in Engineering take up in 2011/12 for males was 1178 and for females 31, equal to 2.6%; there had been little change from 2008/9 to 2011/12.[[10]](#footnote-9) In 2014/15 this had increased to 61, equal to 5%.[[11]](#footnote-10) This is a welcome increase though, as the numbers are so small it is not yet indicative of a shift; nevertheless it is a better point upon which to build.

If as shown in the graph above there is an approximately equal entry at SCQF level 5 into the sciences, and as female students are academically more successful, then we need to consider how to amend the processes that lead to the loss of so much talent and skill. Central to this is good quality professional careers advice and support for female school pupils and their families.

## Schools and Careers Advice

In reviewing the research evidence in *Engaging Girls in STEM: What Works* (2012) WISE identified failures in careers advice, lack of job profiles and female role models, perception of greater sexism in the workplace, influence of parents and wider family and the need for greater collaboration between organisations and initiatives promoting STEM study and careers.

Currently the Institute of Physics (IOP), in partnership with Skills Development Scotland and Education Scotland, is managing the Improving Gender Balance (IGB) project. It builds on previous IGB work done by the IOP in England, from which valuable lessons have been learned. This pilot project involves only six secondary schools and their associated primary schools. This cluster-based approach is welcome, as is that this issue is being addressed with younger pupils, and parents, in addition to secondary age pupils.

The findings from the Scottish IGB pilot should be widely disseminated and all pupils should have an entitlement to good quality advice and support.[[12]](#footnote-11)

#### Recommendation 4

* **The findings of the Improving Gender Balance pilot project managed by the Institute of Physics and funded by Skills Development Scotland should be disseminated and incorporated into the practice of all school clusters.**

In the transition from school to apprenticeships, college and university there is UK evidence that careers advice follows stereotypical approaches. Careers advice still does not seem to be providing young people with the information they need. In 2011, the CBI reported[[13]](#footnote-12) that almost half (43%) of 16-18 year olds feel they received poor advice or none at all from a careers service. Careers information, advice and guidance continue to reinforce gender stereotypes.[[14]](#footnote-13)[[15]](#footnote-14)

The recently published Equalities Action Plan for Modern Apprenticeships in Scotland by Skills Development Scotland (SDS) seeks to address these issues. The development by SDS of a national action plan for Careers Advice similar to the plan for Modern Apprentices would be valuable. Additionally, the five most recent Careers Advice inspections carried out by Education Scotland shows that equalities are dealt with in a short paragraph or one sentence. An appropriate complement to work in this area would be a more detailed analysis by ES Inspectors of equalities when carrying out their Careers Advice inspections.

#### Recommendation 5

* **SDS should publish a national action plan for Careers Advice dealing with Equalities and Education Scotland’s Inspectorate should give greater prominence to this area when conducting their Careers Advice inspections.**

Research conducted at Yale University[[16]](#footnote-15) demonstrates that there is bias against women in science academia in Physics, Biology and Chemistry. Briefly, identical job applications different only in the gender of the applicant were sent to senior academics in physics, biology and chemistry, who were not aware that this was an experiment. The outcome expressed itself in decisions to hire fewer female scientists. This leads to the conclusion that it was not the best candidates that were to be appointed but that men were chosen solely because they are men. The problem for women scientists did not stop there for, if they were to be hired, they were offered lower wages and less mentoring. These last two points perhaps indicate elements of the process in which women do not continue to progress to senior levels in the same numbers as men although equally qualified.

An example of success in responding to this and other issues is ECU’s Athena SWAN Charter. This was established in 2005 to encourage and recognise commitment to advancing the careers of women in science, technology, engineering, maths and medicine (STEMM) employment in higher education and research. Take up was patchy until it was made important when the National Health Research Institute (NHRI) made research grant approvals conditional upon applicants having attained Athena Swan Silver Level and when the UK Research Councils announced in 2013 that, in determining grant awards, there would be an expectation that universities would demonstrate their progress by taking up the Athena Swan programme. Following this Athena Swan Awards in Scotland grew from 12 to 57. This demonstrates that setting formal targets that are required to be met rather than optional can be successful and serves as a model of what might also be achieved in school education.

Perhaps the failure to bring about substantial improvement over the past few decades has been a failure to treat the matter with practical discipline and sustained programmes, as Athena Swan does, that are necessary to effect substantial permanent change. Funding for short term projects that try to provide support for individual women, to detach themselves from the ‘sticky carpet’, avoid being expelled out of the ‘leaky pipe’ or break through the ‘glass ceiling’ whilst welcome are not going to solve the problem and can imply that the problem is for women rather than for society to address.

## Recent Studies and Reports

Common to the reports on women in the sciences and successful experiences is a systemic approach that defines numerical targets to be attained over a relatively short time period, leadership from the top, the establishment of the policy and structural changes necessary, and identifying individuals and teams to carry out the implementation. These four elements will be essential to any strategy to effect sustained change nationally or within organisations.

There have been many reports dealing with the position of women within STEM education and employment. Some of the more recent include:

* Tapping All Our Talents, produced by the RSE[[17]](#footnote-16)
* It’s Different for Girls, IOP[[18]](#footnote-17)
* Improving Diversity in STEM by the Campaign for Women in Science and Engineering (WISE)[[19]](#footnote-18)
* The ‘Status of Young Women in Scotland’, YWCA 2015, is more anecdotal but what it may lack in quantitative content it makes up in the quality of its range and power.[[20]](#footnote-19)

All of these recent reports are welcome, but the most relevant has been the RSE’s Tapping All our Talents.

In response to it the Scottish Government established three separate but related groups to take forward the recommendations applying to itself and to provide national leadership on the issues:

* The Strategic Group on Women and Work, Chaired by the Minister for Youth and Women’s Employment reporting to the Scottish Parliament,
* The Occupational Segregation Cross-Directorate Working Group, reporting to the Strategic Group,
* The Science and Engineering Profession Equality and Diversity Group, reporting to the Chief Scientific Adviser for Scotland.

It is now well over three years since the RSE Report was published. One of its recommendations was that there should be a 3-year review of progress on its recommendations. The Strategic Group is best placed to review progress, identify revised targets and to consider further development and action.

#### Recommendation 6

* **That the Scottish Government through the Strategic Group on Women and Work should prepare a report on progress on the RSE’s Tapping All our Talents Report’s recommendations.**

# 7. Teacher Numbers

Later in the report we deal with the shortages of teachers apparent in a number of scientific disciplines that we consider are resolvable with a medium term co-ordinated campaign, but there is a more general issue regarding the overall number of teachers.

It is Scottish Government Policy to maintain teacher numbers, though several Local Authorities have found it difficult to implement this policy.[[21]](#footnote-20)

For several years the Scottish Government has increased the number of ITE places available in Scottish Universities, including an additional 260 places for 2016/7.[[22]](#footnote-21)

Nevertheless pupil-teacher ratios for Local Authority funded schools have increased in recent years.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Pupil teacher ratio | 13.0 | 12.9 | 13.2 | 13.3 | 13.4 | 13.5 | 13.5 | 13.7 |

*Summary Statistics for Schools in Scotland, No.5 ¦ 2014 Edition 10th December, 2014 (amended 25th February 2015)*.[[23]](#footnote-22)

This is a non-trivial increase in the pupil teacher ratio since 2008. When schools run at minimum staffing levels, exacerbated by absences and lack of supply teachers, it makes it difficult to release teachers for a wide variety of tasks and responsibilities that are not class facing. This is an issue directly experienced by our Committee when some of our teacher members could not be released from their schools to participate in a National Government Advisory Committee. STEC reports difficulty in recruiting teachers to Masters and other courses which they consider to be due, in part, to the difficulty teachers have in obtaining time off for sustained additional study. The situation for STEM teachers is made more difficult by the reduction in school technicians as indicated in the Learned Societies Group report on resourcing of school science in Scottish schools (see Section 12).

Effective education systems are ones where teachers work collaboratively and have time to meet and plan together, participate in effective career long professional learning (CLPL) including observing colleagues teach as well as attending cluster meetings and external continuing professional development (CPD). For this to occur it is essential to have an adequate supply of teachers across all stages and subjects and for teaching to be seen as an attractive profession.

Minimum staffing levels particularly impact upon professional development and the successful operation of clusters. The independent evaluation by the Robert Owen Centre for Educational Change[[24]](#footnote-23), Glasgow University, of SSERC’s Cluster Programme in Science and Technology “highlighted the importance of having sufficient time in schools for mentors to plan and provide appropriate support”. The Evaluation also noted that “information gathered from a sample of LA officers across the participating Councils …reveal(ed) that support for professional development and learning is being diminished because of funding cuts that reduce key personnel”.

The OECD review of Scottish Education is positive about Curriculum for Excellence but recommends the development of a “*coherent strategy for building teacher and leadership social capital*”.

The successful delivery of this recommendation will only be possible with adequate time for teachers to build their social capital which rests on their being sufficient teacher numbers to allow this.

Compared to other OECD nations Scottish teachers already have one of the highest teacher contact hours.

 *Education at a Glance 2015: OECD Indicators, OECD, (2015)[[25]](#footnote-24)*

The experience of Finland is instructive in this respect, which is summed up well by Pasi Sahlberg’s Paradox 1 “Teach Less, Learn More”[[26]](#footnote-25). In the same context the recent flurry of interest in England in respect of Chinese teaching methods[[27]](#footnote-26) of mathematics exposed that Chinese mathematics teachers deliver only two, 35 minute lessons a day, the remainder being spent on other professional activities.

The success in the approach taken in schools in Shanghai is well summarised in *School Turnaround in Shanghai the Empowered-Management Program Approach to Improving School Performance* by Jensen and Farmer[[28]](#footnote-27).

*“[It is] worth noting the strengths of education in Shanghai and considering the differences between teachers’ work and careers there and teachers’ work and careers in the United States and most other OECD countries. Shanghai makes significantly larger investments in effective professional learning, classroom observation and feedback to teachers, professional collaboration, and the development of teachers’ research skills to create schools that are learning organizations. These areas are emphasized in the empowered-management program and throughout the education system in Shanghai.”*

The teaching contact time in Shanghai is a relatively extreme outlier compared to other countries and likely to be a distant aspiration. However, Nordic countries such as Finland, Estonia, Norway and Denmark, which are more similar to Scotland, benefit from significantly lower teacher contact hours.

The third element is the administrative burden that teachers work under, some of it not being appropriate to professional work. This has been recognised and the Minister announced[[29]](#footnote-28) in January 2016 the establishment of an Expert Group to review bureaucracy and make recommendations. This is welcome but a deeper comprehensive engagement is required as described below.

The OECD Report describes the CfE process, commencing with a national debate, the reaching of a broad consensus, a transparent plan of implementation and, when unforeseen problems arose, action taken to deal with them; this should be a matter of pride. It needs nevertheless to be seen through to full completion where teachers are interpreting, researching, developing and delivering the curriculum, encouraged and supported to do so by the provision of time and facilities. The OECD Report also acknowledges the great complexity of CfE and the need to simplify and clarify core guidance, reduce bureaucracy and provide for improved collaboration and innovation.

We do not make any detailed proposals but identify a serious problem that is wider than STEM but needs to be addressed in a serious, sustained and rounded manner. It is not susceptible to ‘sound bite’ politics about teacher numbers but requires a properly researched and developed strategy that considers teacher numbers, workload, contact time and bureaucratic demands. The strategy should build upon the best experience elsewhere and premiate professional teaching with sufficient time and resources to become the Masters led profession that is self-reflective and research led as the CfE requires.

A recurring theme in this report is the need for *time* to allow teachers to collaborate effectively on ensuring good research informed learning and teaching outcomes for their pupils. This needs a two pronged approach requiring short term action around a relatively small increase in the number of teachers, thus extending current Scottish Government strategy, integrated into a longer process, extending over a decade or more, that sees the continued development of a Masters led profession but crucially involving a restructuring of practice allied to the introduction of greater professional autonomy and responsibility.

The development and implementation of this process will assist in improving the image of the profession as presented in the media and thus aid in the recruitment of teachers.

#### Recommendation 7

* **The Scottish Government should extend its current policy of increasing ITE places in Scottish Universities.**

#### Recommendation 8

* **The Scottish Government should lead the development of a coherent national strategy for building teacher and leadership social capital which allows teachers sufficient time to collaborate, undertake career long professional learning and lead the delivery of CfE through consideration and restructuring of teacher numbers, workload, contact time and bureaucratic demands.**

#

# 8. Initial Teacher Education

## Primary Teachers

The SEEAG Report *Supporting Scotland’s STEM Education and Culture* *pp16-20* identified the lack of science based qualifications of primary school teachers and their lack of confidence in teaching science as key, major issues needing rectifying. In consequence we recommended an increase in the tariff of entry qualifications for students entering ITE so that all entrants would be required to have on entry to, ***or on leaving***, university an SCQF Level 5 in a science as soon as it can be reasonably implemented and, to be introduced in a further five years, a SCQF Level 6.

The GTCS recently released a survey[[30]](#footnote-29) it had conducted of entry qualifications to ITE for Foreign Languages, Science and Mathematics. The figures for primary students show that there is considerable variation between the universities. For those studying to become primary school teachers through a full time degree, those with SCQF Level 5 in a science varied from 35% to 89% but the majority of universities exceeded 50%, often comfortably; those with a SCQF Level 6 in a science were lower from 30% to 79% but over 50% in five (out of the seven that responded) universities.

As regards Mathematics all entrants have Level 5, for Level 6 the figures show a similar band as for Level 6 Science, from 30% to 84% but the general level is lower in each university with three universities (out of seven) exceeding 50%.

These figures indicate that with appropriate notice period for universities, schools and pupils meeting the SEEAG recommendations could be achieved.

#### Recommendation 9

* **The qualification requirements for applications from students wishing to study to become primary school teachers should be raised to an SCQF Level 5 in a science and that after a further five years the requirements be increased to Level 6 in mathematics and a science.**

It is important that regardless of their entrance qualifications primary teacher students gain adequate pedagogical content knowledge as part of their degree or PDGE ITE courses at university. Universities should review their current practice and the time allocated to science with a view to ensuring that they are confident it is fit for purpose.

Nevertheless it is necessary to recognise that with only 36 weeks in a PDGE course and many other needs to be met that there is a limit to what can be achieved in consequence Local Authorities, working with Universities, should introduce structured support in science pedagogical content knowledge for newly qualified, PDGE primary school teachers beyond their ITE course for at least the first two years in a teaching post.

#### Recommendation 10

* **Universities should review the provision of science education within their primary ITE courses, and Local Authorities should work with Universities to provide structured support for PDGE teachers in primary science pedagogical content knowledge for newly qualified primary school teachers for at least the first two years in a teaching post.**

## Secondary STEM Teacher Numbers

The allocation of resources for the various STEM disciplines is manged through the Teacher Workforce Planning Working Group (TWPG) chaired by the Scottish Government. The recent adoption of specific targets for the number of students entering the different ITE disciplines, as recommended by SEEAG, has been implemented and will be essential for dealing with the current imbalances. This will allow the effective allocation of resources to permit sufficient student teachers to be funded for each discipline to overcome current shortages, provide for replenishment and, where necessary, growth.

The Scottish Government has increased the number of ITE places available in Scottish universities in recent years, including an additional 200 secondary teacher places in 2016-2017.[[31]](#footnote-30)

Despite this, the numbers of entrants to PGDE courses in the STEM subjects continues to fall short of targets in 2015-2016.

|  |  |  |  |
| --- | --- | --- | --- |
| Subject | Target intake | Actual intake | Percentage of places unfilled |
| Biology | 88 | 81 | 8 |
| Chemistry | 69 | 57 | 17 |
| Computing | 37 | 20 | 46 |
| Mathematics | 146 | 76 | 48 |
| Physics | 54 | 38 | 30 |
| Technological Education | 58 | 35 | 40 |

*TESS, 11 December 2015, pp7[[32]](#footnote-31)*

The replenishment rate in some subjects is not being met and there are serious shortages in subjects such as physics, chemistry and computer studies.

As an example, a report in 2014 by Computing at School Scotland[[33]](#footnote-32) identified that there has been a drop in Computer Science teachers of 14% in the previous two years; that 12% of schools did not have a Computer Sciences teacher; and 10 of 32 LAs had difficulty recruiting Computer Science teachers. In addition the target of 25 students for PDGE in 2014 had not been met and the quality of applicants for PDGE was poor, thus a bad situation is becoming worse.

The area of teacher numbers in Technological Education requires greater clarity. This TWPG category includes subjects such as the practical craft skills, graphic communication, design and manufacturing, and engineering science and covers many teachers in disparate subjects. This is compounded by a large number of varied descriptions in use across education for teachers of these subjects. This needs to be unravelled so as to allow proper identification of numbers in each discipline. Improved data will allow better teacher workforce planning in this area, particularly in the case of engineering. The Developing Scotland’s Young Workforce report[[34]](#footnote-33) places significant emphasis on the STEM subjects, especially those of engineering, for ensuring success in this area. A good supply of well qualified teachers will be required to deliver this vision both within schools and beyond.

The shortage of specialist secondary school teachers in STEM subjects is major and urgent and requires more ITE places in these disciplines, linked to a strategy for improved recruitment.

## Recruitment

The problem is not just one of funding training places, as the experience with Computer Science demonstrates; in consequence it is necessary to attract more applicants to take up teaching as a career.

The report commissioned by the TWPG, *An analysis prepared by TMP[[35]](#footnote-34) of the challenges facing the Scottish Government’s initiatives to increase the recruitment of STEM based teachers*, and delivered in January 2015 is valuable. It describes some of the issues and indicates possible actions some of which have been previously initiated. There are already a few good examples, such as projects involving Geosciences final year students at the University of Edinburgh and work by the Institute of Physics but much more could be done by university undergraduate departments and the learned societies to promote teaching as a career; for example, Heriot Watt and Stirling Universities, with Scottish Government support, are combining to offer ITE education to STEM students.

On the other hand recruiting from industry will require not just marketing but ITE course restructuring and tighter timetables to minimise loss of income for entrants leaving a current job. As an example Dundee University, with its partner Local Authorities, has established a course for Local Government workers to retrain and requalify as teachers.

The Scottish Government has commissioned a social media campaign aimed at recruiting more student teachers. Whilst social media campaigns and promotional activities may well convince some to consider teaching as a career the situation is such that it is likely that more is required to address the situation.

Potential teachers can come from school, university, industry and from abroad. For each of these there needs to be prepared marketing programmes and actions, including incentives, aimed at the different sectors. This could include: restructured PGDE courses to be more attractive to people moving from industry; targeting STEM graduates currently not working in STEM fields; improved recruitment in university STEM undergraduate departments; bursary arrangements for student teacher; “golden hello” arrangements; and more overseas advertising and recruitment.

Possible actions include:

* restructuring PDGE courses for students coming from industry to allow paid employment to commence after only a few months, so that there is a reduced financial penalty for a career change, with increased support and mentoring during the paid employment;
* advertising overseas in areas where there is a surplus of teachers, e.g. New South Wales, Australia, has 44,000 trained teachers waiting for a full time job[[36]](#footnote-35);
* considering whether or not a similar campaign to the recently announced Scottish Government £450,000 three year campaign to recruit and retrain past nurses and midwives might be taken up for teachers[[37]](#footnote-36);
* of the 56,000 women who graduate in STEM, over 40,000 do not work in the sector and some might be recruited to a career in teaching;
* in England ITE students studying shortage subjects are provided with a scholarship from the DfE[[38]](#footnote-37).
* ITE departments mounting recruitment campaigns in their own and other universities to match the efforts of private employers.

Increasing recruitment into teaching, and retaining them in teaching, will only be successful if teaching is seen to be an attractive career. Elsewhere, such as in Finland, where only around 8% of applicants are accepted into ITE each year[[39]](#footnote-38), this has been the achieved through teaching being a high status profession with high standards of entry, continuing professional learning and high levels of teacher autonomy and responsibility.

The fact that the GTCS has introduced the Provisional (Conditional) Registration category and has already recognised alternative routes into teaching, such as the University of Buckingham’s iPGCE, is to be welcomed and all avenues that might allow people to become adequately qualified in shortage subjects should be explored.

#### Recommendation 11

* **The Scottish Government, working with the GTCS, Higher Education Institutions, ITE providers, Local Authorities and Professional Bodies, should develop a five year strategy to address teacher shortages in the STEM subjects with consideration given to appropriate incentives to encourage people to gain teacher appropriate STEM teaching qualifications.**

#### Recommendation 12

* **Improved data for Technological Education should be gathered to allow for improved teacher workforce planning.**

#### Recommendation 13

* **The TWPG should publish a five year rolling programme of target numbers for teachers in all disciplines, updated annually, providing confidence to individuals and institutions in planning and implementation and that shortfalls in shortage subjects are being addressed.**

## Beyond Initial Teacher Education and Towards a Masters Level Profession

Strengthening ITE for primary school teachers is clearly essential given the lack of confidence in teaching science reported by existing primary teachers. However, this will take a long time to have a deep national impact. Thus there is also a need for support to allow existing primary school teachers, individually and collectively, to improve their knowledge of science and the pedagogy of teaching science.

Scotland currently has around 23,000 primary school teachers working in just over 2000 primary schools. In order to provide means by which they can develop and improve their scientific knowledge and pedagogy there is a need for a number of different routes to be available and for teachers to be supported in gaining access to them.

Scotland is already rich in resources that could be utilised to support primary teachers, both with basic science knowledge and with pedagogical content knowledge. For example:

* SCHOLAR – this independently evaluated, highly successful programme provides support for those wishing to study mathematics and the sciences at Higher (SCQF Level 6) and Advanced Higher (SCQF Level 7). This could be used to allow both primary teacher students and existing teachers to obtain SCQF Level 6 qualifications. The SCHOLAR Committee have confirmed that they would be supportive of teachers using it to gain qualifications.
* With Scottish Government support the University of Glasgow ran a PG Certificate in Primary Science course; this was a distance learning scheme running in Aberdeen and Dumfries with access to laboratories provided by secondary schools. It cost £125,000 pa for two years.
* The University of Dundee is running a programme with its four partner Local Authorities to improve the confidence and competence of primary school teachers

Whilst these are only a few examples of what can be done they nevertheless represent small and/or short term initiatives whereas what is required is a ten year programme that will change the situation across Scotland. This requires a national programme that involves university ITE departments, providing full geographic coverage with financial support for teachers and time off for practical study from Local Authorities.

The Scottish Teacher Education Committee (STEC) has confirmed that with proper preparation the universities could provide an MSc in Primary Science and Pedagogy. It is estimated that the cost would be around £6000 per student. In consequence it would be possible to train 230 primary school teachers for around £1,400,000 per annum. If such a programme was established and run for ten year then 10% of the current workforce would be specially trained, providing slightly more than the equivalent of one specially trained teacher for each primary school nationally.

#### Recommendation 14

* **A short life working party comprised representatives of STEC, ADES and Scottish Government should be convened to develop and implement a long term programme of financial and practical support for primary school teachers to obtain Diplomas and Masters in Primary Science and Pedagogy.**

For the Scottish teaching profession to move to an all Masters profession there is a need also for suitable Masters level modules and courses for secondary STEM teachers, both in terms of generic pedagogical issues and ones specifically in STEM pedagogical content knowledge, again as a national strategy with clear targets.

#### Recommendation 15

* **Higher Education Institutions working in partnership with others to ensure that the needs of teachers and their learners are met, through Masters accredited courses recognising the development of pedagogical content knowledge in the STEM subjects.**

Finally it is now over five years since the Donaldson Report *Teaching Scotland’s Future[[40]](#footnote-39)* was published. It is appropriate and valuable that its impact be reviewed. STEMEC welcomes the commissioning of an independent review by the Scottish Government. This is being carried out by IPSOS-MORI and the results are expected in spring 2016.

# 9. Primary Science

## Introduction

In 2008, the publication of two major reports, namely the 2007 *Scottish Survey of Achievement* (SSA)[[41]](#footnote-40) and the 2008 Trends in International Maths and Science Survey (TIMSS)[[42]](#footnote-41) highlighted a significant lack of confidence amongst Scotland’s primary teachers when delivering the science curriculum, and a decline in pupil attainment.

This was one of the main drivers which led to the Scottish Government launching a *Science & Engineering 21 – An Action Plan for Education[[43]](#footnote-42) in* 2010and establishing an advisory group (SEEAG), responsible for overseeing key work streams and outcomes. SEEAG’s report, *Supporting Scotland’s STEM Education and Culture[[44]](#footnote-43)* made several primary science recommendations, including:

* raising the qualification requirement for primary teaching students to include a minimum of SCQF level 5 or above in a science and mathematics, increasing to SCQF level 6 or above in a science and mathematics within five years.
* the need for at least 15 hours per year for high quality STEM CPD.

The report also supported several recommendations from the Donaldson Report, *Teaching Scotland’s Future*,[[45]](#footnote-44) around STEM Primary ITE and noted that ‘*an increased intake of primary teachers with much stronger science and mathematics qualifications up to and including degree level, with additional subject extension and enrichment during ITE, would introduce the necessary level of STEM knowledge and specialism at primary level’.*

## Progress since SEEAG

Since the publication of the SEEAG report in 2012 there have been several initiatives to help address some of the issues regarding the delivery of primary science.

SSERC (Scottish Schools Education Research Centre), in association with The Scottish Government, the National STEM Learning Centre and Local Authorities, designed a Primary Cluster Programme in Science and Technology which provided a systematised approach to professional learning in science and technology for primary teachers and has piloted its implementation over the period 2012-2015.

The cluster approach involves centralised training comprising two residential events, separated by a five month period when teachers implement a ‘gap task’ in their schools and clusters. The gap-task is devised at the first residential event and typically focuses on activities and processes that will promote science and technology teaching within individual schools and clusters.

Experiences are shared at the second residential event and the process is supported by follow-up CPD events and activities at school and cluster levels. Each school also identifies a mentor-teacher to carry out a range of responsibilities including the dissemination of relevant activities / information, promoting science and technology across CfE levels and supporting colleagues in a variety of learning and teaching approaches. They also become part of a wider network that can share ideas and expertise around appropriate CPD.

This programme has engaged with 16 of Scotland’s 32 Local Authorities and involved 240 primary schools from 41 clusters. The programme’s independent evaluation[[46]](#footnote-45) confirms that participation in the programme enables teachers to significantly raise their levels of confidence and expertise in science and technology, with increased levels of pupil engagement.

The evidence shows that this high quality CPD is making a sustainable impact within the 240 schools involved in the programme and SSERC has exceeded all the targets set out by The Scottish Government.

However, it should also be noted that this only represents approximately 12 percent of the total number of primary schools within Scotland. Therefore, for all primary schools to directly benefit from this SSERC experience, under the present format, it would take close to thirty years. Consequently, in order to build a timely and more appropriate capacity from this CPD programme, it is essential that further work and investment is undertaken to investigate suitable models that can cascade the confidence and expertise from the SSERC CPD programme across participating local authorities while continuing to extend this effective CPD experience across the rest of Scotland.

It is important that support be continued and expanded for SSERC to ensure all remaining Local Authorities have access to the Primary Cluster Programme and additional support can be provided to clusters beyond their first year of participation in the Programme, and to identify sustainable models to extend the impact of participation in the Programme across all local authority clusters.

#### Recommendation 16

* **There should be continued and expanded support for SSERC to ensure the all Local Authorities have access to the Primary Cluster Programme and additional support can be provided to clusters beyond their first year of participation in the Programme.**

SSERC is a much respected organisation which provides excellent science CPD services within Scotland. However the role of the local authority is central to the longer term and sustainable impact of science CPD. This must involve adopting a strategic and collaborative approach to the improvement of learning and teaching in science at primary. In May 2011 Aberdeen City took the decision to make science a priority area in the Local authority’s primary schools. Much can be learned from ‘The Aberdeen Science Journey’[[47]](#footnote-46) as an example of how one local authority made wide scale and strategic changes in order to address a known weakness within the primary sector.

Since 2012, Education Scotland has also initiated a number of activities in support of primary science teaching. The procurement of Tigtag, an award winning online resource, provides free access through GLOW to a range of short films, lesson plans and background information specifically aimed at primary teachers. A number of new Education Scotland websites contain relevant resources for primary science. A dedicated Primary Science Development Officer has also organised Glowmeets, presentations and activities at a range of events across Scotland. In September 2012, Education Scotland published ‘*The Sciences 3-18’* impact report[[48]](#footnote-47) which highlighted a variety of findings around primary science teaching and identified some key strengths and aspects for development. Following the publication of this report, Education Scotland organised a series of Science Conversation Days around the country to collectively identify *priorities for action* in order to secure improvements in science education nationally. Primary science was consistently identified as a priority area.

#### Recommendation 17

* **Education Scotland should continue to provide a dedicated Primary Science Development Officer Role with associated responsibility for primary science content across Education Scotland platforms.**

## On-going Challenges

Evidence from SSERC and Education Scotland would suggest that there has been progress in the teaching of science at primary, and in the raising of awareness about this very important area.

However, Scotland no longer participates in Trends in Mathematics and Science Survey (TIMSS), making it difficult to assess our current primary science performance using international comparisons as we did in 2008. The Scottish Government has also replaced the Scottish Survey of Achievement with the Scottish Survey of Literacy and Numeracy (SSLN), which no longer gathers data about science in primary. There is also evidence from England[[49]](#footnote-48) to suggest that a narrow focus on literacy and numeracy outcomes and testing can lead to science, along with other curricular areas, being perceived to be less of a priority. The OECD review of Scottish education[[50]](#footnote-49) highlights the need for “*an integrated framework of assessment and evaluation*” that is both fit-for-purpose and minimises unintended consequences.

#### Recommendation 18

* **National surveys like the SSLN survey should include information gathering about the confidence of primary teachers to deliver the science curriculum and pupil attitudes and performances in science.**

Despite the lack of formal national statistical data, both Education Scotland and STEMEC have attempted to gather relevant evidence at a series of nationwide Science Conversation Days and SSERC’s mentor-teacher conference respectively. This highlighted several on-going issues with regard to the teaching of science at primary including:

* lack of subject knowledge and understanding
* lack of time for development, CPD and planning,
* lack of resources and/or ideas
* not enough cluster working
* the low priority given to science in schools, clusters and LA’s
* ITE and a lack of science knowledge in new teachers

This would suggest that despite the recent professional development initiatives from Education Scotland and SSERC, more work needs to be done.

## Cluster working

The importance of developing effective professional learning communities (PLC) with associated research evidence relevant to Scotland’s educational landscape is addressed within the Career Long Professional Learning section of this report.

In relation to primary science, the benefits of the PLC approach include:

* Support for primary teachers to develop pedagogical content knowledge which will benefit pupil learning outcomes.
* Effective sharing of ideas and best practice to help build confidence in science amongst primary teachers.
* Access to specialist advice and wider support networks for information on topics such as up-to-date real life science example, hands-on experiments, and experiential learning.
* Shared CPD opportunities and enhanced cluster working.
* More effective primary-secondary liaison and transition in the sciences.

#### Recommendation 19

* **As PLCs develop, Education Scotland should consider quality assurance mechanisms based on a collaborative cluster approach to primary science. This would encourage open sharing of innovative approaches and allow primary schools to use their strengths to benefit whole clusters rather than just individual schools.**

## Initial Teacher Education (ITE)

In order to fully address the continuing issues in primary science, Initial Teacher Education (ITE) plays a central role. In 2012the SEEAG report made several ITE recommendations including raising the qualification requirement for primary teaching students to include a minimum of SCQF Level 5 or above in a science and mathematics, increasing to SCQF Level 6 or above in a science and mathematics within five years. The GTCS subsequently did not endorse this recommendation at the time but pledged to work in partnership with STEMEC and others towards having revised requirements in place by 2020 at the latest. Consequently, and given recent evidence highlighting ongoing concern about the lack of subject knowledge and understanding in the sciences amongst primary teachers, STEMEC once again calls upon GTCS to raise the entrance qualification for primary teaching students in science and mathematics (see Recommendation 9 in Section 8 of this report)[[51]](#footnote-50).

STEMEC also notes that GTCS draft recommendations aim to raise the minimum entrance qualifications in modern languages to reflect the Scottish Government Languages Working Group report[[52]](#footnote-51) Language Learning in Scotland: A 1+2 Approachand state:

*In line with the Scottish Government Languages Working Group report Language Learning in Scotland A 1+2 Approach (2012) all students undertaking a programme leading to a teaching qualification for Primary education must have attained a languages qualification at Higher level or equivalent (SCQF level 6) either on entering the programme of initial teacher education or on its completion. (At a future date, within the next five years, consideration will be given to making this a requirement which must be met prior to entry to a programme of Initial Teacher Education.)*

STEMEC is supportive of modern languages and the benefits they bring; however, it is essential that equal weight is given to the importance of science qualifications for those wishing to enter primary teaching. This is also supported by Recommendations 12, 13 and 14 of the Donaldson Report[[53]](#footnote-52).

Further evidence regarding the importance of science education is provided in the report, *Education Working for All*, from the Commission for Developing Scotland’s Young Workforce which states that ‘…*we can be confident that higher level skills and knowledge of science, technology, engineering and maths (STEM) will be increasingly important in the years ahead’*.

Indeed, Recommendation 12 of the report is: *A focus on STEM should sit at the heart of the development of Scotland’s Young Workforce.[[54]](#footnote-53)*

Selection criteria for primary ITE students across Scotland are crucial to achieving a balance of provision and specialism within the primary teacher workforce, especially during a time of increasing importance of STEM subjects within Scotland’s job market and to Scotland’s economy.

## Content of ITE courses

The amount of time dedicated to science modules within primary ITE courses varies considerably between different institutions. However, science remains one of the largest curricular areas with a total of 56 CfE Experiences and Outcomes at Early, First and Second Level. Since evidence continues to suggest on-going weaknesses in the delivery of primary science it is recommended that ITE institutions review their current practice and the time allocated to science with a view to ensuring that they are confident it is fit for purpose (see Recommendation 10 in Section 8 of this report).

## Curriculum

Education Scotland and the Scottish Government are working to establish new national forums to secure, consolidate and embed improvements to Curriculum, Learning, Teaching, Assessment and Support while maintaining relevance to deliver high-quality outcomes for all learners. This provides an opportunity to address teacher concerns about the number of science experiences and outcomes at Early, First and Second Level. The science curriculum at primary is significantly larger in terms of numbers of Experiences and Outcomes compared with other curricula areas, for example social studies. This is not only off-putting to many teachers who come from a non-science background but also fosters a culture of ‘box ticking’ and contrived inter-disciplinary learning in order to ‘cover all the Es and Os’. While we welcome the *'Assessing Progress and Achievement in the Significant Aspects of Learning*' guidance[[55]](#footnote-54) (June 2015) from Education Scotland, teacher feedback suggests more work is needed to reduce in number and simplify the 56 experiences and outcomes within the science curriculum from early to second level. Once that work is complete further exemplification would be useful.

#### Recommendation 20

* **The Science Curriculum, Learning, Teaching, Assessment and Support Forum should look at ways to reduce in number and simplify the 56 Experiences and Outcomes within the primary science curriculum as a priority; subsequently providing further exemplification.**

#### Recommendation 21

* **Education Scotland should continue to offer guidance and support around the delivery of the Experiences and Outcomes, both in terms of science knowledge and science skills at early, first and second levels.**

## Informal Science Learning

Scotland’s primary schools continue to benefit from a strong science engagement sector in Scotland which provides a rich variety of informal science learning support to both learners and teachers.

Scotland’s Science Centre Network, Science Festivals and science engagement organisations remain active in providing extensive schools programmes which focus on engaging, relevant and hands-on science activities.

In 2012 the SEEAG report made a series of recommendations to help promote better awareness, quality and coordination of this activity. While some issues remain, it should be noted that engagement with the primary sector has continued to grow as evidenced by increasing school numbers at science centres and festivals, and an increasing amount of science club activity within primary schools.

SCDI Young Engineers and Science Clubs (YESC) now operate in over 900 primary schools across Scotland (approx. 45%), providing a range of high quality, topical STEM resources in line with the Scottish Government’s key economic sectors such as the Life Sciences, Energy and the Creative Industries.[[56]](#footnote-55)

Projects are interdisciplinary with relevant curriculum links and are introduced to primary teachers via a series of supportive CPD workshops. The clubs engage employers from business and industry while working in partnership with other STEM organisations and the STEM Ambassador programme in Scotland. YESC aim to engage 100% of primary schools in Scotland by 2022.

#### Recommendation 22

* **Scottish Government and Local Authorities should work with SCDI YESC’s to support engagement with 100% of primary schools in Scotland by 2022 in order to promote the embedding of YESC activities within the curriculum and ensure an entitlement for all.**

Many informal science learning providers continue to develop innovative partnerships that benefit both teachers and learners. Again, local authorities can play a key role within these partnerships. For example, Glasgow Science Centre, working with Glasgow City Council and West Dunbartonshire Council, has established a programme of free primary school visits from these local authorities to the science centre. This allows primary teachers to embed strong CfE linked activities to their planning and delivery of science lessons on an annual basis and promotes closer links between primary teachers, scientists and wider science engagement opportunities

#### Recommendation 23

* **Scottish Government should continue to provide funding to the Scottish Science Centre Network and Scotland’s Science Festivals while maintaining a wider programme of science engagement grants to support Scotland’s varied science engagement activities.**

Young people’s perceptions of science and how science benefits society begins in primary school. In order to continue inspiring the next generation of Scottish scientists and to equip our young people with the skills required to make informed decisions in the future, it is essential they are provided with the highest quality science experiences from an early age. Scotland has made progress during the past 3 years, but increased support is required to ensure our primary sector can embrace the rapidly increasing number of science opportunities which will benefit Scotland and all our young learners.

# 10. Effective Career Long Professional Development and Professional Learning Communities

## Some developments since SEEAG

The SEEAG report *Supporting Scotland’s STEM Education and Culture* included[[57]](#footnote-56) sections on Professional development for teachers and Support structures for teachers and learners. Building on the research available a number of recommendations were made regarding the Continuing Professional Development (CPD) and the development of Professional Learning Communities (PLC). Both CPD and PLCs are a means of facilitating the effective Career Long Professional Learning (CLPL) of teachers, a term now coming into increased use. CLPL increases the professional capital of teachers and in turn facilitate improved learning of pupils. In the three or so years since the SEEAG report the issues facing us in this area have remained largely the same, however, there has been good progress on a number of topics but less so in others. These are discussed below leading to a number of recommendations.

In December 2012 the General Teaching Council for Scotland (GTCS) introduced updated Professional Standards and supporting guidance has been developed by both GTCS and Education Scotland (ES) to support self-evaluation within professional learning.

The GTCS Standards[[58]](#footnote-57) for Registration and Career Long Professional Learning (CLPL) require teachers to work collaboratively, critically engage with professional literature and educational research, and engage in reflective practice all with the aim of enhancing the learning of our young people.

In its introduction to its Career Long Professional Learning pages on its website ES states:

*“Teachers work in a complex and dynamic society. This means that teachers need to be critically informed, have professional values and knowledge and take actions that ensure a positive impact on learners and learning. Teachers therefore need opportunities to develop in order to address these changing demands.*

*The most successful education systems invest in developing their teachers as reflective, accomplished and enquiring professionals who are able, not simply to teach successfully in relation to current external expectations, but who have the capacity to engage fully with the complexities of education and to be key actors in shaping and leading educational change[[59]](#footnote-58).”*

The importance of high quality career-long professional learning for all teachers is clearly recognised by both the GTCS and ES. This chimes very much with the discussion and recommendations made in the SEEAG report around Teacher Education, Continuing Professional Development (CPD) and Professional Learning Communities (PLC). We all wish to see the development of the capacity within the teaching profession for deep learning and reflection and sustained improvement of pupil learning.

It is clear that the GTCS vision for self-directed CLPL facilitated through Professional Review and Development and Professional Update requires a shift in culture for many involved in education: teachers; school leaders; in education authorities, and in CPD providers.

* Teachers require to be more proactive in identifying and requesting the CLPL which best assists them to meet the needs of the learners in their care and planning coherent but extended programmes of CLPL which draw upon CPD from a range of sources.
* Leaders in schools and education authorities require to provide the vision and leadership which facilitates and supports the provision and participation of themselves and teachers in effective CPD with impact on pupil learning outcomes.
* CPD providers require to ensure that the CPD offered meets the needs of teachers looking to improve pupil learning outcomes and blends together effectively subject knowledge and pedagogical knowledge.

Progress has been made in a number of areas which will help make this shift:

* The GTCS Professional Update itself is now being phased in across a five year period.
* GLOW has been updated and has a more user-friendly interface and areas to facilitate professional dialogue and to allow the open national sharing of resources. A wider range of professionals across Scottish education now have access to GLOW. It is nevertheless work in progress and still suffers in some quarters from a poor reputation as a hangover from its previous versions and a reluctance by some to allow the advantages of full national sharing of resources rather than only on a local basis.
* A number of cluster pilot projects have and are being developed across STEM. These include initiatives on primary science led by SSERC, in a number of education authorities by Education Scotland, on improving gender balance led by the Institute of Physics for Skills Development Scotland and Education Scotland.
* Improved professional dialogue, collaboration and sharing within national subject specialist groups has been made possible by the setting up thanks to the drive and leadership of a number of individuals, professional bodies and organisations. These include the well-established Physics Teacher Network, Sputnik and sptr.net for physics, but now also Strontium for chemistry, Synapse and a Biology Teacher Network for biology, regular #ASEchat sessions on Twitter, an active CDT Facebook group and PlanC for computer science. These initiatives often involve a mixture of face-to-face and virtual communication and have helped promote an ethos of professional communication and collaboration not present previously.
* As well as subject specialist professional communities more generic fora for teachers to engage in professional dialogue, collaboration and learning have grown in popularity such as pedagoo.org and #ResearchEd. Pedagoo, started as an online community in Scotland by teachers, has shown that there is a demand from at least a significant minority for professional learning focussed on the needs of the teacher. It has also shown that modern communications and social media can quickly lead to this taking on an international dimension. The development of active online communities using Twitter and other media have also quickly developed a demand for related face-to-face meetings and events, often in the style of Teachmeets consisting of short presentations on activities directly related to student learning.

In January 2015, at a meeting of teachers and representatives of professional and government bodies involved in supporting PLCs in Scotland, the shortage of time was identified as the single greatest barrier to making progress. Effective CLPL and the building of professional capital of teachers requires time for teachers to collaborate and engage in professional activities both with peers and the wider community. However, Scotland compares poorly in international comparisons of teaching hours expected of our teachers[[60]](#footnote-59). This inevitably leaves less time available for effective CLPL.

#### Recommendation 24

* **The GTCS Professional Update process should be used as the framework and catalyst for effective CLPL for all teachers with sufficient time for effective delivery provided.**

For this to occur, a number of conditions need to be in place.

1. Education authority and school leaders provide protected time to allow teachers to meet and collaborate regularly over extended periods of time. This is especially necessary to facilitate effective primary-secondary liaison and therefore transition, effective interdisciplinary learning and to allow sustained improvements in the professional capital of teachers and in their pedagogical content knowledge which will then have beneficial impacts on pupil learning outcomes.
2. The GTCS ensures that its Professional Update process and its user-interface is fit for purpose and easy to use and by doing so does not discourage any teacher from properly engaging with the process.
3. Teachers and their reviewers at all levels undertake the Professional Update process with the high level of professionalism it deserves.
4. Teachers be more proactive in reflecting on needs, identifying and requesting the CLPL which best assists them to meet the needs of the learners in their care and then plan coherent extended programmes of CLPL which draw upon CPD from a range of sources.
5. Leaders in schools and education authorities provide the vision and leadership which facilitates and supports the provision and participation of themselves and teachers in effective CPD which has impact on pupil learning outcomes and meets the needs of professionals completing Professional Update.
6. CPD providers ensure that the CPD offered meets the needs of teachers looking to improve pupil learning outcomes and blends together effectively the development of subject knowledge and pedagogical knowledge, i.e. improvements in pedagogical content knowledge.
7. Education authorities and national agencies must avoid short term initiatives which have funding or other support removed before sustainable change can be effected or even properly evaluated. Where short term initiatives are developed, such as PlanC in Computer Science, provision must be provided for longer term sustainability.

## Developing the Professional Capital of Teachers

Curriculum for Excellence has increased the freedom of teachers to adapt the curriculum to meet the needs of their pupils (even if the nature of SQA assessment has restricted this significantly in the Senior Phase). Other aspects of the Scottish education system have not yet been transformed to best allow teachers to make the most of this new found freedom, particularly at a time of financial restraint.

To best effect such change there is required a growth in the professional capital of teachers as described by Hargreaves and Fullan (2012)[[61]](#footnote-60). Professional capital is defined as a function of three other kinds of capital: human, social, and decisional. *Human* capital in teaching is about having and developing the requisite skills and knowledge. It is about knowing your subject and knowing how to teach it, pedagogical content knowledge. However, human capital cannot be built in isolation. The deliberate use of teamwork and networks of communication to build a culture of learning, collaboration and trust can accelerate learning and change. This is *social* capital. The essence of professionalism is the ability to make discretionary judgements, often in complex situations. Professionals acquire and accumulate *professional* capital through experience, practice and reflection.

The revolution in professional capital has to be bottom-up as much as top-down. Actions required by various key stakeholders include:

Teachers should:

* be reflective professionals by examining their own experience;
* build their human capital through social capital;
* professionally push and pull their peers;
* invest in and accumulate decisional capital;
* manage up to help leaders be the best they can be;
* be prepared to take the first-step;
* and most importantly, connect everything back to their students.

School and local authority leaders should:

* promote professional capital vigorously and courageously
* know their people and understand their culture;
* secure leadership stability and sustainability;
* avoid contrived collegiality (and other irritating associates) where teachers are forced to meet in ineffective groupings;
* reach out beyond their borders;
* be evidence-informed, not data-driven.

This is consistent with developing a more activist approach to the teaching profession leading to transformative change in the professionalism of teachers as described by Sachs (2003)[[62]](#footnote-61).

Six principles that provide the conceptual and practical basis for a new professionalism to be established have been identified by McLauchlin (1997:89)[[63]](#footnote-62):

* increasing opportunities for professional dialogue;
* reducing teachers’ professional isolation;
* providing a rich menu of nested opportunities for learning and discourse;
* connecting professional development opportunities to meaningful content and change efforts;
* creating an environment of professional safety and trust;
* restructuring time, space and scale in schools.

Key features of effective change through transformative professionalism are ensuring action is focussed on the improvement on the learning outcomes of pupils and collaborative working through the development of effective professional learning communities and networks. This means teachers will have to work collaboratively, not only with other teachers but also with others interested in education and improving student outcomes. Transformative professionalism must come from the membership of the profession and be supported by other interest groups and stakeholders. Transformative professionalism across the whole profession is something to aspire to and may well take considerable time and energy to achieve. The aim is ultimately to move to a position which allows and encourages individuals and groups to have the confidence to make things happen rather than let things happen to them.

The characteristics of transformative professionalism include:

* inclusive membership
* public ethical code of practice
* collaborative and collegial
* activist orientation
* flexible and progressive
* responsive to change
* self-regulation
* policy-active
* enquiry-oriented
* knowledge-building

Schools involved in progressing the agenda of teacher professionalism have:

* increased opportunity and responsibility of teachers to exercise discretionary judgement over issues of teaching, curriculum and the care that affects one’s students;
* opportunities and expectations to engage with the moral and social purposes and values of what teachers teach, along with major curriculum and assessment matters in which these purposes are embedded;
* commitment to working with colleagues in collaborative cultures of help and support as ways of using shared expertise to solve ongoing problems of professional practice, rather than engaging in joint work as a motivational device to implement external mandates of others;
* a self-directed search and struggle for continuous learning related to one’s own expertise, rather than compliance with the obligations of endless change demanded by others (often under the guise of continuous learning or improvement);
* become part of a national social movement in which teachers individually and collectively develop skills, competencies and dispositions of mind that will contribute to the enhancement of teaching and the improvement of student learning outcomes.

These new kinds of affiliations and collaborations move all parties beyond traditional technical notions of professional development. To quote one teacher:

*“Getting to talk to other people makes you have a good hard look at what you’re doing”.*

The managerialist form of professionalism segments and divides educational interest groups and hinders rather than facilitates dialogue among them. It does not allow the development and facilitation of networks. A politics of transformation is not self-interested; its concern is with wider issues of equity and social justice. Its focus is on the longer term rather than the short term, even though short-term gains are important in sustaining the energy and interest of participants.

Networks of activist professionals sidestep the limitations of institutional roles, hierarchies and histories, and promote opportunities for diverse groups to work together. These networks can develop through existing professional or industrial associations, or by coming together to review specific needs, or by a slow and evolving process that requires continuing oversight and governance. The establishment of effective networks often depends on the vision and commitment of a few. However, when networks, coalitions and partnerships last long enough, they develop into on-going learning communities, into deeply embedded cultures that are based on mutual knowledge, learning, collaboration, and understanding.

## Effective Professional Learning

The Teacher Development Trust commissioned a review of the international research into what constitutes effective professional development for teachers. Its findings, published in *Developing Great Teaching* (2015)[[64]](#footnote-63), are instructive for any country, including Scotland, and supports the GTCS’s model of professional learning that makes explicit four interconnected dimensions of the learning experience: Reflection on Practice; Experiential Learning; Collaborative Learning, and Cognitive Development[[65]](#footnote-64).

Developing Great Teaching considers the research of Whitehouse[[66]](#footnote-65) (2011) into what makes effective CPD for teachers.

“It is difficult to establish cause and effect between teachers taking part in CPD and improvements in the attainment of their students, therefore student outcomes are rarely used as a measure of effectiveness of CPD. Nonetheless, a number of reviews on the topic of teacher CPD agree to a large extent on what constitute the six characteristics of effective CPD for teachers. Effective CPD is:

* based on identified learning needs for both students and teachers;
* sustained;
* subject specific;
* based in the classroom;
* collaborative (particularly in establishing professional learning communities); and
* uses external expertise.

Effective CPD for teachers is iterative in nature to allow time for personal teaching theories to be challenged and teaching practices to be changed through participation in professional learning communities.

The research review found that in facilitating effective CPD school and education authority leaders must distinguish between:

* professional development opportunities that are aimed at operational and procedural knowledge (e.g. how teachers comply with legislation or MIS systems) where simple briefings may suffice; and
* professional learning directly aimed at building on teachers’ starting points to significantly enhance pupil learning – where a sustained and dynamic mix of activities will be required.

In doing so they should avoid promoting ineffective CPD which includes:

* a didactic model in which facilitators tell teachers what to do, or provide materials without giving participants opportunities to develop skills and enquire into their impact on learning;
* professional development which does not have a strong focus on aspirations for students and assessing the impact of changed teacher practices on pupil learning.

The research review also found that effective CPD has a number of characteristics and suggested a number of key actions or behaviours.

1. Effective CPD has a duration of at least two terms, more usually a year or longer. However, long duration in itself is not sufficient and one CPD provider is unlikely to be able to provide for the variety of needs of any teacher over an extended period of time. Schools leaders must be prepared to ensure that staff are given the necessary support and time to engage with longer duration planned programmes of CPD. CPD providers and external facilitators must therefore be prepared to embed sessions in longer planned programmes of CPD rather than one-off, one day support.
2. It has a sequence of follow-up, consolidation and support activities. Time here is key. School leaders must support teachers allowing engagement in this sequence. Teachers also need time to translate their learning into their classroom; to experiment in their classroom, and to reflect on the results.
3. All reviews found that an essential element of successful CPD is generating buy-in from the participants. Schools and CPD providers must consider how they support teachers in identifying and understanding needs and in developing the capacity to reflect on their classroom practice and then respond appropriately.
4. The review points out the achieving a shared sense of purpose during professional development is an important factor for success, regardless of whether teachers were conscripted or volunteered to take part.
5. The review indicates that effective CPD programmes feature a variety of activities to reinforce their messages and test ideas from different perspectives. No single type of activity, or configuration of multiple activities, was shown to be universally effective. What matters is a logical thread between the various components that create opportunities for teacher learning that are consistent with the principle of the student learning being promoted. Schools and CPD providers should consider carefully the delivery methods used.
6. The review highlights the equal importance of both pedagogic and subject knowledge. Findings from the strongest review went further, showing that professional development focussed on generic pedagogy is insufficient.
Effective CPD must be underpinned by a number of “key building blocks”:

	1. subject knowledge
	2. subject-specific pedagogy (pedagogical content knowledge)
	3. clarity around learner progression
	4. content and activities dedicated to helping teachers understand how pupils learn in specific subject areas and more generally
	5. formative assessment and supporting the differing needs of all learners
	6. It is important to consider how subject-specific pedagogy is developed alongside generic skills. School leaders and CPD providers must ensure programmes address all of these five areas.
7. Effective collaboration. Teachers must be able to collaborate together and build on peer group experiences, but also to draw on external inputs from appropriate specialists, experts, mentors and coaches. CPD providers need to focus on activities that explicitly link professional learning to improvements in pupil outcomes.

Countries that wish to improve the effectiveness of professional development provided to teachers should increase the amount and variation of school embedded offerings such as mentoring and coaching, creating networks of teachers who learn together, and supporting collaborative research and instructional problem solving by teachers[[67]](#footnote-66).

## Professional Learning Communities (PLC)

Much of the above can be facilitated and enhanced through effective Professional Learning Communities. In the introduction to its guidance on developing PLCs from 2013 the Welsh Government states[[68]](#footnote-67):

“The research evidence consistently highlights the importance of interdependent learning and collaboration as the cornerstone of school improvement and effective professional development. It reinforces that where teachers collectively investigate ways of overcoming barriers to **their** students’ learning, the outcomes can be dramatic. Working in this way, as a PLC, can bring many benefits but most importantly, if done well, PLCs can result in improved learner outcomes (Verscio et al, 2008; Saunders et al, 2009). In addition, networks of PLCs (between and across schools) enable the groups to widen their expertise and to share their most effective practice.

“Extensive research evidence shows that teachers who are part of a PLC tend to be more effective in the classroom and achieve better student outcomes (Lewis and Andrews, 2004). PLCs can also improve teachers’ professional learning and secure improved school performance, irrespective of the school context and its socio-economic profile (Elmore, 2002; Goldenberg, 2004).

“In short, a PLC engages teachers in collaborative enquiry, about a specific issue or problem, with the prime aim of changing professional practice so that improved teaching and learning follows (Dufour et al, 2009). The purpose of a PLC can be summed up in three words – ‘improved learner outcomes’ (Harris and Jones, 2010).”

Clusters of teachers and schools working together could form the nucleus of a PLC but effective PLCs are likely to collaborate with and draw upon a range of expertise and specialist advice from a range of networks and sources such as local authority support staff, CPD providers, universities and colleges, and the local community and industry.

## Supporting collaboration and developing professional capital

To effect long-lasting improvements both in the professional capital of staff and in pupil learning a clear vision and sustained support is required. One such example is the improvement in primary science learning in Aberdeen City schools in recent years. This has involved a clear vision from the local authority leadership backed up with sustained support over many years including:

* the appointment of subject specific support staff;
* the provision of good quality CPD from a range of providers including: SSERC; the local science centre which works collaboratively with a range of other CPD providers, and learning festivals, often delivered in teacher holiday time;
* providing an incentivised development framework through the Primary Science Quality Mark;
* developing innovate strategies such as the use of S6 pupil Science Ambassadors in primary schools.
* recognising positive achievement.

With the regionalisation of further education colleges it is now easier for school clusters to identify their local college. Such a structure should include also a university so that all schools have an established relationship to which they can benefit and contribute. As with the Colleges this does not restrict either the University or the School to one relationship but its recognition will allow both formal and informal relationships to flourish to all partners advantages. Given the distribution of universities in Scotland this will need some careful thought but the submission from Universities Scotland to the STEMEC indicates an interest in exploring this and this should be encouraged.

In Finland a nationwide network of twelve LUMA Centres (STEM Centres) has been developed. These are based in universities but involve partnerships with local authorities, schools, industry and others to facilitate communication between all of these groups in a co-ordinated manner. This has been managed despite Finland’s large geography and often sparsely populated areas.

Given Scotland’s existing network of Science Centres, universities and regional colleges, as well as support services such as SSERC it is not too difficult to see how a similar network of STEM Centre support could be developed to support pupil learning and teacher CPD as well as facilitate researcher engagement with schools and the public.

#### Recommendation 25

* **Education authority and school leaders should facilitate the participation of teachers in meaningful and effective PLCs, be it local clusters, national subject fora, professional associations or others which allow teachers to develop as professionals and improve the learning of the students in their care and avoid the promotion of contrived collegiality.**

#### Recommendation 26

* The Scottish Government should encourage universities, the Scottish Funding Council, colleges and science centres to develop, along with schools and local authorities, a network of STEM Centres to act as hubs and give a focus for cluster working, CLPL, pedagogical development and communication between organisations. This model can be extended to other areas of the curriculum.

To support effective PLCs:

1. Leaders at national, local and school level ensure there is greater support for subject teachers and the development of confident teachers with good pedagogical content knowledge.
2. Education authority and school leaders provide protected time to allow teachers to meet and collaborate regularly over extended periods of time to develop sustainable developments and collaborate effective interdisciplinary learning.
3. The lessons learned and examples of best practice from cluster pilot work should be used to build sustainable, effective cluster working across Scotland with the aim of increased professional capital education system wide.
4. Education authorities and national agencies must avoid short term initiatives which have funding or other support removed before sustainable change can be effected or even properly evaluated.
5. Education authority and school leaders should facilitate GLOW to be developed as a national collaboration and sharing tool as it was initially intended.

Whilst recognising the considerable progress made in Scottish education in its report *Improving Schools in Scotland: An OECD Perspective[[69]](#footnote-68)* the OECD review team make a number of observations and recommendations consistent with the need to strengthen collaborative working and PLCs which we support, for example:

*“We believe in reinforcing the “middle”, through fostering the mutual support and learning across LAs, together with schools and networks of schools. If the LAs are given a more prominent role as part of a reinforced “middle”, together with the collegiate activity of schools, networks and communities, then their varied capacity and expertise will need to be addressed through processes of professional accountability.”*

and

*“Teachers who work in cultures of professional collaboration have a stronger impact on student achievement, are more open to change and improvement, and develop a greater sense of self-efficacy than teachers who work in cultures of individualism and isolation. Not all kinds of professional collaboration are equally effective. We suggest that collaboration in improving teaching, assessing CfE, and connecting schools to take collective responsibility for each other’s improvement and results, should be top priorities. In line with current commitments of the Scottish College of Education Leadership, the Standards Frameworks could emphasise even more the importance of and expectations for collaborative professionalism and leadership.”*

This suggestion from the OECD Review Team recognises the recent development of the Scottish College for Educational Leadership’s *Framework for Educational Leadership*[[70]](#footnote-69) which emphasises the important role all teachers have in leading learning and managing change in challenging times. The framework has self-evaluation and research based professional development embedded in its core.

SSERC’s Primary Cluster Programme in Science and Technology has proved to be very successful in empowering mentors, promoting collaborative working and promoting collegiality within and across cluster schools as well as increasing teacher and importantly pupil engagement with science and technology[[71]](#footnote-70).

The provision of high quality CPD is available across the STEM subjects. SSERC, working with a wide range of partners (89 listed in Table 2 of its 2014-15 Annual Report, many of whom also provide similar CPD separate to that delivered in collaboration with SSERC), continues to offer a not insignificant level of well received and regarded CPD across science and technology. In 2014-15 SSERC co-ordinated CPD reached more than 2000 teachers, student teachers and technical support staff with representatives from all education authorities and 15 independent schools. In order to provide such an extensive programme SSERC were able to draw upon their core local authority funding, that from Scottish Government but also to draw in significant additional funding from other sources such as the National Science Learning Centre (NSLC), Research Councils UK (RCUK) and The Wellcome Trust. In doing so SSERC was able to extend their premises allowing for improved provision in support for secondary engineering and technology, and primary science and technology.

Despite this increased level of provision it still involves a minority of the Scottish teaching workforce. It is unrealistic to expect these individuals to have a large impact across all schools and education authorities as it is likely they will be given limited opportunities to cascade their newly gained enthusiasm, knowledge and skills gained to other staff. Sharing and collaboration time is often at a premium during normal school working and therefore communication can be poor resulting in little cultural change across institutions. As expected from the research evidence on effective CPD, a core feature of much SSERC CPD is embedding subject specific, hands-on, experiential activities which may be difficult for a teacher to fully replicate and cascade to colleagues in the times made available.

#### Recommendation 27

* **Scottish Government, Education Scotland and Local Authorities should ensure that there is sustained funding to both increase the capacity of SSERC and to allow them to plan extended programmes of professional support crossing over several financial years.**

# 11. Interdisciplinary Learning (IDL)

## Why should we care about Interdisciplinary Learning (IDL)?

* IDL is one of four contexts for learning in CfE that connects curriculum areas and subjects with the wider contexts and settings where young people learn, develop and achieve.
* IDL enables learners to make strong connections between different areas of their learning within and beyond the school, outdoors, in communities and the workplace, developing higher order skills and preparing young learners for the world of work.
* IDL is founded on strong disciplinary knowledge. It does not take place at the expense subject learning but complements and enriches subject learning and facilitates learning beyond subject boundaries.
* IDL fosters an understanding of the inter-relatedness of phenomena in our world.
* IDL is a key element of school improvement that provides practical approaches to engaging disengaged learners, encouraging them to participate actively in their learning and contributing to the implementation of the National Improvement Framework.
* Creativity relies on making connections through teamwork and the breaking down of discipline boundaries; it is founded on – and fostered - by IDL.
* The key to successful innovation is the ability of people with different knowledge, skills and competences to collaborate, building on and developing existing ideas.
* Published research offers good evidence for the positive impact of IDL on learners’ attainment and attitudes, and contributes to teacher satisfaction.
* IDL should build a culture of collaboration amongst teachers, schools and local authorities, and with external support agencies (universities, colleges, industry, business and other agencies), strengthening the ‘middle’ of Scottish education.
* In the absence to date of clear understanding, articulation and exemplification of what constitutes IDL, its implementation in Scottish schools has been a low priority; Scottish education now requires the strategic development of a culture of learning in an interdisciplinary way.

## IDL within Curriculum for Excellence

Learning, teaching and assessment have traditionally taken place *within* curriculum areas and subjects, with little consideration of the connections *between* and *beyond* subjects and curriculum areas. CfE now places much greater emphasis on learning beyond the boundaries of traditional subjects, recognising that in practice young people learn in a range of places beyond the classroom or the school, for example outdoors, beyond the school and in communities[[72]](#footnote-71),[[73]](#footnote-72),[[74]](#footnote-73),[[75]](#footnote-74). This requires a radical shift in the philosophy and practice of learning and teaching beyond the traditional ‘curriculum areas and subjects’ to embrace interdisciplinary learning (IDL) and other wider learning contexts.

The remit of the Science and Engineering Education Advisory Group (SEEAG) included an intention to ‘*value interdisciplinary learning’*. The SEEAG Report[[76]](#footnote-75) envisaged that CfE would create a framework for improving science teaching and learning, providing rich contexts and opportunities for interdisciplinary and cross-curricular learning across the STEM subjects and beyond. It encouraged teachers to teach beyond the confines of their specialist knowledge with colleagues in other subject areas in order to point out the connections between the science disciplines and across into other curricular areas.

Cross-cutting themes draw together outcomes from one STEM area or subject with another to highlight the real world relevance of STEM to contemporary issues and challenges and provide rich opportunities for active learning in open-ended investigations and critical thinking. The report recognised that these changes would require a cultural change in the profession, particularly in the secondary sector.

## So what’s the problem?

IDL is not a new idea. Debates around the relative merits of disciplinary and interdisciplinary learning go back decades[[77]](#footnote-76),[[78]](#footnote-77). The starting point for STEMEC’s IDL workstream was a sense from reviewing the available reports and literature, and from talking to - and working with – many teachers and educators, that beyond the original statements about IDL in CfE[[79]](#footnote-78),[[80]](#footnote-79),[[81]](#footnote-80),[[82]](#footnote-81), there was little or no clear, unambiguous explanation of what constitutes IDL, how IDL relates to the disciplines (subjects) and curriculum areas, and why it is important for learners and for CfE. Neither was research evidence presented for its positive impact on learners and on learning and teaching.

While we know of a number of positive examples of schools where IDL is now being successfully implemented[[83]](#footnote-82), in other schools little or no co-ordinated or planned progress has been made, a conclusion supported by summary evidence from Education Scotland reports[[84]](#footnote-83),[[85]](#footnote-84),[[86]](#footnote-85) indicating patchy implementation at best. There is a dearth of clear exemplification of good practice of IDL to provide practical help to practitioners. We believe that clear articulation and exemplification of IDL in STEM and across the curriculum, including what constitutes IDL, why it is important and evidence for its impact on learners, are essential for its successful implementation and development in Scottish education.

## STEMEC’s IDL Work Strategy and Scope

A strategy was devised for STEMEC’s IDL workstream in order to create and articulate a better understanding of the nature and importance of IDL and its relevance to current priorities and initiatives in Scottish education, to consider and review mechanisms and initiatives to support implementation of IDL, to identify the main challenges in implementing IDL, and to recommend strategic priorities and actions necessary to embed IDL within CfE.

Research has been undertaken to establish what constitutes IDL, how it relates to the disciplines in principle and practice, and why it is important in the context of CfE. An understanding of what constitutes IDL is found in the educational research literature, significantly in higher education[[87]](#footnote-86) where research and teaching have become increasingly interdisciplinary in recent decades, and especially (but not only) in the STEM subjects that define the context and remit for this workstream.

STEMEC’s strategy on IDL has been developed in collaboration with the Learned Societies Group for STEM Education in Scotland (LSG), launched in 2012 and hosted by the Royal Society of Edinburgh (RSE), which has adopted IDL as a major focus of its work programme. This shared working led in 2013 to the establishment of an IDL National Action Group (NAG) involving leadership representatives of all key educational organisations and agencies across Scotland in a five-year programme and action plan (2013-18) to agree the principles, conditions, actions and support necessary to enable teachers to deliver and sustain IDL in Scottish education, and to implement these, building on existing good practice.

A brief ‘National Statement’ on IDL has been agreed by the NAG to underpin its work[[88]](#footnote-87). The NAG’s work to date has contributed substantially to this part of the STEMEC report. Execution of the various elements of its action plan by its constituent educational organisations and agencies will be central to embedding IDL within Scottish education.

The key elements of the STEMEC IDL strategy have included:

* Gathering of evidence about the nature of IDL, progress of IDL implementation, its impact on learners’ attainment and in schools, and teacher views and feedback on IDL.
* Research on the wider importance of IDL for enhancing transferable skills, skills for learning life and work, and the relevance of IDL to the workplace and economic development.
* Articulation of the principles and practice of IDL to (inter alia): schools, school leaders, local authorities, Universities Scotland, parent groups, teacher groups, business/industry and others through presentations and published articles.
* Work around the impact of IDL beyond the curriculum, outdoors and in communities, with relevance to engaging disengaged learners and closing the attainment gap.
* Practical development, exemplification and implementation of IDL through workshops with teachers and educators, PowerPoint presentations and published articles.
* Development of new strategies and models within Scottish universities (including ITE) for wider support for IDL implementation in schools, linked to sustainable educational partnerships (learning communities) and online resources.

A substantial piece of work on IDL was undertaken and reported by the teacher-led Building the Curriculum Self Help (BOCSH) Group[[89]](#footnote-88), which reviews Scottish, UK and international case studies on the implementation and impact of IDL. The work and recommendations of the BOCSH group complement STEMEC’s conclusions and recommendations.

The Royal Society’s 2014 Vision Report for Science and Mathematics Education[[90]](#footnote-89) contributed substantial commissioned educational research on integrated and interdisciplinary studies in STEM education that provides important evidence of the impact of IDL on learning and teaching in the UK and internationally[[91]](#footnote-90). Relevant outcomes, priorities and issues emerging from the recent National Improvement Framework[[92]](#footnote-91) and OECD review of CfE[[93]](#footnote-92) have also been considered.

The STEM Education Support Officer for Higher Education and Industry links, based at SSERC and funded by Deans of Science and Engineering of the Scottish Universities and Education Scotland from 2013 to 2015, undertook ‘to contribute to the development of interdisciplinary approaches to enhance the learning experience’. Key outcomes from the final report of his work[[94]](#footnote-93) are reported.

Education Scotland contributed to work on IDL through its CfE Briefing Paper[[95]](#footnote-94) and other related reports.[[96]](#footnote-95),[[97]](#footnote-96),[[98]](#footnote-97),[[99]](#footnote-98) Good progress has been made within the timescale of STEMEC (2012-15), but this work is part of an ongoing process to be taken forward by the IDL NAG (2013-18) and the LSG. Thorough academic research on IDL implementation and its impact on learners is needed if we are to fully understand what works and doesn’t work. A methodology for undertaking such research is proposed.

## IDL as an Integrating Context for Learning in CfE

CfE has a degree of interdisciplinarity and connectedness built into its eight curriculum areas (Expressive Arts, Languages and Literacy, Religious and Moral Education, Social Studies, Mathematics and Numeracy, Sciences, Technologies, and Health and Wellbeing), insofar as Literacy, Numeracy and Health and Wellbeing are specified as cross-cutting or interdisciplinary ‘curriculum areas’ and are seen as the responsibility of all teachers and practitioners irrespective of their specific teaching responsibilities.

There are also specified topics or themes across learning such as sustainable development, global citizenship, enterprise, financial education and Scotland’s culture. However, we are concerned first and foremost with the development and implementation of IDL at a much more fundamental and strategic level, where it is firmly embedded within the contexts for learning of CfE.

The founding principles for CfE[[100]](#footnote-99),[[101]](#footnote-100),[[102]](#footnote-101),[[103]](#footnote-102) encompass the four contexts for learning: curriculum areas and subjects; the ethos and life of the school as a community; opportunities for personal achievement; and IDL. *Building the Curriculum 382* stresses the connections between all four contexts, including within them extra-curricular activities and learning outwith the school (including outdoors learning), and states that the curriculum should include space for learning beyond subject boundaries so that learners will make connections between different areas of learning. *Building the Curriculum 483* further asserts that skills for learning, life and work should be developed across all areas of the curriculum in interdisciplinary studies, and in all contexts and settings where young people learn, while *Building the Curriculum 584*states that achievement covers not only curriculum areas and IDL, but also other areas within and beyond the school.

Curriculum areas and subjects must remain at the heart of the curriculum, providing a structure for knowledge82. However, *IDL assumes a central and integrating role within CfE by connecting the curriculum areas and subjects to these wider contexts and settings where young people learn, develop and achieve, providing the potential to enhance systemically the development of all four capacities of CfE*. As a cornerstone of CfE, IDL represents a radical new element of curriculum change.This is why there must be a clear understanding amongst teachers, school leaders and educational agencies about what IDL is and is not, and why it is important.

The development and implementation of IDL within CfE, both within the formal curriculum and beyond, must be strategically planned to impact all areas of the curriculum. It cannot simply be bolted on to CfE and to existing teaching plans and resources, or left to the capacities of busy teachers without sufficient resources and time to develop and implement it. IDL implementation requires leadership at all levels of Scottish education if it is to be seen as transformational rather than as a threat to the integrity of curriculum areas and subjects.

The OECD Report[[104]](#footnote-103) recognises “a high value [being] placed on interdisciplinary project-based learning…”, yet, beyond the important but brief statements in the *Building the Curriculum* papers 65-68 little more has been said about the development and implementation of IDL in CfE[[105]](#footnote-104) by Scottish Government and its educational agencies since CfE was first introduced in Scottish schools in 2009 -2010. The ‘CfE 2015/16 Implementation Plan’[[106]](#footnote-105) mentions IDL and ‘cross-curricular themes’ just once each in a total of over 240 tabled actions, perhaps an indication of the low level of priority that currently appears to be attached to the implementation of IDL. The teacher-led BOCSH report concluded that IDL appears to have been consigned to ‘official obscurity’[[107]](#footnote-106).

*Recommendation 28*

* High priority should be given by Scottish Government, Education Scotland and SQA to empowering and resourcing schools, school networks and local authorities to take responsibility for the articulation, exemplification, implementation, development and assessment of IDL within CfE. This should be a strategically planned process that impacts all areas of the curriculum.

## What is IDL?

The development and implementation of IDL as a context for learning require a clear understanding of what constitutes IDL. Education Scotland provides general guidance on IDL in its CfE Briefing Paper[[108]](#footnote-107). However, beyond the general statement that “interdisciplinary learning…is a planned approach to learning which uses links across different subjects or disciplines to enhance learning”, there is insufficient clarity to guide teachers as to what IDL might *be* despite practical advice about what it might *do*, where and how it might take place, and how it might be planned and taken forward. Research around the nature and definition of IDL carried out to underpin the work on IDL undertaken by STEMEC, the LSG and the IDL NAG led to the following conclusions[[109]](#footnote-108).

IDL cannot be properly understood without a clear understanding of the nature, benefits and limitations of disciplines (subjects). Disciplines are branches of learning characterised by distinct objects, principles, theories, skills, tools and applications. By ensuring depth of knowledge and understanding, disciplines give rigour and structure to the development of knowledge.

However, disciplines may also be inward looking and fail to address new and relevant real-world problems, whereas major new insights and breakthroughs increasingly occur in interdisciplinary areas, especially in the STEM disciplines. Many contemporary issues are too complex to be addressed within a single discipline[[110]](#footnote-109).

*In IDL learners draw on and integrate knowledge, understanding and skills from two or more disciplines in order to advance understanding of a subject or solve a problem that extends beyond the scope of any single discipline.* In good IDL, learners tackle relevant and meaningful questions or problems that will allow them not simply to make connections between two or more disciplines but also to draw on and develop their disciplinary knowledge, understanding and skills and thereby deepen their understanding of these disciplines. IDL involves a dynamic interaction between two or more disciplines that involves the transfer and application of disciplinary knowledge, understanding and skills to new problems and applications, and into other areas of learning.

The terminology used to describe IDL is varied and often confusing[[111]](#footnote-110),[[112]](#footnote-111),[[113]](#footnote-112),[[114]](#footnote-113),[[115]](#footnote-114). **Contextual learning** is a common type of IDL in which different disciplines or curriculum areas are focused on a context, issue or problem. Contexts are typically practical, real-world problems or issues, such as for example energy or climate change. When the disciplines are in different curriculum areas, for example sciences and social subjects, this is often described as **cross-curricular** learning. The term **transdisciplinary** has also been used to refer to learning that is beyond the scope of disciplines insofar as it starts with a problem or topic and brings to bear and apply knowledge from various disciplines*76,80*.

By contrast, **multidisciplinary learning** involves the juxtaposition of disciplines and knowledge that may have no apparent connection and may be taught as separate disciplinary entities around a theme or topic. The term **interdisciplinary learning** is often widely used (and misused) as a *general* term for these *various types of learning that involve the wider use and application of disciplinary knowledge*. Simply linking or juxtaposing discrete subjects together around a theme is not by itself strictly i*nterdisciplinary* (as defined above), but rather multidisciplinary. While multidisciplinary learning is not in itself a bad thing, it may fail to convey the transferability and applicability of disciplinary knowledge and understanding.

IDL cannot exist separately from disciplines and in practice it is founded on strong disciplinary knowledge, understanding and skills. Furthermore, teaching specific topics or skills without clarifying their relationship to broader and more fundamental principles makes it difficult for learners to transfer and generalise their learning to make it useable beyond the situation in which the learning occurred.

Students undertaking IDL should obtain a deeper understanding of the links between disciplines, the transfer of learning and the inter-relationships of phenomena. IDL should not take place at the expense of curriculum areas and subjects, but should complement and enrich subject learning, and facilitate learning across and beyond subject boundaries.

In summary, interdisciplinary working requires that all subjects should be founded on deep and coherent pillars of knowledge and understanding[[116]](#footnote-115)*.* IDL will lack rigour and utility if it is not part of a structure in which the disciplines are pillars with interdisciplinary work as lintels. Without the pillars, the lintels will fall.

The balance between disciplinary and interdisciplinary learning presents different challenges for primary and secondary teachers, and between the Broad General Education and the Senior Phase. The prevailing challenge for primary teachers is the breadth of subject knowledge, especially in STEM subjects. This leads to learning linking of two or more Es & Os around a theme or project that may be predominantly *multidisciplinary* rather than *interdisciplinary*, as feedback from primary teachers (below) suggests.

The twin challenges for primary teachers, especially in STEM-related work, are a clear understanding of what IDL is and sufficient STEM knowledge and skills (or access to appropriate STEM support). Primary teachers are trained to work across the curriculum and have a culture of working and planning together. Creating a broad and well-balanced culture and understanding of interdisciplinary, multidisciplinary and subject teaching in primary learning should provide a foundation for IDL across the BGE and across the transition into secondary schools where the rather different challenge for subject specialists is working as individuals outside their subject areas.

While the BOCSH report[[117]](#footnote-116) asserts that it would be irresponsible for an education system to allow *anything* as IDL, it urges caution in being over-prescriptive in the definition of IDL if and where high-quality learning is taking place that fulfils the criterion of bringing together subject knowledge and skills from at least two subject areas in learning that is both creative and challenging, offering high quality experience for learners and professional development for staff. This is sensible as long as relaxing of the criteria for IDL is always founded on a clear understanding of what IDL is and is not. Limited evidence (see below) and wide experience of working with teachers and in schools leads us to recognise that IDL is currently often poorly understood and implemented, with the result that much of what passes for IDL is at best multidisciplinary or simply an extension and enrichment of existing subject learning and teaching through for example project work.

There are inevitably grey areas in the interpretation and implementation of IDL. For example, the attachment of a focus on literacy and/or numeracy to a learning programme or project might be perceived as making it interdisciplinary. However, literacy and numeracy are essential foundation skills for learning, life and work[[118]](#footnote-117),[[119]](#footnote-118) that should underpin all areas of learning as and where appropriate rather than providing an easy way to adapt or rebrand existing learning as IDL rather than adopting a deeper, more strategic approach to embedding IDL in a school’s learning. Scottish education needs to develop a transformative culture of ‘learning in an interdisciplinary way’, founded on a clear understanding of what constitutes IDL, consistent with its place as an integrating context for learning within CfE.

## IDL in the National Improvement Framework: Engaging Disengaged Learners

Many countries are trying to close the gaps in educational attainment between (and within) schools in their most and least socio-economically deprived areas. Improving educational attainment is now a top priority of Scottish government[[120]](#footnote-119). By the age of 5 children in poverty lag between 10 and 13 months behind their more affluent peers in attainment and school readiness[[121]](#footnote-120). Identifying new ways of engaging and supporting disengaged learners and reducing barriers to learning is one of the prime challenges of 21st century education, and one that is of fundamental importance to the improvement of Scotland’s workforce and economy.

Within and beyond the classroom, IDL as a component of school improvement is a practical approach to the challenge of engaging disengaged learners, providing alternative ways of encouraging them to participate actively in their learning. IDL encourages team building and other ‘soft’ skills and values such as resilience and resourcefulness, reflectiveness and reciprocity[[122]](#footnote-121) that will benefit all pupils, but especially the disengaged*.* Providing an alternative curriculum and encouraging engagement with employers increases the likelihood of disengaged pupils progressing to employment or training[[123]](#footnote-122). Employers may become co-investors and co-designers of interdisciplinary projects, contributing to creating greater parity of esteem between academic and vocational sectors[[124]](#footnote-123).

Implementation of IDL also creates an extra dynamic within the school system, building a rapport between staff, sharing resources between departments and promoting an ethos of shared responsibility. Group work on real-life scenarios encourages creativity, the use of literacy, numeracy and IT skills across the curriculum and beyond, and team building.

Links between schools and local communities and employers develop an awareness of careers and life beyond school. It is in this process of engaging disengaged learners that the CfE learning contexts IDL, the ethos and life of school as a community and personal achievement converge and connect with the curriculum[[125]](#footnote-124). It is also in this context that ‘learning in an interdisciplinary way’ may take precedence over adhering to an overly prescriptive definition of IDL if high quality learning is taking place that brings together subject knowledge and skills from two or more areas of learning in a creative and challenging way[[126]](#footnote-125).

Schemes such as the John Muir Award can provide additional motivation and aspiration through outdoors interdisciplinary learning, promoting a ‘hands-on’ approach involving designing, building, creating – all higher-order thinking skills. For example the building of raised beds can involve numeracy, design and technology, while developing and maintaining gardens involves knowledge of biology and geography.

*Recommendation 29*

* IDL has a central role to play in engaging disengaged learners and closing the attainment gap, and should be recognised and developed as a key element within the strategy for implementation of the National Improvement Framework by Scottish Government, Education Scotland, local authorities and school leaders.

## The scope of IDL in STEM and beyond: dangerous liaisons?

There appears to be a widespread perception that IDL and STEM are synonymous, with IDL being seen as a matter for implementing *within* the STEM subjects. This unfortunate perception may be an unintended consequence of the active development of a national IDL strategy led from within the STEM subjects[[127]](#footnote-126) by STEMEC, LSG, the IDL NAG, and by Education Scotland[[128]](#footnote-127).

It is beneficial that IDL within the STEM subjects encourages a wider view of the relevance of STEM subjects to each other and to the real world. However, IDL and STEM are not synonymous. The principles of IDL as a context and process of learning are applicable across all areas of the curriculum and beyond92.

The relevance of STEM subjects to learners may be greatly stimulated and enhanced by cross-curricular engagement and learning contexts, for example in social subjects, technology or the arts and humanities. In our experience, the implementation of IDL may also initially attract more support, enthusiasm and engagement in curriculum areas *beyond* the STEM subjects, and be more readily led from within these other curriculum areas. In the development and implementation of IDL, where teacher buy-in may be difficult, *cross-curricular* learning that includes STEM subjects may be a good starting point for IDL implementation. A curriculum-wide vision of IDL is required that extends beyond STEM to encompass cross-curricular and contextual (transdisciplinary) approaches.

## Why IDL matters

### Creativity and innovation

*Creativity*–having original ideas that have value – is widely regarded as the highest order skill in Bloom’s taxonomy and is the foundation for *innovation* – the process of putting original ideas into practice[[129]](#footnote-128). Creativity and innovation happen when we make novel connections, bring together ideas or ways of looking at the world not previously related or connected, combine ideas in novel or unusual ways, or solve questions or problems not previously considered to be associated127.

The rapid increase in human knowledge, especially in STEM subjects, leads to increased specialisation and a failure to see how ideas interconnect and inform each other[[130]](#footnote-129). Creativity relies on making connections through collaboration, teamwork, and the breaking down of disciplinary boundaries; it is typically founded on – and fostered by – IDL and systems thinking. Sill[[131]](#footnote-130) identified creativity and critical and higher order thinking as key benefits of interdisciplinary activities; other benefits identified include an inquisitive attitude (*curiosity*), sensitivity to alternative points of view and to ethical issues, an enlarged perspective, and more original and unconventional thinking.

In public perception, creativity is usually considered to be associated with the arts, particularly the so-called ‘creative’ or performing and visual arts. This is a false - but unfortunately widespread – public perception. Creativity is possible in every discipline, not just in the creative arts, and is by no means confined to conventional ‘academic’ pathways of learning. Creativity is as central to STEM subjects, and to enterprise, innovation and economic success as it is to other more artistic areas of human culture. A recent report on creativity by Education Scotland[[132]](#footnote-131) highlights 20 case studies from across Scottish education that focus primarily on the creative arts, touch on maths, enterprise and IT, but ignore science, thereby unintentionally reinforcing widely held misconceptions.

Narrow educational curricula and cultures that create boundaries between curriculum areas (for example between arts, STEM and social subjects, or within STEM disciplines) are likely to stifle IDL and thus to inhibit innovation and creativity. By contrast, creative teams comprise people with diverse backgrounds and skills who think differently but work collaboratively and interact in interdisciplinary spaces towards common goals[[133]](#footnote-132). Creativity relies on making connections through collaboration, teamwork, and the breaking down of disciplinary boundaries; it is typically founded on – and fostered by – IDL and systems thinking.

*Recommendation 30*

* The creative potential and capacities of STEM subjects need to be recognised, developed, demonstrated and encouraged through IDL by Education Scotland, SQA, local authorities, practitioners and CPD providers, and in ITE.

### Skills and the Changing World of Work[[134]](#footnote-133)

There has been a fundamental shift in the nature and structure of employment in developed countries. The number of higher skilled professional, technical and managerial jobs has risen in response to rapid scientific and technical innovation in a global marketplace in trade, supply, finance, information, skills and knowledge exchange, generating widespread benefits through improved living standards but also greater complexity across economic systems. These changes have irreversibly altered the demand for skills.

Employment growth will favour highly skilled (tertiary-educated) workers. What are the implications for education and skills in general and for STEM education in particular? Skills have become the global currency of the 21st century and are the key to translating creativity, curiosity and innovation into economic growth and employment. For developed economies with ageing demographics such as Scotland the need to ensure that their human capital keeps pace with rapidly evolving skills demands of labour markets is particularly acute.

Working life in 2020 will be even more networked, and jobs less routine. Work will increasingly be done on a project basis in collaboration with various contributors with complementary skills, and tasks will become more variable. A developing ‘on-demand’ economy will favour ‘freelance’ workers able to master and sustain multiple skill sets, and job flexibility will increasingly be the norm. An ability to apply network skills is the foundation of future work; network skills find their application in the ability to find, use, connect and disseminate knowledge, to identify new opportunities and find solutions to problems.

Many of the most commercially significant innovations in industry and business are expected to result from cross-disciplinary fertilisation. The key to successful innovation is the ability of people with different competences to work together in teams, learning from one another and building on existing ideas. These are skills that need practice, requiring development of both the curriculum and teaching/classroom practice, that are founded on interdisciplinary and co-operative learning, and that should be developed throughout education at all levels through what we teach and how we teach it.

An OECD report identified the following key elements as essential in 21st century education systems in relation to skills and employment:

**Knowledge:** relevance, real-world experience, rethinking of the significance and applicability of what is taught to strike a far better balance between the conceptual and the practical.

**Skills:** higher-order skills, such as creativity, critical thinking, communication and collaboration are essential for absorbing knowledge as well as for work performance, requiring expertise in combining knowledge and skills in a coherent ensemble.

**Character** (behaviours, attitudes, values): to face an increasingly complex world it is important to teach character traits, such as performance-related traits (adaptability, persistence, resilience) and moral-related traits (integrity, justice, empathy, ethics).

A new and higher-level inter- and multi-disciplinary knowledge and skills base will be essential to meet these challenges, with a shift or rebalancing away from narrowly focused specialists to flexible individuals with interdisciplinary academic and technical training. In key areas such as STEM-related subjects a more general emerging skills set is needed for interdisciplinarity within the science, technical and business areas, for which teachers will need to be able to combine approaches to teaching, work collaboratively internally and externally, and acquire strong technology skills. Specifically:

* Businesses will require young people with flexible skills and the ability to innovate cope with change and learn continuously throughout life; knowledge transfer is as much about communication as specialist skills.
* Schools must stimulate a child’s ability to solve new, non-routine problems, combine different bodies of knowledge and interact productively with others, which is essential if individuals are to become competitive in the globalized economy.
* Active learning based on student participation, experiential learning models and learn-by-doing approaches will matter more than passive approaches.
* Core skills should be delivered in a way that excites and engages learners.
* Skills development is more effective if the worlds of learning and work are linked. Learning that incorporates business-related case studies and simulations and learning in the workplace allows young people to develop ‘hard’ and ‘soft’ skills, together with real-world relevance and experience. It is apparent through SCDI’s network of Young Engineers and Science Clubs (YESCs) that industry-set school challenges from a range of sectors are usually designed to require teamwork and an interdisciplinary approach.
* In STEM, students should be encouraged and supported to run their own experiments, involving more open-ended questions and more organised group activity.

CfE marks a major and timely shift from knowledge acquisition to one in which knowledge and skills are equally important. The priorities of 21st century learning change the focus to skills that are both higher level and transferable, with a particular focus on skills for learning, life and work. Higher order cognitive skills are particularly important for higher-level learning and the workplace.

*Problem-solving* involves some combination of subject, transferable and cognitive skills appropriate to the problem; none of these skills is peculiar or exclusive to IDL but they are strongly promoted by and within IDL. Systems thinking in particular is a higher order cognitive skill that is demanded in drawing together (transferring) knowledge, evidence, understanding and arguments of different types from different sources and disciplines in an interdisciplinary way.

The Higher Order Skills Group (HOSG) Report to Scottish Government[[135]](#footnote-134) advocates the deployment of ‘*learning approaches*’ that include: collaborative learning, experiential learning, problem-based learning, outcome-focused learning, interdisciplinary and multi-disciplinary learning, systems thinking, high-level discussion, interactive questioning, action-based research and peer reflection. These learning approaches reflect workplace practice and should be promoted across our education system, particularly through IDL.

There is one additional aspect of these learning approaches that may offer particular benefits to learners wherever learning takes place. This is the capacity to experience something beyond traditional forms of learning - to develop capacities as independent and self-directed learners who take more responsibility for their own learning. Teachers become mentors. Pupils may also readily engage in different styles of learning such as co-operative and inquiry-based learning[[136]](#footnote-135).

The combination of all of these learning skills and approaches describes a culture of IDL - ‘learning in an interdisciplinary way’ - that provides a skills focus across the curriculum and beyond and constitutes a major development in the culture of learning and teaching, whether it be disciplinary, interdisciplinary or multidisciplinary.

## How will IDL be assessed?

*“We make what is measurable important rather than making what is important measurable”*

Assessment has a powerful effect on what is taught and learnt wherever education takes place, particularly in education systems with high levels of high-stakes external (national) testing, such as in England, whereas in countries in which national high-stakes testing is almost absent, such as Finland, innovative learning, teaching and assessment are more possible[[137]](#footnote-136).

National standardised testing emphasises measurable outcomes with an emphasis on recall of factual knowledge and on skills that can be measured comparatively rather than on the ability of learners to weigh evidence and apply knowledge. It takes little account of experimentation, creative thinking and innovation.

If IDL is a key context for learning in CfE, creative assessment methods must be researched and developed otherwise it will be undervalued. However, the meaningful assessment of IDL is a major and complex challenge. Clear success criteria are needed about what it is within IDL that will be assessed, for example subject-specific content, subject, transferable and higher order skills, and the delivery of contextual project work.

If IDL is seen as important, yet exam systems don’t measure its impact, then research evidence about its impact on learners may be suspect. An Education Scotland report[[138]](#footnote-137) noted that “staff are often unclear about how they will assess progress in developing knowledge and skills that are acquired in an interdisciplinary context”, while the OECD Report[[139]](#footnote-138) recognised a “..lack of clarity about what should be assessed in relation to the Experiences and Outcomes” creating “..a risk that CfE comes down to the examinations”. These comments accord with informal teacher feedback (below).

The SEEAG Report[[140]](#footnote-139) saw assessment of IDL in senior phase STEM as a key challenge, and recognised a need to identify new ways of assessing interdisciplinary learning and working and common skills sets, for example in project work and by setting problems and the application of knowledge in unfamiliar contexts. If a desired learning outcome involves an interdisciplinary approach, then assessment should reflect that.

The SEEAG report made two recommendations regarding assessment of IDL, both of which were ‘partially accepted’ in the Scottish Government response:

* that SQA develops exemplars of interdisciplinary questions, together with assessments that measure the different inputs from the different sciences.
* that SQA assessments should use a broader range of interdisciplinary contexts within which to locate examination questions, and explore innovative courses (perhaps units within courses) that deliberately blur traditional subject boundaries. These courses should include innovative assessment methods (synoptic questions, extended assignments and collaborative project work).

We are not aware of significant progress in the development and assessment of IDL in the senior phase since the SEEAG Report was published, although SQA’s intention to establish a working group to develop IDL assessment methods is welcomed because the recognition IDL is accorded in the senior phase will be an important element in its being embedded more widely in CfE.

The BOCSH Report[[141]](#footnote-140) concluded that successful accreditation of IDL would be a major motivation for its credibility and delivery, and proposes “a campaign to develop nationally recognised approaches to the certification of IDL”. Research is required nationally and internationally for examples of good practice in IDL assessment, for example from the International Baccalaureate, which combine service and personal development with intellectual achievement. Despite the small numbers of students presenting across Scotland, the SQA Science Baccalaureate interdisciplinary project assessment should provide new ideas and thinking around assessment of IDL.

Evidence should also be gathered about how IDL in the Broad General Education phase is being assessed. More widely, gathering evidence about learners’ progress in acquiring and applying skills is similar to what might be expected in gathering evidence about creativity, evaluation or systems thinking, for example through professional judgements around open–ended activities[[142]](#footnote-141). A learner’s ability to carry out and complete a task, skill or project can be designed so as to provide evidence of whether they have successfully achieved the aims or outcomes of the task or project.

Howes et al[[143]](#footnote-142) argue that to achieve significant improvement in pedagogy and student engagement in STEM there must be a shift in emphasis to formative assessment in the classroom based on dialogue and learners’ self-knowledge, and away from graded, exam-based summative assessment. This is important for achieving higher level learning outcomes such as deep conceptual understanding and problem solving, and is key to encouraging learners to take ownership of their own learning. New, more valid forms of assessment are needed that assesses higher-level knowledge, understanding and application, problem solving and creativity, and a broader range of learning outcomes such as student attitudes. This will require extensive research and development.

*Recommendation 31*

* SQA and Education Scotland should take responsibility for researching, developing and delivering methods of assessment of IDL in and across the Senior Phase and the Broad General Education, in collaboration with local authorities, practitioners and schools.

## Evidence about the Impact, Understanding and Implementation of IDL

The benefits that interdisciplinary and cross-curricular learning confer on learners within and beyond the STEM disciplines have been widely recognised, particularly in addressing the perceived disconnect between school learning and life beyond school and in the workplace. However, evidence-based research on the impact of IDL on attainment in school education and on learners and on education system improvement is limited, and its reliability may vary depending on what is understood by IDL and how it has been implemented.

We have reviewed evidence from evaluations and meta-analyses of pupil attainment and attitudes to learning, drawing extensively on recent research reviews by Howes et al107, the BOCSH report[[144]](#footnote-143) and literature review work undertaken for STEMEC by Scottish Government[[145]](#footnote-144). STEMEC and Education Scotland have also undertaken informal evidence-gathering amongst teacher groups relating to perceptions, understanding and implementation of IDL; although more anecdotal in nature, this is nonetheless useful to the extent that comments and opinions that recur within the feedback obtained provide pointers to progressing and improving IDL articulation and implementation, and identifying what might work or not work and where obstacles might lie, as a basis for more rigorous research.

Rigorous evaluations and meta-analyses of the impacts of IDL on achievement and attitudes in teaching both within and beyond STEM subjects found good evidence for positive impacts on pupil attainment and also on attitudes to learning including attendance, discipline, study habits, enthusiasm and engagement. One study in England (cited in [[146]](#footnote-145)) reported a 15% improvement in academic performance accompanied by positive improvements in engagement, behaviour and enjoyment of learning together with higher teacher fulfilment. Other studies were more neutral in their assessment of impact but noted that the more interdisciplinary the activities the greater the cognitive engagement, with greater enthusiasm for sharing of ideas amongst teachers (an important foundation for developing IDL).

Surveys and questionnaires with teachers conducted through a SSERC primary cluster STEM conference (see Section 9 of this report) found that teaching approaches to science such as IDL were considered to be weak in primary schools and that subject knowledge was universally seen as a major challenge. The latter view indicates a serious limitation to both STEM delivery and IDL implementation involving STEM in primary schools.

Informal circulation in 2013 of a short paper on IDL[[147]](#footnote-146) to (predominantly) primary teachers in the East of Scotland to gauge views on IDL and its implementation drew a range of interesting responses that included: very limited awareness about what constitutes IDL; teachers skilled in planning multidisciplinary learning, but not equipped with the knowledge to plan coherent IDL; resources and planning not allowing or encouraging staff to plan progressive IDL; pressure on scores and attainment getting in the way of developing truly useful IDL; concern about the necessary balance between discrete science and IDL science; what skills sets that can be assessed and measured are required for IDL?; a need for the time, training and resources to develop science and IDL further; more confidence about IDL in social subjects; lack of confidence making some areas of science less open to IDL. Nonetheless teachers appreciated the benefits of IDL, and with support the involvement of STEM in IDL is improving.

Education Scotland has published stakeholder feedback relevant to IDL from its Science Conversation Days[[148]](#footnote-147). In primary science, *there is a call for science to be made more explicit in schools and not just taught through IDL,* a view that accords with the need for IDL to be grounded in disciplinary knowledge and skills in principle and in practice, and with the need to build confidence in primary STEM. Factors contributing to quality science learning include engaging activities inside and beyond the classroom, subjects that are interlinked and connected, and learning through real-life examples, all key elements and contexts for IDL.

STEM Education Support Officer Scott Bryce, based at SSERC from 2013 to 2015 and a member of STEMEC, obtained feedback[[149]](#footnote-148) from teacher participants following delivery of IDL projects involving STEM, Design and Technology, Art, English and Home Economics. Key outcomes and feedback were: a recognition that there must be a strong focus on maintaining disciplinary rigour so that pupils learn from the knowledge and techniques they are using and applying; there is confusion in understanding what constitutes IDL, with some teachers seeing teaching in context as sufficient to demonstrate a commitment to IDL. Time, resources, logistics of timetabling, an assumption that IDL is already built into a school’s approach or a teacher’s teaching, the challenge of engaging with other subject teachers or departments, and a perception that IDL is something that primary teachers do, are all attitudes and opinions that feature recurrently amongst the main barriers to IDL implementation[[150]](#footnote-149).

In summary, consistent messages emerge from the responses of these diverse teacher groups about the limited understanding of what constitutes IDL, the challenge of breadth of subject knowledge, the lack of time for development and implementation of IDL and engaging with teachers in other subject areas, concerns about the assessment of IDL and the logistics of timetabling, the availability of resources and CPD, and the balance between disciplinary and interdisciplinary learning.

Howes et al[[151]](#footnote-150) note that thematic education is more common at primary level, which allows scope for interdisciplinary STEM in most systems, while systems with extended general education such as Finland and now Scotland can continue such practices much later into school life because the curriculum and assessment regime imposes less of a disciplinary focus (note however that this is not currently the case in the senior phase in Scotland).

There is little evidence of interdisciplinary STEM in the curricula of nations that rely on individual subject examinations, whereas countries that encourage or require a broader range of subjects post-16 including maths or science (e.g. Finland) also tend to get higher participation rates in STEM[[152]](#footnote-151). Interdisciplinarity is most advanced at secondary level in matriculation/leaving certificate type systems that allow room for over-arching connecting modules. Not all research around IDL implementation is positive.

In conclusion, published research offers good evidence for the positive impact of IDL on learners’ attainment and attitudes, and contributes positively to teacher fulfillment and satisfaction. Lack of confidence and subject knowledge, especially in STEM subjects, is a limitation to the implementation of IDL in primary schools.

## Educational research: impact and implementation of IDL

*“A thousand flowers might bloom and at least a few might be well researched…”132*

The process of educational reform requires high quality research and development. The spend on R&D in education is the lowest of any knowledge industry, yet educational research is needed to address the problems and challenges of innovation and change and to identify practices that have the potential to enable system change132. Curriculum and assessment need to be subject to continuing independent research if a thorough understanding is to be gained of the key factors that determine what works and doesn’t work in implementing IDL and – more generally - CfE. Without this work, it will be impossible to demonstrate any related improvements in learning and teaching.

The OECD Report[[153]](#footnote-152) notes the absence of large-scale research or evaluation projects by universities or independent research agencies on how CfE is being implemented in schools and communities across Scotland, and recognises that the research community could and should be making an invaluable contribution, including designing learning and teaching to engage those most at risk from disengagement.

With regard to IDL, the modest amount of research conducted internationally indicates that implementation of IDL has had largely positive impacts on learners and learning as measured by assessed performance and attitudes to learning. We now have a clear idea of what constitutes good IDL. A sustainable programme of independent research is now needed to investigate:

* the extent of implementation of IDL in primary and secondary schools across Scotland
* the ways in which schools are responding to the requirement to implement IDL
* the extent to which classroom and teacher education practices reflect our understanding of IDL
* the impact of the increasing emphasis on IDL on young people’s learning, attainment and attitudes
* the challenges of introducing a focus on IDL
* a strategy for addressing any inadequacies and misconceptions that emerge from the research

This constitutes a major long-term research commitment.

An initial and relatively straightforward educational strategy would be to explore through meetings with representatives from individual schools whether, how and to what extent pupils are learning in an interdisciplinary way. This is already underway. A follow-up strategy will be to use the information gained to frame a questionnaire to a representative number of schools across Scotland. The outcomes of this initial research will create a platform to inform the development of more thorough academic research that investigates a series of research questions similar to those posed above.

*Recommendation 32*

* The process of implementation and development of IDL within CfE should be subject to thorough and on-going independent research if a clear understanding is to be gained of the key factors that determine what works and doesn’t work, and an evaluation of its impact. Teachers as researchers should play an important role in this process.

## Supporting the Development and Implementation of IDL

The SEEAG Report[[154]](#footnote-153) recognised that STEM IDL and the development of links to other curriculum areas should be supported by the creation of strong, interconnected support systems and the establishment of creative partnerships to ensure that changes in classroom practice are matched by provision of additional subject knowledge and skills required to build bridges within and between traditional STEM subjects and other curriculum areas.

Successful development and delivery of IDL within CfE is dependent on teacher skills, classroom organisation and practice, a sound understanding of the nature of IDL and its relation to STEM and other disciplines, a sufficient breadth and depth of subject knowledge, understanding and skills, and experience in curriculum design[[155]](#footnote-154). Support from external sources should encompass CLPL/CPD, initial teacher education and sustained collaboration and engagement between schools, local authorities, universities and colleges, business, industry and other agencies.

Teachers need the time to plan and develop IDL. Good, clear and widely available exemplification of IDL is urgently needed.STEMEC members and colleagues, together with other external agencies and organisations, have worked to develop, deliver and test new approaches and ideas to meet this challenge. Initiatives and progress are summarised here, particularly from higher education.

### Higher Education support

The Deans of Science and Engineering of the Scottish universities made a major input into the work of SEEAG[[156]](#footnote-155), particularly in advocating the importance of IDL in STEM learning and teaching. The input of HEIs to the development of IDL in schools is piecemeal and uncoordinated.

Scottish universities engage with the school sector to support education in STEM and beyond at a number of levels and in ways in addition to initial teacher education (ITE). A report by Universities Scotland on STEM education in Scotland[[157]](#footnote-156) recognises that virtually all the good practice in STEM engagement is underpinned by the principle of partnership. Schools draw on the expertise in universities to benefit young persons’ education, allowing universities to access schools to support educational attainment and build aspiration for access to university STEM programmes. Underpinning the longer-term success of such partnerships between and schools are three key principles:

* Quality of engagement
* Sustainability of the partnerships and programmes
* Researching the relationships and support programmes to identify, create and promote successful general models

A general, widely applicable and researched model for university support for IDL and the development of learning communities is based on a senior undergraduate course at the School of Geosciences at the University of Edinburgh (Geoscience Outreach and Engagement)[[158]](#footnote-157),[[159]](#footnote-158). Senior undergraduates and masters students as ‘para-professionals’ develop expertise in disciplinary and interdisciplinary STEM engagement, learning and teaching, communication and project management through self-directed project work with and for external clients in schools and community organisations to develop and deliver a project for a ‘client’ to an agreed brief. The 200 hour (20 credit) and 100 hour (10 credit) optional courses allow students to support teachers and pupils through partnership working in primary and secondary schools and school clusters, as well as in other areas of community engagement activity.

The course model is now being promoted across the University of Edinburgh as a model for effective, sustainable low-cost HEI support for CfE, STEM, IDL and learning communities in schools, and is being adapted and implemented in other universities (e.g. University of West of Scotland, Heriot Watt University). Projects create a legacy of educational resources (e.g. learning resources, teacher guides, materials for professional development, videos, blogs etc.) for schools and community organisations that can be utilised, further developed, and made widely available on the web, including amongst the University’s developing portfolio of open education resources.

*Students* gain experience of working to a brief to develop and deliver resources, acquiring a range of transferable skills and enhancing employability. Some students are attracted into the teaching profession or into STEM engagement work. Student satisfaction is very high. *Teachers and pupils* benefit from the dissemination of knowledge and understanding (often in areas of science that are not widely taught and understood).

Projects increasingly support and promote *widening participation* in higher education by pupils in schools in areas of educational disadvantage by increasing awareness and aspiration and providing young role models. This aspect of the course model contributes particularly to engaging disengaged learners and bridging the attainment gap, and thus to the aims of the National Improvement Framework[[160]](#footnote-159).

Because students work both in schools and community organisations, the university may act as a hub that helps to connect schools with organizations in their local communities in shared projects and resources. New partnerships are created and developed amongst and between all participants, and Scottish education is enhanced. Students in different Schools and departments in a university may also work together in shared interdisciplinary projects.

IDL resources created by University of Edinburgh outreach students have been delivered to groups of teachers in schools to exemplify IDL, as a starting point to assist them to engage in IDL in more depth, with greater rigour and in an active way. This enables cross-curricular groups of teachers to take ownership of the resources and to develop them further by building to their own strengths and interests, where appropriate encompassing other STEM subjects and curricular areas. This strategy provides a starting point for wider IDL implementation, exemplification and staff engagement, and promotes a general model of practical IDL (and CfE) support and exemplification that connects schools, universities and colleges in learning partnerships in which universities and colleges act as, or contribute to, regional hubs.

The embedding of IDL within initial teacher education (ITE) is at the heart of the longer-term support that Scottish universities provide for the implementation of IDL in CfE. Initial evidence for this process has been provided by STEC[[161]](#footnote-160). IDL in all ITE institutions extends beyond the bounds of STEM subjects (see above), although STEM is commonly at the heart of much of their IDL work.

IDL is increasingly being taught both explicitly as part of pedagogical and curriculum design teaching and training, and implicitly in various contexts, particularly through learning for sustainability and sustainable development, environmental understanding and health and wellbeing programmes, within curriculum areas and disciplinary work including ‘Science’, in collaborative projects and topic areas, and in students’ work in and for schools. The extent of reported IDL teaching varies widely amongst ITE departments but this may be largely balanced by the amount of interdisciplinary training and development that is implicit in ITE programmes.

These encouraging developments augur well for the future implementation of IDL in schools provided that an enabling culture and supportive environment for IDL are simultaneously being actively developed in schools, to ensure that young teachers entering the profession are not weighed down by expectation but are supported in their efforts to develop and impart their IDL experiences and training. To this end, we welcome the inclusion in the General Teaching Council Scotland (GTCS) Standards for Leadership and Management (2012) of the expectation that “teachers are reflective, accomplished and enquiring professionals who work collaboratively across disciplines, professions and communities, locally and globally to create, contribute to and lead a collegial structure, through collaborative enquiry, sharing practice and learning together”, which is required if “IDL in school is to be able to provide the rich and deep learning opportunities outlined in the curriculum reform”[[162]](#footnote-161).

The Standards for Registration (2012) also require teachers to “know how to work collaboratively with colleagues to facilitate IDL” and “know how to work with the local and global community to develop realistic and coherent interdisciplinary contexts for learning…”. These formal requirements are fundamental to the development and establishment of a culture of learning in an interdisciplinary way.

A positive example of the embedding of the principles and practice of IDL in ITE is described by McLaren[[163]](#footnote-162) in the context of the training of PGDE students at the University of Edinburgh. The *Natural Partners Project* brings together student teachers in design and technology, physics, chemistry, biology and geography in a joint partnership with Forest Research, Forestry Commission, Forest Engineering Group and the Ellen McArthur Foundation in STEM groupings in an outdoors context. Feedback from 91 students, 4 tutors and 5 external partners is overwhelmingly positive about the benefits of IDL. The wider training of teachers in interdisciplinary and partnership working in real world contexts holds out the promise of transformative implementation of IDL in Scottish schools within a suitably enabling and supportive environment.

*Recommendation 33*

* Universities, colleges and local authorities should co-ordinate their efforts to support formal engagement and partnerships with schools, school networks and their communities (including business, industry and research institutes) to develop sustainable regional hubs, professional learning communities and related partnerships as appropriate, building around emerging effective new models of engagement. The implementation and development of IDL should be a key element of this support. This is consistent with Recommendation 26 in Section 10.

### Exemplification of IDL

Exemplification of IDL is a high priority in communicating the principles and practice of IDL to learners and teachers in order to promote a clear understanding of what IDL is, the benefits it can confer on learners and some of the big ideas that interest and excite learners by providing real world relevance to STEM. Little by way of sufficiently detailed and widely available exemplification of IDL that demonstrably matches key IDL criteria yet exists.

A Science 3-18 Update report[[164]](#footnote-163) from Education Scotland may well include some good examples of innovative and well-planned science-based IDL, although there is insufficient information or evidence to assess whether the essential characteristics of good IDL characterise many of the examples mentioned in the report. However, the outreach and engagement model and related HEI-based initiatives described above provide a rich potential source of exemplification of IDL through creation, dissemination and delivery of substantial resources, knowledge and skills.

The articulation of IDL has involved delivery of presentations and articles, most of which were supported by presentation of IDL principles that are illustrated by real examples consistent with these principles. These presentations have been made widely available, and further examples will be made available online.

### Other Support

***STEMEC***

Articulation of what IDL is, its relation to the disciplines (subjects) and curriculum areas, its importance, evidence for its impact on learning and teaching, approaches to its development and implementation, and its exemplification are all fundamental to its implementation. STEMEC members have articulated the principles and practice of IDL in presentations, articles, workshops and discussions to: teacher groups; schools; Universities Scotland (Learning and Teaching Committee); parent groups (National Parents Forum Scotland – “IDL in a Nutshell” (draft)); Scottish Parent Teacher Council[[165]](#footnote-164); Children in Scotland[[166]](#footnote-165); Royal Society of Edinburgh[[167]](#footnote-166); Scottish Council for Development and Industry (SCDI) Policy Committee; Scotsman newspaper[[168]](#footnote-167); School Leaders Scotland[[169]](#footnote-168). Presentations were usually illustrated by practical examples of IDL (e.g. *147,150*).

**Young Engineers and Science Clubs (YESC)**

Science clubs play a key role in developing and delivering IDL in STEM to schools. The Young Engineers and Science Clubs (YESC) already reach 82% of secondary schools and 44% of primary schools in Scotland[[170]](#footnote-169). SCDI aims to have clubs in all Scottish secondary schools by 2018 and all primary schools by 2022. Most YESC projects are interdisciplinary, delivering topical STEM resources and workshops to teachers, supported by equipment and grants. Two new projects are launched per year. Evaluations show that the majority of teachers aim to use these projects and materials within the curriculum.

The work of YESC provides an important way of delivering STEM-based IDL to schools across Scotland, supporting IDL implementation in the curriculum (e.g. *134*). YESCs provide a context for developing partnerships amongst schools, industry and colleges – one of the key recommendations of the Wood Commission report on Scotland’s Young Workforce[[171]](#footnote-170). SCDI should be encouraged and supported to continue to embed IDL in the STEM curriculum through the work of YESC.

**SSERC**

SSERC is the main STEM CPD provider for teachers in Scotland. SSERC staff are able to review their CPD programmes for primary and secondary teachers for opportunities to reflect the principles and practice of IDL, to capture, highlight and share innovative IDL-related practices in their bulletins, CPD programmes and website (e.g.[[172]](#footnote-171)). More widely, the principles, practice and implementation of IDL should become a strong element of Career Long Professional Learning (CLPL) as recommended in section 10 of this report.

The work of the STEM Education Support Officer based at SSERC in 2013-15 and a member of STEMEC, has also contributed strongly to the articulation and exemplification of IDL through classroom projects and workshops[[173]](#footnote-172). One of his aims was ‘to contribute to the development of interdisciplinary approaches to enhance the learning experience.’ He examined how to structure and plan IDL within the normal timetable in secondary schools in which IDL is currently allocated time outwith the normal timetable through science clubs (see (ii) above). Working with schools, SSERC and industry partners, he developed several IDL projects involving STEM, Design and Technology, Art, English and Home Economics137.

Many models for IDL delivery exist137 and most will involve local solutions in each school. The importance of maintaining disciplinary rigour and identity in IDL work requires careful consideration of when IDL can be effective in developing understanding of STEM concepts and whether there are areas of science in which concepts are better taught initially in more traditional science lessons.

## IDL and the narrow science base

The SEEAG Report drew on data from the 2007 TIMSS report[[174]](#footnote-173) to show that Scotland has a narrow science subject base within its secondary education system. Scottish STEM education has remained rooted in the three ‘big sciences’ at the expense of other sciences (Fig 1). At eighth grade (S2) level, Scotland’s pupils spend much less time on ‘other’ science (7%) than the OECD average (22%), and more time on the traditional sciences (chemistry, physics and biology; 30-32% each) than the average. Scotland ranked 39th of 41 OECD countries in the percentage of all ‘other science’ taught, i.e. science that is not classified as physics, chemistry or biology (7%). This represents a narrow foundation of subject knowledge on which to develop interdisciplinary learning.


Figure 1

That said, the deficit in teacher subject knowledge implied by these figures may be mitigated *to some extent* by the creative possibilities offered by the development and delivery of interdisciplinary and cross-curricular learning and teaching resources, the outputs across various disciplinary and interdisciplinary areas from outreach and engagement work (e.g. University of Edinburgh), the University of Strathclyde’s Engineering Education Enhancement project[[175]](#footnote-174) and other similar initiatives. As the breadth of SQA STEM qualifications has been reduced with the introduction of the new qualifications, and IDL is only formally recognised by SQA in the interdisciplinary project of the Scottish Science Baccalaureate, no such mitigation is currently available in the senior phase. Nonetheless, as feedback evidence from teachers demonstrates breadth of teacher subject knowledge remains a major challenge for IDL implementation.

## Creating the conditions for successful implementation of IDL: A Finland case study

Through its high rating in successive international PISA surveys, the Finnish education system has attained iconic status over the past decade as a system to emulate. Its framework for learning bears many similarities to CfE with its curriculum and its capacities and contexts for learning, yet major differences exist in its paradigms and practices, and many myths surround its iconic status[[176]](#footnote-175). Its successes in PISA ratings in 2000 and 2006 reflect radical reforms and development from the 1970s and resulting improvements through the 80s and 90s.

Reforms were initially highly centralised and imposed through a system of testing and inspection140 followed by decentralisation and greater teacher autonomy in the 80s and 90s. Finland’s recent decline in the 2013 PISA results has led to current concerns and further reforms, but the Finnish education system nonetheless remains internationally high-performing by PISA standards. Furthermore, the Estonian education system, which appears to be closely modelled on the Finnish system[[177]](#footnote-176), has recently risen strongly in the PISA rankings, lending further credibility to the strengths and characteristics of these systems whilst recognising that there may also be strong and distinctive cultural influences at work that contribute to their success.

PISA rankings matter because they measure and reflect young people’s abilities to use their knowledge and skills to meet real-life challenges, and to analyse, reason and communicate effectively as they identify, interpret and solve problems in various situations. These are all skills and capacities strongly associated with IDL. Yet paradoxically IDL has until very recently merited very little specific mention in the Finnish national curriculum.

The Finnish curriculum was originally designed around a subject-based approach, but recent and current reforms have led to the adoption of ‘***competences***’ (the sum of knowledge, skills, understanding, values, capacities, attitudes and wellbeing) and ‘***phenomenon learning’*** (IDL by another name) in response to the challenges of the exponential increase of ‘knowledge’ and its easy accessibility across societies, the increasingly prominent role of technologies, the recent economic downturn and wider social changes. As a result, subject content is becoming a lesser (but nonetheless still important) aim.

The development of a more competence-based curriculum incorporating phenomenon learning requires change across the whole system, particularly in ITE. “Integration and cross-curricular themes” (2016 curriculum) refers not specifically to IDL but to particular (and familiar) themes across learning and wider issues such as personal development, cultural identity, media and communication, citizenship, environmental responsibility, wellbeing and sustainability, technology and safety.

Building on this learning culture the very recent (2015-16) implementation of ‘phenomenon learning’ across all subjects aims to remove the boundaries between subjects, provides a more active role for learners to take responsibility for their learning, and requires teachers from different disciplines to work collaboratively across subject boundaries. This initiative is being piloted in Helsinki schools in 2015-16. About 40% of the school year will no longer be taught in a subject-specific way[[178]](#footnote-177).

These reforms are not without their critics. Some educators argue that the recent decline in Finnish learning reflects a need for more not less subject-based learning because less deep learning will take place, while others argue for even more extensive phenomenon learning. There is also a concern that progressive (e.g. ‘phenomenon’) learning serves more able learners in better-educated families more than those from less well-educated families, although Finnish education is already characterised by a remarkably high degree of equity by international standards[[179]](#footnote-178). As always, a clear understanding of what constitutes IDL and of the relationships between IDL and the supporting disciplines is essential in striking the correct balance between subject and ‘phenomenon’ learning.

The remarkable capacity of Finnish education for effective implementation of centrally directed reform is a consequence of its adaptable structure and resilient educational culture. Key elements of this supportive culture for interdisciplinary learning include: a flexible, broad curriculum in which all pupils take courses at some level in all core subjects until the end of upper secondary school (age 18); the real-world relevance of the core curriculum; a strong culture of collaboration at all levels within schools and across the school system; a high level of teacher autonomy in determining what is taught and how it is taught within a national framework; a progression in skills and values to encompass and promote curiosity, problem-solving, inclusiveness and participation; and assessment of pupils carried out by the teacher rather than by standardised testing as the basis for the further teaching of each pupil.

Other important characteristics include: a national culture of respect for – and trust in - education and the teaching profession; an on-going commitment to maintaining and developing teachers’ disciplinary knowledge; a highly qualified teaching profession trained to masters level over 5-6 years and recruited very competitively from amongst the best graduates; a strong guidance and support system incorporating career guidance. The professional capacities of teachers in research methods enable them to analyse and evaluate what works and what doesn’t work in implementation of new aspects of the curriculum reform such as phenomenon learning, content and pedagogy, and to resolve problems, identify solutions and recommend these for wider dissemination to other schools and municipalities. The absence of national standardised testing except at the point of graduation from upper secondary school creates more time for innovation in learning, teaching and formative assessment[[180]](#footnote-179).

Among educational specialists and researchers, the strength of STEM education in Finland is seen to include: educational technology innovations; a balance between disciplinary curricula and problem-based, innovative and creative interdisciplinary work; a balance in assessment between summative, project-based, practical and oral assessments. In STEM this culture is strongly supported by the admirable LUMA Centre (STEM Centre) system that connects schools, municipalities and universities through well-equipped university-based hubs across Finland to support STEM clubs in schools, lifelong learning including parental engagement, teacher professional development and ITE - a model that has developed since 2003, which a small country like Scotland with an internationally excellent university system can surely emulate.

Where does Scotland sit in relation to the positive culture and context for IDL created within the Finnish education system? There are many elements common to both systems. In principle, CfE is well configured to offer much of the curriculum space, structure, content and real-world relevance in the Broad General Education that is necessary for the creative development of IDL within and beyond STEM, although its complex multi-dimensional array of capacities, contexts, attributes, capabilities, attributes, principles, aims, entitlements, Es & Os etc has led the OECD[[181]](#footnote-180) to question its comprehensibility to all but the most experienced practitioners.

Scotland is a small country with a similar population to Finland and an area less than a quarter of that of Finland; it has an internationally outstanding higher education system that successfully exploits its small size and population to create powerful research and teaching collaborations. It is surprising that Scottish education as yet lacks a similar culture of collaboration within and amongst schools, and with universities, colleges and other external agencies that is necessary to create sustainable learning communities within which IDL can develop andthrive*.*

The high levels of high-stakes national standardised testing and ongoing ‘curriculum clutter’ leave little time and scope for innovation in learning, teaching and assessment, including IDL implementation, diminishing the time and capacity required for thinking, reflecting, researching and planning. Sahlberg[[182]](#footnote-181) identified two paradoxes of Finnish education as ‘teach less learn more’ (paradox 1) and ‘test less learn more’ (paradox 2), both of which have resonance for Scotland’s education system. The importance of making much more time available to teachers for professional learning and development is also highlighted in section 7 of this report; Scotland fares poorly in international comparisons of teaching hours expected of its teachers.

## Reflections and Ways Forward

Upon reviewing the nature and importance of IDL, evidence for its impact on learning and teaching, and its particular relevance to current key priorities and initiatives in Scottish education, we believe that the case for implementation of IDL as a key context for learning within CfE is now as urgent as it is incontestable. The process of implementation and development requires the development of a culture of learning in an interdisciplinary way, with strong support from within professional learning communities that connect universities, colleges, business and industry and other external agencies with networks of schools in regional hubs. The wider case for regional hubs is made elsewhere in this report, and a good model for these hubs that deserves further investigation is found in the LUMA Centre (STEM Centre) hub system that support STEM education in Finnish schools.

The six recommendations arising from this section of the report provide strategic priorities for IDL implementation in Scottish education that may be taken forward by the IDL National Action Group over the next three years. Fundamental to this strategy is that Scottish Government and its agencies choose to invest in IDL and recognise that this key context for learning of CfE will enhance learning, teaching and collaboration across all areas of the curriculum, supporting the Government’s current priority initiatives including the National Improvement Framework.

Insofar as Scottish Government and its agencies do not yet appear to have assigned a high priority to the development and implementation of IDL[[183]](#footnote-182),[[184]](#footnote-183), there are perhaps four ways in which, in combination, its implementation should now progress. The first is demonstrated by the admirable work on IDL of the teacher-led Building Our Curriculum Self-Help Group (BOCSH) – the clue is in the name! The second is through the agency of external support from - and within - professional learning communities that connects schools, local authorities and networks of schools with universities, colleges, business, industry and other agencies in regional hubs. The third element is time - time for teachers to engage strategically with the many challenges of IDL implementation; the need for much more time has been a constant theme throughout this report and has been repeatedly highlighted in the teacher feedback documented in this report and in the media.

The *leadership* and *direction* of the implementation and development of IDL must ultimately come from schools, networks of schools, local authorities and communities, including regional hubs. These represent ‘the middle’ of Scottish education. The OECD report[[185]](#footnote-184) sees leadership operating best in and from an extended ‘middle’ as essential in allowing CfE, and the professional judgement of teachers on which it is founded, to reach its full potential.

This marks a progressive move away from the centralisation and top-down management of CfE towards greater autonomy of teachers, schools and local authorities that CfE promised at the outset. Successfully implementing this – and related – CfE developments and reforms at this middle level would imply and require the significant transfer of responsibilities and accountabilities from the Scottish Government and its agencies to the middle, where it belongs. This is the fourth element. Accordingly, our recommendations about IDL are largely about ‘empowering and strengthening the middle’, in line with the OECD report’s recommendations180.

The final recurrent theme in this report, and in the OECD report180, which is critical to strategic IDL implementation is *research*. The case – and an outline plan – for research around the implementation of IDL has been made above and will be progressed by the IDL NAG. An extended view of research would include teachers as researchers, able to analyse and evaluate what works and doesn’t work in implementing aspects of CfE (for example IDL), to resolve problems, identify solutions and make recommendations for dissemination to other schools and local authorities.

The successful implementation and delivery of IDL is ultimately dependent on the skills, capacities and motivations classroom teachers and school leaders, and with local authorities with whom (together with Scottish Ministers) statutory responsibility for school improvement rests. It is to them above all, within an enabling culture, that support should be provided to help to ensure that learning and teaching takes place in Scotland in a more interdisciplinary way.

In many respects the implementation of IDL as a context for learning in CfE is a case study with wider relevance to on-going school improvement through implementation of CfE.

# 12. Additional Barriers to Success

## (I) The Senior Phase Curriculum and Assessment

In 2012 the Senior Phase of CfE had not yet been implemented and SEEAG made the following recommendation.

*Recommendation 4.6*SEEAG supports the SSAC Recommendation 9 that there should be close monitoring by Education Scotland of the curriculum models introduced across Scotland to ensure that a sufficient breadth of opportunity to study the full range of sciences is available to all pupils across Scotland[[186]](#footnote-185).

There are now concerns that a number of unintended consequences are manifesting themselves in the implementation of the Senior Phase.

There is widespread concern amongst science teachers that despite new National Qualification courses specifically not being designed to allow bi-level teaching, as was the case, for example, with Standard Grade, many schools are expecting multi-level or multi-course classes to be taught in order to deliver pupil subject and level choices. Such a scenario cannot provide a quality learning experience for all and may contribute to a perception that STEM subjects are particularly difficult[[187]](#footnote-186).

#### Recommendation 34

* **Wherever possible bi-level/course or multi-level/course classes should not be taught in the sciences as the courses were not designed to be delivered in this manner.**

After several years of gradual growth in the uptake of the STEM subjects at SCQF levels 5-7 the 2015 SQA examinations show a notable drop in uptake across STEM subjects compared to 2014. It is only with the completion of courses during 2015-2016 and beyond that a full picture of likely uptake of subjects under CfE can be ascertained. In consequence it is important that this is kept under review and that action is taken if the reduction continues.

#### Recommendation 35

* **The uptake of STEM subjects at SCQF levels 5-7 should be monitored and action taken if a decline in uptake is manifest.**

SEEAG also made the following recommendation:

*Recommendation 4.7*It is recommended that SQA ensure that assessment instruments build on the strengths of the current procedures and are more holistic in nature. Innovative methods should be employed for the assessment of practical, research and investigative skills. These could involve the use of pre-release resources, synoptic questions and open-ended questions, and should be designed to avoid the pitfalls of previous assessments, including undue bias due to the background of candidates.

It is now widely acknowledged that the introduction of Curriculum for Excellence had the unintended consequence of triggering widespread over-assessment of learners in the senior phase. Following the first CfE examination diet, the Curriculum for Excellence Management Board reported, “it is clear that in the past year there has been a significant and unsustainable level of over-assessment in many parts of the system. This increase in assessment was not intended, and requires to be addressed at both national and local level”[[188]](#footnote-187).

Although there has already been a simplification of the unit assessment of some science courses by SQA there is still significant concern that unit assessment is overly atomistic, complex and bureaucratic to implement. In the sciences, unit assessment is of limited formative assessment value in terms of preparation for final course assessment.

#### Recommendation 36

* **SQA assessment of units and courses in the senior phase should be simplified to reduce the assessment burden on candidates and administrative burden on teachers. Assessments should be more holistic and unit assessments more formative in nature.**

## (II) National Standardised Assessments

The National Improvement Framework for Scottish Education involves the introduction of national standardised assessments. This raises the possibility both of increased assessment, even if not intended, and of a distorting effect on the primary curriculum due to their focus on literacy and numeracy. Research in England following the introduction of national assessments in English, maths and science and the subsequent abolition of those in science shows that this resulted in a decline in science teaching and science being regarded as less important than the other subjects compared to previously[[189]](#footnote-188).

These concerns are echoed in the OECD’s review of Scottish education[[190]](#footnote-189):

*“the intensive focus on literacy and numeracy has tended to side-line other important areas of learning such as science, history and geography, physical and health education, the arts, citizenship, and a wide range of what are now termed 21st century skills.”*

#### Recommendation 37

* **The purposes and nature of any national standardised assessment introduced in the BGE stages should be primarily designed to increase the depth of learning of pupils and not for the assessment of the education system, which could be achieved through a thoroughly applied sampling approach.**

#### Recommendation 38

* **The introduction of national standardised assessment should be continuously monitored for unintended consequences that detract from the overall aims of Curriculum for Excellence.**

## (III) Resourcing for practical work in the STEM subjects

The SEEAG report[[191]](#footnote-190) highlighted the need for adequate resources for practical work in the STEM subjects to allow young people to develop good practical skills. The Commission for Developing Scotland’s Young Workforce Final Report[[192]](#footnote-191) emphasises the importance of young people developing appropriate skills which will enable them to progress to employment:

It is important that all young people in Scotland are provided with the opportunities to develop and use the skills and abilities necessary to become an active member of the labour force and to maximise the benefits to them and their contribution to economic growth. In consequence there needs to be more focus on providing them with the skills, qualifications and vocational pathways that will lead to employment opportunities. The following recommendations were made in the SEEAG Report:

*Recommendation 4.11*It is recommended that SSERC build on its previous work and that of The Royal Society to research the cost of adequately delivering the STEM curriculum at all stages in Scottish schools. Budget recommendations should be based on reasonable assumptions for use of consumable materials by pupils and the writing off of costs of equipment over sensible lifetimes. These figures should be widely circulated and regularly updated.

*Recommendation 4.12*It is recommended that schools and their local authorities ensure pupils are provided with quality learning experiences where they can develop the skills of practical investigation and problem solving. This can only be done when there is sufficient equipment for hands-on pupil practical work in small groups or individually. Schools must be provided with adequate funds to provide and maintain sufficient equipment for effective hands-on experiences for all pupils based on the figures provided in SSERC’s recommendations in 4.11 above.

*Recommendation 4.13*It is recommended that Education Scotland in carrying out their inspection of schools should review and comment on the school’s allocation of resources against SSERC’s recommendations in 4.11 above.

*Recommendation 4.14*It is recommended that local authorities and schools ensure that STEM departments and faculties have sufficient well trained, specialist technicians to ensure delivery of practical STEM work within CfE, and that in parallel with recommendation 2.1 the Scottish Government ensures that a clear and detailed record of the number, qualifications and capacities of the STEM technician force in Scotland is collected and maintained.

Despite these recommendations not being supported in the Scottish Government’s response, the Learned Societies Group on Scottish STEM Education considered this to be a sufficiently important issue that it commissioned some independent research on this issue. The Learned Societies, working collaboratively through SCORE (Science Community Representing Education), had already commissioned some research in this area in England and research in Scotland would enable not only an assessment of the current position in Scotland but a comparison with that in England.

The funding available to the Learned Societies Group enabled data to be gathered from a sample of Scottish state funded secondary schools across the majority of local authorities plus a smaller sample of state funded primary schools.

The results of the research[[193]](#footnote-192) show that the majority of primary and secondary schools sampled do not have adequate resources to deliver practical work in science.

Looking forward over the next two years, 82% of schools indicated that they are not confident of having enough equipment and consumables to deliver science practical work effectively.

*“Students invariably have to work in large groups or have to share equipment with other classes,
or do not do particular practical sessions due to the lack of suitable equipment.”*

Almost all surveyed secondary schools raised the issue of funding as a critical barrier to investing in new and innovative equipment, repairing or replacing old and outdated equipment, and covering the cost of associated staff training to ensure its effective use.

*“Budgets have been frozen and more is spent on paper based course materials over
practical science.”*

44% of secondary school respondents are dissatisfied with the level of technician support for delivering effective science practical work. A small number of schools raised concerns that limited or no technician support places great pressure on teachers and takes up valuable time for lesson preparation.

*“The erosion of services such as the staffing ratio of technicians to pupils seriously threatens the delivery of practical science as teachers cannot teach and prepare experiments at the same time.”*

Moreover, the funding levels reported by Scottish schools in the Learned Societies Group survey was significantly lower than that reported by English schools in the similar SCORE survey[[194]](#footnote-193).

The average annual spend on science in 2013/14 in Scottish primary schools was £1.62 per pupil. This compares with £2.89 in England in 2011/12, according to figures obtained by SCORE. The situation is similar for the Scottish secondary schools surveyed; with an average reported annual spend on science of £7.33 per pupil, compared to £10.12 as detailed in the same SCORE findings.

Based on equipment and curriculum guidance from SSERC the Learned Societies Group estimated the budget required to adequately deliver and maintain practical science resources in a typical Scottish secondary school is over five times their current budget.

The Scottish Government Report, *A Manufacturing Future for Scotland[[195]](#footnote-194)*, states “Industry consensus is that significantly more investment will be required in Science, Technology, Engineering and Mathematics, the so called ‘STEM’ subjects, both in schools, and manufacturing-oriented degrees, apprenticeships and vocational courses”. Whilst it is possible to do some excellent practical science with low cost resources it is clear from the research data that pupils in Scottish schools are not getting the practical science experience to enable them to develop the skills necessary to make Scotland a world leader in STEM education, or to enable pupils to be well equipped with the practical skills desired by industry.

#### Recommendation 39

* **The Scottish Government should commission further research to identify the requirements, including the appropriate funding, to enable the adequate delivery of practical science and the development by pupils of practical skills across all STEM subject areas.**

#### Recommendation 40

* **Education authorities and school leaders should ensure that adequate resources are available in schools to allow teachers and technicians to implement practical work in schools so that pupils can develop good practical skills.**

#### Recommendation 41

* **CPD providers should ensure that teachers have good opportunities to develop effective teaching and learning of practical skills that meet the needs of learners and of the new curriculum.**

#### Recommendation 42

* **Technicians play an essential role in STEM education. The Scottish Government, through the TWPG, should collect statistics on technician employment in schools, as part of its annual survey of all teachers, to allow proper planning and delivery of technician recruitment, training and CPD.**

#### Recommendation 43

* **Education Scotland’s Inspectorate should report on whether or not schools have sufficient resources to provide sufficient hands on work in the STEM disciplines to meet the needs of learners and the new curriculum.**

# 13. Overarching Issues and Recurring Themes

Through the different workstreams addressed in this report a number of recurring themes have emerged. These can be considered as overarching issues which require to be addressed to ensure effective implementation of the recommendations made. Whilst these issues apply to STEM education they also have wider implications beyond the STEM subjects. All also have strong resonance with recommendations in the OECD’s review of Scottish education[[196]](#footnote-195).

## Improving educational research

In order to evaluate change and innovation in education robust data are required. This is a point that has been made previously by the Royal Society of Edinburgh’s Education Committee and in the OECD review.

There is a need to strengthen the independent educational research base in Scotland. This will provide both better baseline data and an improved research culture involving those with specialist research skills working with practitioners in schools to evaluate and improve pedagogical practices and learner outcomes.

The move to a Masters level teaching profession, as advocated in Teaching Scotland’s Future[[197]](#footnote-196), will increase research expertise within the school teaching profession. As a result, a greater level of research-informed practice and action research activities should facilitate improved pedagogical practices and therefore learner outcomes, which can be shared across clusters, Higher Education Institutions and other Professional Learning Communities, thereby enhancing the professional capital of teachers.

## Strengthening the “middle” (vertical and horizontal) of the educational system

One of the central aims of Curriculum for Excellence was to provide more autonomy for teachers and schools to decide on the detail of the curriculum suitable for their learners. However, as is highlighted in the OECD review, for successful system-wide implementation of CfE:

*“...the centre of gravity needs to shift towards schools, communities, networks of schools, and local authorities in a framework of professional leadership and collective responsibility.”*

This requires a decentralisation away from national agencies to schools, local authorities (where statutory responsibility for school improvement lies) and networks (the ‘middle’ of Scottish education). To achieve this, it is essential that the professional capital of educators is increased through appropriate collaborations. This requires teachers to collaborate, share and meet on a sufficiently frequent basis in Professional Learning Communities within schools, clusters and wider networks including national subject fora. Teachers need to be able to draw upon the expertise of external organisations and agencies including industry and Higher Education, who in turn need to have clear communication routes through which to collaborate with teachers.

The setting up of a series of STEM Centres, similar in concept to the LUMA Centres in Finland, will provide such a focus and conduit for collaboration as well as providing opportunities for our teachers and young people to interact with STEM researchers. These centres need not be solely restricted to the STEM subjects. The effective implementation of IDL, for example, requires collaborations across any and all subject disciplines. These centres could therefore have a pivotal role in supporting teachers not only to collaborate with colleagues within their own schools and clusters but also to act as hubs to share best practice within and between clusters, and to support teacher networking and professional learning communities more widely, in order to strengthen the ‘middle’ of Scottish education.

## Time

Inevitably the improvement of the social capital of teachers and leaders through effective collaboration requires time, as does the implementation of IDL as an effective context for learning. OECD figures show that Scottish teachers have amongst the highest teacher contact hours compared to other comparable countries and, in addition, recruitment of sufficient teachers into some of the STEM subjects is proving difficult. Effective collaboration and sharing in schools and Professional Learning Communities should provide improved educational outcomes and potential efficiency gains, with fewer teachers having to “reinvent the wheel”. However, this level of engagement will only occur if teachers have sufficient non-teaching time and do not have to waste precious time through unnecessary bureaucracy. Teachers, leaders, and others with suitable expertise could then use the time to develop the targeted, networked, evaluated innovation which will provide more effective learning environments, enhanced engagement and the improved attainment and equity we would all wish for from a quality education system.

The Scottish education system must be prepared to invest in time for the effective professional learning of its teachers, in collaboration with external expertise, educational and STEM subject researchers, industry and their local communities in order to improve the attainment of its learners and the closing of the attainment gap.

## Collaboration

Collaboration, and the diverse means by and through which this must happen, is highlighted consistently through this and the OECD reports. Appropriate collaboration is an essential means of increasing the social and professional capital of teachers and is at the heart of the successful development and implementation of IDL. Teachers should collaborate, share and meet on a sufficiently frequent basis, not in contrived ways, in networks at all levels – amongst teachers, within and between schools, in clusters, across transitions and in wider networks such as national subject fora. Teachers need to be able to draw upon the expertise of external organisations and agencies including industry, universities and colleges, who need to have clear structures and communication routes through which to collaborate.

The OECD review of Scottish education[[198]](#footnote-197) emphasizes that not all forms of collaboration are equally effective or have a strong impact on student achievement. STEMEC endorses the OECD view:

*“We suggest that collaboration in improving teaching, assessing CfE, and connecting schools to take collective responsibility for each other’s improvement and results, should be top priorities.”*

Inevitably the improvement of the social capital of teachers through enhanced and effective collaboration requires time.

## Impact of assessment

Assessment is central to effective education. However, too great a focus on summative assessment, assessment with too narrow a focus (be it only literacy and numeracy in primary schools or subject disciplines in the Senior Phase of secondary school), or assessment which is too complex and bureaucratic in nature is detrimental to both pupil learning and attainment, and the use of teacher time. The unnecessary increase in quantity and complexity of assessment in the Senior Phase has already been acknowledged by the working group set-up to review the implementation of the CfE National Qualifications.

The nature of assessment STEMEC would wish Scotland to have is summed up well in the OECD review of Scottish education:

*“It is important to have a coherent and carefully designed framework in order to maximise the quality of the information, to ensure that particular evidence sources are fit for the intended purpose, and to minimise unintended consequences such as reducing rather than promoting teachers’ assessment capacities.”*

14. Conclusion

The SEEAG Report recognized that the improvement of STEM education in Scotland requires a *system-wide* response, in which there are many interdependent elements. The developments and improvements in learning and teaching within this report, and in STEM education more widely, cannot be achieved in isolation either from each other or separately from other areas of educational reform but are intimately and irrevocably interlinked.

It is of note that our Committee, based in Scotland, working within our own time and resources from the bottom up and within the framework of STEM has come to very similar conclusions as the external OECD report’s[[199]](#footnote-198) fully supported, top down approach, considering all education.

It is not surprising therefore that the threads that run through the various elements of our Report are the need for **time** for teachers to be able to fulfil their role in the professional manner which the CfE requires and that teachers wish to deliver; the need for **systemic action** with clear strategic leadership and support from the top to resource and empower the ‘middle’ of Scottish education, especially teachers, and the importance of **collaboration** between and amongst teachers, schools, school leaders and Local Authorities.

These threads that run through our Report together with detailed recommendations are also essential for the practical implementation of the strategy embodied in the National Improvement Framework[[200]](#footnote-199).

Finally, the objectives of education are social, economic and cultural. It is perhaps not surprising that consideration of STEM is often framed in economic terms, either for individuals in the job market or in respect of the needs of employers. In consequence we consider it is important to conclude by emphasising the social and cultural role and importance, even necessity, of education in enriching the lives of both young and lifelong learners in a country in which all can contribute to and participate in all aspects of our democracy and society – as the Framework, quoting one of the National Outcome targets, states199:

*“successful learners, confident individuals, effective contributors and responsible citizens”.*

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# Appendix I - Membership of STEMEC

Professor Ian Wall Chair

Stuart Allison ADES and Scottish Science Advisors’ Group (until January 2015)

Fraser Booth Headteacher, Carnoustie High School and School Leaders Scotland

Scott Bryce STEM Education Support Officer for Higher Education and Industry Links, now Physics teacher, Broxburn Academy

Christine Emmett St Elizabeth’s Primary School, South Lanarkshire

Stuart Farmer Robert Gordon’s College, Aberdeen and Scottish Science Advisory Council

Professor Colin Graham Royal Society of Edinburgh

Rosemary Gallagher Dunblane High School

Jennifer Rees-Jenkins Association for Science Education

Dr Heather Reid Glasgow Science Centre

Gareth Williams Scottish Council for Development and Industry

Supporting the work of the Committee:

Frank Creamer Curriculum Unit, Scottish Government

Barbara Morton Curriculum Unit, Scottish Government

Graham Norris Education Scotland (until October 2014)

Elizabeth Morrison Education Scotland (from October 2014)

# Appendix II - Acronyms

BGE: Broad General Education

BOCSH: Building Our Curriculum Self Help Group

CBI: Confederation of British Industry

CfE: Curriculum for Excellence

CLPL: Career Long Professional Learning

CLTA: Curriculum Learning Teaching Assessment and Support Forum

CPD: Continuing Professional Development

ES: Education Scotland

Es & Os: Experiences and Outcomes

GTCS: General Teaching Council for Scotland

GUS: Growing Up in Scotland

HEI: Higher Education Institutions

HOSG: Higher Order Skills Group

IDL: Interdisciplinary Learning

IGB: Improving Gender Balance

IOP: Institute of Physics

ITE: Initial Teacher Education

LSG: Learned Societies Group for STEM Education in Scotland

LUMA: Finnish for STEM

MA: Modern Apprenticeship

NAG: National Action Group (for IDL)

NHRI: National Health Research Institute

NIF: National Improvement Framework

NSLC: National Science Learning Centre

OECD: Organisation for Economic Co-operation and Development

OFSTED: Office for Standards in Education, Children's Services and Skills

PISA: Programme for International Student Assessment

PLC: Professional Learning Community

RCUK: Research Councils United Kingdom

RS: Royal Society

RSE: Royal Society of Edinburgh

SCDI: Scottish Council for Development and Industry

SCORE: Science Community Representing Education

SCQF: Scottish Credit and Qualifications Framework

SDS: Skills Development Scotland

SEEAG: Science and Engineering Education Advisory Group

SG: Scottish Government

SQA: Scottish Qualifications Authority

SSA: Scottish Survey of Achievement

SSAC: Scottish Science Advisory Council (previously Scottish Science Advisory Committee)

SSERC: Scottish Schools Education Research Centre

SSLN: Scottish Survey of Literacy and Numeracy

STEC: Scottish Teacher Education Committee

STEM: Science, Technology, Engineering and Mathematics

STEMM: Science, Technology, Engineering, Mathematics and Medicine

STEMEC: Science, Technology, Engineering and Mathematics Education Committee

TIMSS: Trends in Mathematics and Science Survey

TWPG; Teacher Workforce Planning Group

WISE: Women in Science and Engineering

YESC: Young Engineers and Science Clubs

YWCA: The Young Women’s Movement

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