Introduction

The establishment of the Review Group on STEM is timely in the context of the recent publication of PISA 2012 and the Framework for Junior Cycle. It is, moreover, twelve years since the publication of the Report of the Task Force on the Physical Sciences. The world has changed exponentially since then in terms of the speed of technological developments, the globalisation of economies, the instantaneous availability of vast amounts of information online, and the increasing diversity and inter-connectedness of society. The global economic crisis has heightened political focus on education and its outcomes.

Articulating education goals

The demands placed on education across all societies are aptly summarised in the editorial introduction to the 2013 OECD Education at a Glance report, "*Learning their way out: Youth, education and skills in the midst of the crisis*". *(1)* Education must enable young people to engage in work, to create work, to continue to learn throughout their adult lives. Productive employment is a pre-requisite for individual and social well-being. But education is more than the economic dimension. It is a core social good whose outcomes reach beyond individuals' employability and a country's economic competitiveness. Indeed, the OECD Education at a Glance series is providing a strong evidence base on how education is inextricably linked to other social goods such as health status, civic engagement, social cohesion, and trust in political institutions.

It is important that public discourse on education reflect the multi-dimensional goals of education. A discourse which focuses exclusively on the human capital dimension is falling short of society's need. Such a policy will fail to engage teachers and the young people. A core strength of the Irish education system is the commitment of teachers and schools to the provision of a holistic educational experience to young people. The latter not only encompasses curriculum and out-of-classroom learning but also underpins an ethical orientation to education aimed at assisting the young person to reach their potential across many domains.

The current STEM review provides a policy space for the stakeholders in education, including the educators, to share knowledge; to spread innovation; to promote communication both within the system and with the wider policy communities. Such an approach is most likely to produce policy which will embed in the practice of teachers.

Building on our strengths

From the STEM perspective, there are many strengths in the current system which provide a good foundation for future policy options. Central to the former is the nature of the curriculum itself. Unlike many other OECD countries, a large majority of Irish second level students study several STEM subjects throughout their progression in second level education. The ***broad and balanced nature of the curriculum*** at both Junior and Senior Cycle is crucial in sustaining this uptake. The explication of the twenty-four statements of learning in the Junior Cycle Framework reinforces this curricular orientation: the statements both provide for learning in the STEM subjects and simultaneously draws attention to the inter-disciplinarity of learning across subject areas and future short courses. The high school completion rate in Ireland of over 90% is also important as is the high level of transition to further and higher education – approximately 66% of the school-leaving cohort.

The ***partnership model of curriculum development*** is strength in our system. The international evidence demonstrates that engaging with the teaching profession is a key factor in successful education reform. *(2)* It is a tautology to say that learning outcomes at school are the result of what happens in the classroom; thus only reforms which are successfully implemented in classrooms can be expected to be effective. Educational reform will not work unless it is supported from the bottom-up. The same maxim applies to education policy shaped outside the NCCA. There is an onus on policy makers to communicate their aims well and to consult with, and listen to, those who are expected to implement changes.

The ***quality of the Irish teaching profession*** is high and increasingly so, given the work of the Teaching Council in setting standards of entry into to the profession, accreditation of initial teacher education, publication of codes of professional conduct and the various other statutory duties. Unlike many other OECD countries, Ireland does not have a problem in attracting high quality graduates into teaching. There is a high level of trust and public confidence in the teaching profession which adds to its status.

There is already a good spectrum of ***enrichment and/or partnership activities*** for the STEM subjects. These partnerships allow for multiple levels of learning between the stakeholders – schools, teachers, business/industry – and of course the students. The BT Young Scientist of the Year Exhibition is perhaps the best known example of such activities. It is also important to note that other projects such as Young Social Innovators and the Concern debates also engage with issues relevant to STEM subjects. The role of the media in disseminating information about these activities is very positive.

Areas of concern

Notwithstanding the systemic strengths in second level education, **investment in education** remains a major challenge. The annual OECD series of Education at a Glance has provided year-on-year empirical evidence of an under-funded education system at key levels – expenditure per student, class size, availability on ancillary/non-teaching staff, school leadership. Over five years of austerity budgets have gravely undermined the capacity of schools to deliver the broad curriculum and provide core educational services such as Guidance and Counselling; supports for SEN and disadvantaged students; pastoral care.

There is up-to-date empirical evidence from both the teachers' organizations and the school managerial bodies of the impaired capacity of schools to deliver the expected curriculum at the level of subject choice and allocated time to specific subjects. The 2013 ASTI MillwardBrown *(3)* survey found that 75% of schools lost an average of 2 teaching posts since 2009 while 83% stated that enrolments had increased in this period. A particularly worrying finding from the ASTI research was the impact of teacher shortages on STEM subjects at Senior Cycle.

Middle-management structures in schools are collapsing from the moratorium on appointments to such post; such structures should be the driving force for whole-school planning and evaluation that is central to curriculum reform. The cumulative impact of these cutbacks has led to a precipitous decline in teacher morale. Proposals for system change invariably do not gain traction in this environment.

Term of Reference 1: The preparation of second-level teachers for STEM education in Ireland

Policy for Teacher Education

The Teaching Council has developed a "roadmap" for ensuring quality teacher education. Its 2011 statement on "*Policy on the Continuum of Teacher Education"* is premised on three principles, namely, ***innovation, integration and improvement*** which underpin the dynamic approach. *(4)* Specifically, the Council's policy will enable it to develop criteria and guidelines for ***reconceptualised programmes*** of initial teacher education, induction and continuing professional development.

Stakeholders in STEM education must engage with the Continuum. It is aimed at ensuring quality in teacher education and maintaining a balance between different social demands on education. It is a truism to say that while education takes the long-term view, industry's needs are changing almost on a monthly basis. ***On-going dialogue*** such as the current review is important in mediating such multiple demands on schools, the curriculum and teachers.

An important dimension of the Council's policy is its recognition of the role of the State in sustaining teacher quality by supporting teacher education in higher education institutions. It makes a strong case for the continuation of this supportive role, not least because education is understood as a public good. This is a particularly pertinent issue for STEM education.

Demands from some stakeholders that experts in STEM subjects be brought into schools to teach STEM subjects do not hold up to scrutiny when the literature on alternative entry routes into teaching is examined. *(5)*The key message from the latter is that it is extremely important that programmes facilitating such routes are well designed and are not perceived as expedient, ***"fast-track" routes*** with less demanding academic entry and exit standards. In particular, this literature identifies teaching as a highly skilled process and requires deep knowledge of both subject and pedagogy. Proposals to "fast-track" graduates from other fields into teaching won't work unless they include a strong pedagogical knowledge base which is essential for effective teaching.

Key points: *Policy on Continuum of Teacher Education provides a roadmap for STEM teacher education: alternative entry routes to STEM must be of high standard; on-going dialogue between stakeholders and Teaching Council is important.*

Initial teacher education

The Teaching Council has now in place a programme for structured placements for trainee teachers in an extended initial teacher education programme and is currently piloting an induction programme. There are however particular ***challenges in implementing*** these programmes in schools. Both are predicated on co-operation from experienced classroom teachers; support from school leadership and cultures of planning and self-evaluation in schools. Budgetary cutbacks resulting in larger classes and less teachers in schools are but one barrier to embedding these new programmes in schools.

A more persistent and damaging barrier to both is the process of ***casualization of entry*** into the teaching profession that is now pervasive across the second level system. This results in newly qualified teachers unable to secure adequate hours to complete the induction requirements and ***fractured "early-years" professional experiences*** in which they work hours per week, frequently in different schools, but do not get initiated into the community of practice of their subject specialism or that of the wider school community. *(6)*

Arguably, these fractured "early-years" experiences are more damaging for STEM teachers given the particular challenges of pedagogy in their subject areas. The 2011 Eurydice report on "*Science Education in Europe: National Policies, Practices and Research*" identifies specific issues in ***science educators' repertoire of knowledge, skills and competences*** such as modelling, argumentation, knowledge of the Nature of Science, inquiry teaching, issue of cognitive conflicts, and developing self-efficacy. *(7)* It is hard to envisage how newly qualified Science teachers can embed these skills and competences when they may spend up to four years in non-fixed-term contracts, based on as little as five hours teaching per week, and no opportunities for being mentored, co-teaching/team teaching, etc.

Under the Haddington Road agreement, there is a commitment by Government to review aspects of second level teachers' entry routes into employment. The ***Scottish model*** of ensuring that each newly qualified teacher is guaranteed an induction year in a school merits consideration, as does the Scottish practice of workforce planning and stakeholder dialogue.

Key points: *Cutbacks have impacted on the capacity of schools to provide quality placement and induction for trainee and newly qualified teachers; fractured entry into employment must be addressed; needs of STEM teachers particularly significant in this regard; Scottish model merits consideration.*

Continuing professional development

The Teaching Council has initiated the process of developing a Framework for Continuing Professional Development: the latter is identified as both a right and a responsibility. A key challenge for CPD providers and communities will be not so much updating content knowledge as ***deepening teachers' understanding of pedagogy*** and how it connects with the wider world of learning – including the new and emerging technologies and their impact on the social world of the child/student; developments in the neurosciences; changes in global economy and labour markets; the increasing diversity of society. Teachers cannot undertake this challenge on their own. The profession will require several types of support – coherent policy framework, incentives to engage in further learning, opportunities to use that learning in their classroom, accreditation of learning, career progression.

In this regard, the ASTI must put on record its condemnation of the measure in Budget 2012 to remove the payment of ***qualification allowances*** to teachers. Combined with salary reductions, this short-sighted measure has dis-incentivised teachers from taking on Level 9 studies. The financial and opportunity costs of engaging in sustained further study are now excessive for the vast majority of teachers in what is a highly gendered workforce.

Another important issue is that of ***time for engaging in further learning*** and ensuring that teachers are enabled to have a work-life balance. It would be wrong to under-estimate the many professional roles and duties of teachers which now extend beyond the core activity of classroom teaching. Excessive and unrealistic demands on teachers within a CPD framework will undermine morale and damage their capacity to engage in the collegial collective work of the school as a student-centred learning community.

The aforementioned ***EU Report on Science Education*** in Europe provides an insightful analysis into specific issues for CPD for Science teachers. It would be important that the Review Group consider these, in particular the recommendation for teaching in diverse classrooms. The recent PISA 2012 findings on girls' attitudes to Maths, for example, remind us that considerable challenges exist in terms of pedagogies for diversity. *(8)* Another recommendation on developing skills for teaching practical skills in the science laboratory is certainly timely in light of the proposed changes to assessment in the Junior and Senior Cycle science specifications.

The EU Report has also some recommendations on partnerships for ***CPD with stakeholders*** – academic, industry and research partners – which should also be considered. Similar observations can also be made for the other STEM subjects. There is a need for ***research*** into the latter to develop a good evidence base on which to frame CPD policy.

Key points: *A Framework for continuing professional development must include specific supports for teachers and schools; time for CPD must be acknowledged; specific issues for Science teachers should be considered and similar research undertaken for other STEM subjects; teaching for diversity is important to address issues of motivation and improve achievement levels; research is need on teachers' CPD needs.*

Term of Reference 2: Means of supporting/enhancing the current cohort of STEM Teachers within the system

Many of the observations above under CPD are of relevance in responding to this term of reference. At present, there are almost no extrinsic incentives for teachers, STEM or otherwise, to engage in further learning. The ***moratorium*** on the appointment to middle-management posts in schools introduced in March 2009 was particularly significant in this regard.

The attention of stakeholders must also be brought to issues of teacher workload and lack of time for ***peer learning opportunities*** in schools in the form of lesson study and co-teaching in which teachers observe each other, engage in analysis of practice and student learning; mentoring and coaching activities; action research. These findings are underpinned by that of the 2008 OECD TALIS National Report for Ireland: compared to other countries, low incidences of exchange, co-ordination and collaboration between teachers were found. *(9)* The Report also found that Irish teachers had among the lowest levels of feedback on their work. Obviously, the Review Group is not the forum where such issues are addressed: it is, however, important that the stakeholders are aware of the *system barriers* to innovation in the classroom.

Supporting the profession, including STEM teachers, to up-skill and engage in continuous learning is therefore not just a matter of supporting or incentivizing individual teachers. The primary support requirements relate to upgrading the capacity of schools to timetable teachers to engage in innovative peer learning, to attend out-of-school learning and to affect changes in the classroom. It also requires a structure of school leadership aimed at leading learning in the school.

Experience of Project Math's

In terms of supporting STEM teachers, the experience of schools and teachers in Project Maths is particularly instructive. Project Maths focuses on developing students' understanding of mathematical concepts, the development of mathematical skills and the application of knowledge and skills to familiar and unfamiliar problems, using examples from everyday life which are meaningful to students. Moreover, one of the key elements of Project Maths is the greater emphasis on an investigative approach, meaning that students are required to become more autonomous learners. In this regard, Project Maths could be considered as a ***prototype*** for other proposed curriculum changes. For Maths teachers, teaching the new programme has required changes to their subject knowledge, skills and competences.

Commenced in all schools in 2010, the scale of the initiative, its timeframe, its implementation - not to mention its fundamental principles - have presented challenges to schools, teachers and students. Teachers received an ***average of nine days out-of-school*** (equivalent to 45 hours) inservice training over the three years of its implementation as well as opportunities for additional voluntary learning opportunities including summer school and weekend seminars. A very important dimension of the upskilling was the provision of a free Professional Diploma in Mathematics for Teaching, aimed at "out of-field" teachers

Teachers' feedback on their experience of implementing Project Maths indicates a number of important areas for future CPD planning. ***Six themes*** were identified as problematic in the change process; new roles (as facilitators of students' autonomous learning, for example); supporting change and using teaching resources; issues of assessment; time; issues of change; and feedback on syllabus content/strands. *(10)* It is plausible to suggest that these broadly similar themes will be identified for other STEM teachers, given the proposed introduction of the Framework for Junior Cycle and the introduction of second-component assessment at Senior Cycle.

A recurring theme in teachers' feedback on their experiences of implementing Project Maths is their difficulties in "***re-conceptualising***" the new model of teaching and learning Maths. Many teachers found the pedagogical changes deeply challenging to their beliefs about their own abilities. This is a deeply troubling experience for teachers who face over a hundred teenagers each day for up to nine class periods a day. Teachers need to have a high sense of self-efficacy to deliver in this model of education. Curriculum change will invariably challenge teachers. CPD must be carefully planned and delivered so that it supports teachers in what is, for many, a difficult change process. A key lesson from Project Maths is the need to provide adequate and varied inservice, to ask what teachers' want, to engage in qualitative research around their experiences, to provide opportunities for classroom-based peer learning.

In terms of innovative approaches, there is a ***solid data base*** on what kind of CPD is most effective for teachers. *(11)* It is worth summarising some of the key findings:

- Increasing recognition that one-day "inservice" model of CPD is limited in terms of impact on pedagogy.
- Most useful CPD focuses on active teaching, assessment, observation and reflection rather than information delivery: design is important – must allow modeling; peer observation; self-reflection
- CPD more effective if is part of a school agenda as distinct from an individual teachers' interest; in other words, CPD is "job-embedded", meets school needs
- Length of CPD is important: fourteen hours is regarded as the minimum length to sustain teacher learning
- Personal "benefits" from CPD are important: teachers' sense of self-efficacy is integral to their skills and competences
- In-school models of peer learning must be facilitated to develop school as a learning community

Private sector leveraging of current State resources

The experience in Ireland of school-industry partnerships is long established through curriculum developments such as the Transition Year work experience, alternative Leaving Certificate programmes, mini-companies, Young Scientist, Sci-Fest, etc. A key factor in the success of such partnerships is the agreed focus on providing **educational experiences** to young people. A similar precept should apply to partnerships for supporting CPD and innovation more generally in STEM subjects. CPD activities which are perceived as having an overly industry-specific focus will not motivate teachers – largely because the former will not be perceived as being of assistance in the classroom.

As the Teaching Council moves towards new requirements for renewal of registration it is important that good models of public – private partnerships for STEM education are established. A key requirement will be a renewed national strategy in the first instance for STEM education. Investing in high quality STEM teachers must be identified as a ***national strategic investment*** within this strategy. A major strength in this regard is the existing support infrastructure for enterprise, science, technology and innovation in agencies such as Forfás, National Competitiveness Council, Science Foundation Ireland. Indeed, the latter has among its mission statement the advancement of "*co-operative efforts among education, government and industry that support its fields of emphasis and promotes Ireland's reputation for science and engineering research." (www.forfas.ie)*

The case for a ***national support structure*** drawing on the expertise of education and industry stakeholders for STEM education cannot be over-stated. An acknowledged weakness of the many enrichment projects previously referred to is the fact that they depend on individual teachers' information and enthusiasm. This should not be the case into the future. All schools need support to provide high quality STEM education. By the same token, all schools need supports to engage in informal STEM learning activities. There is already a good "ecosystem" for such activities in terms of the broad curriculum provided at both Junior and Senior Cycle. For example, students' high level of interest in environmental issues is sustained by their study of Geography, CSPE, Science and technology subjects. The wide range of entries to the Young Scientists' Exhibition confirms this wide base for blending formal and informal learning.

There are many modalities wherein the private sector could support learning for STEM teachers. The aforementioned EU Report provides information on other national initiatives. Measures to ***support teacher learning*** could include financial support to teacher education institutions to reduce costs for teachers: financial supports for further learning for individual teachers via scholarships; funding for research by teachers – especially action research in their schools; support for the activities of STEM teacher professional networks; research into students experiences of, and aspirations, in learning STEM subjects, including a gender and broader diversity focus.

Key points: *learning from experience of teachers in Project Maths; what makes effective CPD?; investment in STEM viewed as national strategic investment with appropriate support structure; support ongoing teacher learning.*

Term of Reference 3 and 5: The use of inquiry-based and problem-based learning approaches and the impact of different assessment modalities for STEM subjects in the context of, but not limited to, the developing Junior Cycle reforms. Increasing the engagement in and understanding of STEM subjects for students

The NCCA has completed a consultation process on the Draft Background Paper for Science in the Junior Cycle. The Paper aims to provide an explication of the purposes of Junior Cycle Science; the features of 21st century science specifications; issues around the Nature of Science feature and inquiry based learning. The feedback to this draft paper provides perhaps a unique insight into teachers' perceptions across these important domains but particularly in the area of inquiry based learning.
The Review Team should closely study the feedback to the consultation as it provides insights not only into Science teachers' views on how best to teach Science but also into their understanding of the purpose of science education. It is clear that there are opposing views on how to ***approach enquiry based learning***. Such dichotomies were also referenced in the EU Report. As noted above, there is a need for ongoing funding to support research for and by teachers on aspects of pedagogy in the STEM subjects, but particularly in Science where a move to more enquiry based learning could plausibly lead to the "*re-conceptualisation*" difficulties which so evidently occurred in Project Maths.

The differences in teachers' approach to – or belief in – inquiry based learning have implications in terms of students' perceptions of science as a subject. International research concludes that students' low or declining interest in science is partly due to its presentation as collection of detached, de-contextualised and value-free facts that are not connected to students' own experiences. *(7)* The *science-technology-society* approach seeks to contextualise science for young people by engaging with the wider context of science in society. It is not clear at this stage how the new specifications for Junior and Senior Cycle science will address these issue but they must do so to address the ongoing decline in the take up of the Physical Sciences at Senior Cycle.

Issues of ***gender differences*** in attitudes to Science have been well-documented and should inform curriculum design and teacher CPD. The recent Accenture study on "*Attracting more young women into science and technology"* provides a succinct summary of the barriers that exist in terms of girls subject choices and post-school aspirations. *(12)* Indeed, while these barriers are particularly acute for girls, the analysis can be plausibly extended to boys as well. The finding that among students – and their parents – there is fragmented information available about STEM careers is of particular significance and one which one must be addressed by the Review Group. Other findings are also highly significant: career stereotypes about STEM; lack of subject choices in some schools; absence of information in schools on STEM careers.

A necessary first step in this regard would be the reinstatement of Guidance Counsellors to schools outside the mainstream pupil:teacher ratio. A second step would be a support programme for **Guidance Counsellors** and their professional body around STEM careers and subject choices. A national ***needs analysis*** among Guidance Counsellors would be critical: research often concludes that careers advisors are not well-informed about science and technology careers themselves. (*7*)

A forthcoming ESRI longitudinal on Leaving School in Ireland provides important data on sources of information which inform young people's decision-making and choice processes for career planning. *(13)* Parents – mothers in particular - and Guidance Counsellors emerged as the main sources of advice. Young people from less educated and/or working-class families had less immediate knowledge of higher education in their social networks and, as a result, they were found to be more reliant on school-based sources of guidance. One-to-one sessions were particularly valued. It must be put on record that the latter activity has been particularly damaged by the inclusion of the Guidance Counsellor in the mainstream teacher quota. (*14)*

Key points: teachers' views on inquiry based learning; gender differences; role of Guidance service in schools; needs analysis for Guidance Counsellors.

Term of reference 4: The use of technology to enhance learning (especially on-line approaches) and the way in which the private sector could provide support.

As the ASTI is currently preparing a submission to the Department of Education and Skills' review of ICT in schools, the ASTI will forward a copy of same to the STEM Review Group.

Conclusion

STEM subjects are central to a broad and balanced curriculum. The latter is essential to meet the needs of young people and those of the broader society and economy. A discourse on education which focuses exclusively on the latter and ignores the wider societal role of our schools will not engage educators. At the same time, schools must take on board the challenges of preparing young people for the exponential changes ongoing in society and in labour markets as a result of the scientific and technological developments. This imperative is well summarised in the seminal UNESCO document, "*Science Education Policy Making: Eleven Emerging Issue*s":

> *"Sustainable technological development and many other possible societal applications of science require the support of scientifically and technologically informed citizens. Without the support and understanding of citizens, technological development can all too easily serve short term and sectional interests. The longer term progress of the whole society is overlooked, citizens will be confused about what should, and what should not be supported, and reactive and the environment will continue to be destroyed rather than sustained. Sustainable development, and the potential that science and technology increasingly offers, involves societies in ways that can often interact strongly, with traditional values, and hence, making decisions about them involve major moral decisions. All students need to be prepared through their science and technology education to be able to participate actively as persons and as responsible citizens in these essential and exciting possibilities. This goal is far from being generally achieved at present, but pathways to it are now more clearly understood."*

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