Physics teaching in United Kingdom's secondary schools

Kierann Shah

A report by the National Space Academy on behalf of the National Space Centre prepared for the SAT Project

(ERASMUS+ project no: 2015-1-PLO1-KA201-016801)

SAT Project

The publication was financed by the European Commission under the Erasmus + program. The publication reflects only the views of its authors and the European Commission is not responsible for the content in it.

Contents

1. Summary

The educational landscape in the UK is continually changing; both in response to targeted policy and as a result of wider societal changes. The assumption of responsibility for education matters at varying degrees in the devolved national governments of Scotland, Wales and Northern Ireland, along with government policies in England actively seeking to increase levels choice for parents mean that schools provision at secondary level is arguably at its most diverse in the UK for decades, certainly since the imposition of the National Curriculum in 1988.

Physics teaching and learning is, of course, affected by these broader changes to schools, but it also has some very specific challenges. These include the recruitment and retention of high quality physics teachers, concerns around the low uptake of physics at upper secondary level in general, and the fact that certain demographic groups are less likely to study physics than others. The UK's Institute of Physics has been studying these issues and making recommendations to schools and governments, and is an excellent source of recommendations, as well as co-ordinating a number of initiatives that support physics teachers and students.

Another highly varied facet of UK secondary schools is the standard of laboratories, use of practical work for teaching physics, access to computers or other devices, networking capability and the use of technology in the classroom. Education Scotland, the Scottish education body, has made great strides in standardising school IT (information technology) provision and in facilitating the use of technology, and may have lessons for the other nations on the implementation of a considered IT strategy for learning support. In the rest of the UK, there are no guarantees on access to IT although many schools have found their own solutions and best practise for engaging students using technology in the classroom.

Project based learning is not the norm in UK schools, but it is frequently used to enhance learning in some subjects. In physics project based learning has been scarce, and there is a feeling that this is one subject where teachers will "teach to the exam" or stick to a curriculum approach, perhaps due to perception of physics as a "hard" subject. There are examples of schools which endeavour to use project based learning solely, or at least as the prime method of teaching, but there is limited evidence so far on how effective this method is compared with conventional lessons.

The UK is lucky to have numerous education-related projects which exist to support physics teaching, but access to these varies greatly; geography, costs, the demographic mix of students, and the type of school all play a part. Although this report is written from the perspective of the National Space Academy, which is a national (UK-wide) programme that can be used to support teaching and learning, effort has been made to include the most prominent initiatives.

This report has been written to take into consideration all of the above contexts, with a view to familiarising colleagues overseas with the issues affecting secondary school physics in the UK. It has also been written with a view to informing recommendations for the use of project based learning methods alongside new classroom technologies with real-life contexts from space and related science research to enhance physics teaching. The issues and contexts above are explored in more detail in the body of the report, and the resulting recommendations are included as part of the conclusion.

2. Four Nations – the UK's secondary educational landscape

Schools in the UK are either publicly (state maintained) or privately funded (independent), with the vast majority of school children attending state schools; all children in the UK between the ages of 5 and 16 are entitled to a free place at a state school. Young people in all nations can stay on in state-funded full-time education until the age of 18 should they wish, and in England the law has recently been changed (2015) to require all 16-18 year olds to either stay in full-time education, to start a work-based training course, or to study or train part-time. Young people in Scotland, Wales and Northern Ireland can leave education at 16.

Since their creation in 1999, the United Kingdom's devolved national governments each have different levels of authority over schools provision in their regions. In England, Wales and Northern Ireland, the body with overall responsibility for schools is the UK Government's Department for Education, in Scotland it is the Scottish Government body Education for Scotland. However, both the Welsh Assembly Government and the Northern Ireland Assembly have some independent control of schools.

This division in the nations means that the Scottish education system is clearly distinct from the English education system, with separate qualifications and nomenclature. The English, Welsh, and Northern Irish systems are still very similar, but national differences do exist and in some cases are becoming wider.

In 1988 the UK government created the National Curriculum, ensuring that all schools maintained by the state in the UK had to deliver teaching of a government-specified programme of study and target attainment levels across all subjects. Independent schools, which are not maintained by the state, were allowed greater control over their own curricula, but of course they would include the National Curriculum content required to pass national exams. The National Curriculum was partly instigated to allow easier comparison of schools by ensuring that they taught the same content. Since its inception, the National Curriculum has undergone almost constant revision and change to adapt to changing ideals for UK education. In the last 5 years however, in England a new type of school has been encouraged which does not need to teach the National Curriculum: the academy model (which is explored in section 2b).

There is no single type of secondary school in the UK, and even amongst state schools admissions policies, governing bodies and responsibility for the management of the school can vary. Most schools are co-educational (mixed gender) but there are single sex schools. Some schools are able to select students based on academic ability – historically the system of grammar and comprehensive schools divided students up on the basis of their scores on an exam known as the 11 plus: those scoring the highest went on to grammar schools where they were expected to excel academically, those scoring under a threshold mark went to the comprehensive schools for a more all-round or even vocational education. The grammar/comprehensive system was largely dismantled throughout the 70s and 80s, with the majority of state grammars becoming modern comprehensives as part of a movement towards inclusion rather than selection. There are currently 163 grammar schools in England and Wales (Bolton, 2015), however in Northern Ireland there are 68 grammar schools, a far higher proportion of the total number of secondary schools since there are only 140 non-grammar secondary schools (Northern Ireland Statistics and Research Agency, 2015). Most children in the UK will not be examined for entry to most schools.

The independent school sector in the UK is small but strong, these schools receive very limited government funding but are often registered as charities making them exempt from corporate taxation. In order to maintain this status they must work on widening access through scholarships and other initiatives. Independent schools charge fees for the education they provide. The UK does have a small population of boarding schools, which are mainly independent fee-charging schools.

This report primarily focuses on provision in the different types of state-maintained school and those without a selective admissions policy, and does not consider the character of schools along the lines of religious affiliation.

England, Wales, and Northern Ireland have two key qualifications that can be achieved at secondary level, with key examination years at age 16 and age 18 (ages at end of academic year). These can be seen in the table 1, which outlines ages where pupils are expected to gain these qualifications in mainstream education.

In order to allow comparison between the various different qualifications offered at institutions across England, Wales, and Northern Ireland, there exists a National Qualification Framework (NQF). This framework determines levels of equivalence between the qualifications (originally with 5 levels where doctoral studies at University were a Level 5, the framework now has 8 levels, descriptions of which can be seen in Appendix 3).

School Year (England and Wales)	School Year (Northern Ireland)	Age of pupil	Assessment/qualification	Educational Stage	NQF Level
Year 7	Year 8	11/12		Key Stage 3	
Year 8	Year 9	12/13		Key Stage 3	
Year 9	Year 10	13/14		Key Stage 3	
Year 10	Year 11	14/15		Key Stage 4	1/2
Year 11	Year 12	15/16	GCSE	Key Stage 4	1/2
Year 12	Year 13	16/17	AS Level	Key Stage 5	3
Year 13	Year 14	17/18	A Level	Key Stage 5	3

Table 1 Examinations and educational stages in England, Wales and Northern Ireland secondary schools

The examinations for these qualifications are set outside of schools by “exam boards”, which ensure the standardisation of exams across schools. Schools choose between the available exam boards on a subject-by-subject basis: there are about seven of these organisations in England, Wales, and Northern Ireland (Wales and Northern Ireland both have nation-specific boards as well as access to those with a broader remit), however Scotland has only one.

Some state maintained schools have framed themselves as specialist schools, focussing in particular on improving attainment and uptake of a subset of academic subjects through teacher selection, school culture, and extra-curricular provision. Thus there are some state schools that are recognised as science focused, or have a science specialism.

a. Scotland's "Curriculum for Excellence"

In 2010 the Scottish Government, through its executive agency Education Scotland, began implementation of the new Curriculum for Excellence across Scottish schools, for students aged from 3 to 18.

The Scottish system now has three levels of examination: Nationals (subdivided into National 3, National 4 and National 5), Highers and Advanced Highers.

School Year (Scotland)	Age of pupil	Assessment/Qualification	SQF Level
S1	11/12		
S2	12/13		
S3	13/14	National 3, 4 or 5	3, 4 or 5
S4	14/15	National 3, 4 or 5	3, 4 or 5
S5	15/16	National 4, 5, or Higher	4, 5 or 6
S6	16/17	National 5, Higher, or Advanced Higher	5, 6 or 7
	17/18		

Table 2 Examinations and educational stages in Scottish secondary schools

b. Academies: a new school model in England

The policy of "academisation" was first implemented in 2000, and was used to target a limited number of struggling or failing schools in deprived areas (McNally, 2015). Around 200 schools became academies in the first instance. Since then the programme has been massively expanded to allow "converter academies": schools that are rated outstanding by Ofsted have been allowed to fast-track a conversion to academy status.

Academies are state maintained schools, but they are not under the control of the Local Authority – historically Local Authorities (or Local Education Authorities, LEAs) would be responsible for the state maintained schools in their regions. The school would have its own budget, but some of the allocated state funding (around 10%) would be held back by the Local Authority to spend on education initiatives in the region – for example supporting SEN (Special Educational Needs) staff or programmes or to look after students who are excluded from mainstream education. The Local Authority would also monitor standards in those schools. Academies receive the entire funding allocation with the expectation that they will buy in these services from other providers.

Since 2010, the UK government has pursued a more aggressive policy of turning schools into academies (academisation), which has moved education away from a centralised curriculum model with the goal of increasing the level of choice for pupils and parents. Among a number of differences from other state maintained schools, the new academies do not need to teach the National Curriculum, instead they must teach a curriculum that is "broad and balanced" (Miller, 2011). This means that the curricula of academies can vary from school to school, however it is worth noting that students from academies will still be expected to take GCSE and A Level exams, and therefore academies will implement curricula that include the syllabus of their chosen exam board.

Normally, academies are schools that have converted from local authority control, however the 2010 Academies Act allowed for academy-style schools that were original, i.e. not replacing an existing school. These schools are called “free schools”. The impact of free schools on the wider education landscape is limited as their numbers are relatively few, and evidence on their success or otherwise is still scarce.

Academisation is a considerable force in the evolution of English education: as of January 2015 there were 4403 open primary and secondary academies (McNally, 2015), and academies accounted for 61.4% of state funded secondaries (Drake, 2015). The move to increased numbers of academies means that the UK now has one of the largest proportions of students enrolled in privately managed secondary institutions out of all countries assessed by the OECD (Organisation for Economic Co-operation and Development), at the upper secondary level nearly 75% are enrolled in privately managed institutions – and the average across countries assessed by the OECD is 19% (OECD, 2015).

c. The future

The provision of education at secondary level will continue to diverge as government policies on academisation continue alongside national variations in curriculum requirements. A number of changes are about to be introduced that will increase this variation including:

- Changes to the grading of GCSE qualifications in England will be implemented in 2017: GCSEs will be graded from 1 – 9 (where 9 is the top grade) instead of the current grades of A*- G (where A* is the top grade). Wales and Northern Ireland will not be instituting this change
- The Welsh Baccalaureate (WBQ) is a separate qualification that can be studied alongside the existing qualifications taken at Welsh secondary schools, and was introduced in 2015.
- The English Baccalaureate (EBacc) which is described as a school performance measure, requires state maintained schools to provide the numbers of students achieving certain grades at GCSE in the EBacc subjects so that EBacc achievement can be compared from school to school. The EBacc was introduced in 2010, and DfE intend that all students starting secondary school since 2015 will take the EBacc GCSE subjects in 2020.

3. Physics

In the 80s and 90s, subsequent to the implementation of the National Curriculum, schools in the UK moved towards teaching physics, chemistry and biology in an incorporated general science approach, even at the level of GCSE. In 2008, the curriculum was changed to allow students at Key Stage 4 to study physics, chemistry and biology separately if they achieved an appropriate level of attainment at Key Stage 3 (Homer, 2013).

The Insitute of Physics (IoP) acts as a professional body representing physicists and championing physics at all levels including in education, academia, industry and wider society. Regarding education the IoP’s stated aim, taken from its most recent strategy document (Institute of Physics, 2015), is to “make access to high-quality physics education open to all” so that “everyone will have the opportunity to choose to study physics, and those that do will have access to high-quality education and well-informed choices about careers”. To discover how best to achieve this goal, the

IoP has undertaken, and continues to undertake, a range of research to explore the factors affecting the quality of physics teaching and the uptake of physics at post-16 levels in education (16 being the age where pupil choice becomes the deciding factor, for example when choosing A Level subjects).

Research by the Institute of Physics has since shown that doing a combined science qualification at age 16 makes students less likely to carry on studying Physics in their choices of study post-16.

a. The teaching skills pool

The UK continues to fall short of the required number of physics teachers, and is currently experiencing a shortfall in teacher numbers generally, with some indicators suggesting that this shortfall is increasing. According to a recent report from the National Audit Office for the Department for Education 29% of the 1055 places for new entrants to train as physics teachers went unfilled in 2015/16 (Department for Education, 2016). There is also a clear trend that many teachers at secondary school end up teaching subjects that aren't their specialism: the proportion of physics classes taught by someone without a relevant HE qualification rose from 21% in 2010 to 28% in 2014 (Department for Education, 2016).

There is also a problem with specialist physics teachers retiring or leaving state education at a greater rate than those joining it: an estimated 26% more physics teachers left the profession than joined in 2005-6 for example (Smithers, 2008). The numbers of pupils in English secondary schools is expected to rise as primary numbers have done (Drake, 2015), which will mean that without recruiting more teachers classroom numbers will rise, which will affect teaching and learning (Department for Education, 2016).

The lack of physics teachers, and the proportion of those teaching physics without a background in the subject (non-specialist physics teachers), poses a particular problem. The quality of physics teaching is a huge factor in determining the level of uptake in physics at post-16, as pointed out both by the Institute of Physics in various reports, and by a study undertaken by the Centre for Education and Employment Research at the University of Buckingham in 2008 commissioned by the Gatsby Charitable Foundation to look into the supply and retention of physics teachers (Smithers, 2008). The quality of physics teaching necessarily directly affects the levels of attainment in physics, and students' enjoyment of the subject as well – two things that also affect the uptake of physics but which should also be considered important in their own right.

Difficulties in recruiting physics teachers vary across the different regions of the UK; in England "Ofsted have found that isolated schools struggle to attract and retain enough teachers of the right calibre" (Department for Education, 2016). There is also variance across types of schools, independent schools attract more new teachers in physics than state schools and also attract those with higher level qualifications, and schools with a science specialism also felt that made a difference to the calibre of applicants. (Smithers, 2008). This may also be because over a quarter of physics trainees would rather teach physics and maths than generalised science, so they would prefer to teach at schools offering separate physics, which independent and science specialist schools are more likely to do.

In order to fill physics teaching posts schools may offer greater incentives, work with other schools, find ways to offer flexible working, or they will train up teachers from other backgrounds, e.g. training up chemistry or biology teachers (Smithers, 2008). About four times as many biology graduates as physics graduates train to be specialist science teachers and biology graduates make up a third of combined science teachers whereas physics graduates make up only 6% of this group (Smithers, 2008), so re-tasking biology graduates once they are teachers makes sense as one way to widen the pool of physics teachers. This can be successful but is not always ideal, particularly for schools offering physics at upper secondary level where the subject becomes more challenging.

b. The curriculum

The curriculum in science is continuing to undergo changes in England and in fact the pace of these changes is one of the factors in the divergence of curricula across England, Wales, and Northern Ireland as the two devolved governments take greater autonomy in education. However, although the exact content of schools' curricula in physics varies with location and with the type of school, the prevailing attitude of the UK in the development of science and physics teaching since the late 1960s has been to look at the epistemology and methodology of science, through investigatory work rather than just assembling a "miscellany of facts" (Dillon, 2010). Only recently, under the leadership of the coalition and then Conservative governments since 2010, has there been an ideological drive towards developing more factual knowledge (alongside the ideological drive for greater parent choice through academisation in England). This focus is likely to affect England more than the other nations since it is being led from the UK government and the devolved governments are not aligned with the UK government politically on this point.

A central premise of science teaching since the 80s and 90s, particularly at primary and lower secondary as the foundation for learning in science, has been the question of "How Science Works". There is some agreement across diverse curricula that this is a key aspect of learning in science, and also evidence to show that what non-scientists in the general public need to make informed judgement about science is knowledge of how science works, rather than a knowledge of science itself (Dillon, 2010).

i. Practical work

The use of practical work in schools should be used to support inquiry learning, however it can run the risk of being used to back up teachers' assertions rather than seek answers between competing theories (Dillon, 2010). According to a 2005 study by NESTA (National Endowment for Science Technology and the Arts) 84% of teachers considered practical work to be 'very' important with 14% considering it 'quite' important. NESTA also stated that "science teachers are resolutely committed to the principle of practical and experiment-based science enquiry learning" (NESTA, 2005).

However, as will be discussed in section 4a, student access to suitable laboratory learning environments is not guaranteed as a significant proportion of schools do not have adequate facilities (Department for Education, 2010) or even technician staff to support practical learning. This means that the quality and frequency of taught practical work and student-led experimental investigations varies greatly from school to school, and as has been suggested earlier, even from teacher to teacher.

One misconception that needs to be avoided in the classroom is that scientists "take measurements then look for a pattern" rather than following the science investigation process of question and hypothesis, followed by experiment and observation then analysis and evaluation of competing theories (Dillon, 2010). Rather, students experiencing the best of the UK approach to science teaching should learn about creativity and the role of models in science, as "developing causal scientific explanations requires the scientist to draw on their existing conceptual knowledge and imagine a different form of the world. This process of conjecture is one of the key scientific processes and is both as creative and demanding as other forms of work… It is what makes science a creative endeavour, requiring the facility to imagine the world not as it appears but as it might be." (Dillon, 2010)

ii. Process vs content

The debate about focussing on acquiring knowledge vs the process of inquiry based learning is set to continue in the UK, but it may be that the solution is to bring in aspects of both by "problematizing" the content: instead of presenting a fact simply to be memorised, teachers could ask how we might know that fact (Ford, 2008). This allows students to explore how the knowledge has been constructed but also to engage in scientific critique. Of course, the development of skills (process) will still take some of the teacher's time away from delivering knowledge (content) and may depend on an individual teacher's perception of their role as a "facilitator of learning" rather than a "dispenser of information".

Although inquiry- and problem- based learning are both highly represented in the UK education system, project-based learning is less common. Short projects and investigations may be part of science teaching, but this is usually to enhance or enrich teaching and limited in terms of classroom time. Some schools in the UK, such as Studio Schools (a type of Academy for 14-19 year olds) and University Technical Colleges (a type of Academy for 14-19 year olds affiliated to a university) aim to teach their entire curricula through long (3 weeks minimum) projects. In some cases, cross-disciplinary projects are being used to teach more than one subject through the project model, but as yet evidence on the effectiveness of this model is limited. Since the students at these schools will still (at present) take the same exams as their peers at other schools, those schools delivering project-based learning will also include discrete content on the exam syllabi rather than risk low exam performance. It may be that the exams will dictate the content even in academies in England and that this will limit the use of project-based learning.

c. Barriers to uptake

Although all students study physics up until the age of 16, at least as part of a combined science curriculum, uptake of physics at post-16 is lower than both government and interested parties would like to see to ensure the UK's future in science and engineering.

In 2014 the IoP published a series of recommendations arising from a review of research into how socioeconomic status (SES) can affect students' participation in STEM subjects (Institute of Physics, 2014). The report found that "three major demographic factors are correlated with the likelihood of a young person choosing a physics course beyond the compulsory phase of education:

- Gender: girls are much less likely to take physics than boys.
- Socioeconomic status (SES): children from more disadvantaged families are less likely to take physics.
- Ethnicity: people from certain ethnic backgrounds are more (e.g. Chinese) or less (e.g. Black Caribbean) likely to take physics"

Strikingly, the report found that the biggest indicator as to whether or not a student will go on to study physics is their past level of attainment in physics. This would suggest that uptake of physics is predicated on ability, but the report also notes that attainment is strongly linked to SES, meaning that students from lower SES backgrounds are disadvantaged.

Of course, schools and other education providers can only do so much to counteract the effect of socioeconomic status, as the Raising Aspirations in Physics recommendation report notes “it would be most effective to address the underlying issue of economic inequality, rather than attempting to combat inequality of opportunity piecemeal across many independent issues” (Institute of Physics, 2014). This is an issue that must be tackled at the level of wider government policy.

Amongst its recommendations for teachers, schools and government, the report has some recommendations which may be useful for other organisations to consider when planning activities to support physics teaching and learning at secondary level in order to at least avoid contributing to existing barriers, if not to remove them:

- Act to raise attainment in physics at early secondary level through targeted interventions
- Involve parents with their child’s education
- Raise the overall profile of science across the school, not just in the physics classroom
- Build long-term relationships between pupils and role models of similar backgrounds (one off visits are less effective than establishing a STEM club with regular visits for example)
- Explore socio-scientific issues in lessons
- Include information about appropriate subjects to study to apply for HE STEM courses
- Develop partnerships between HE and schools
- Provide opportunities for families to increase their science capital

Perhaps the most well-known issue concerning barriers to accessing physics is the gender disparity in uptake of physics at upper secondary and higher levels. In fact, the IoP’s 2012 report “It’s Different for Girls” found that in 2011 49% of state-funded, co-educational schools in England sent no girls on take A Level physics. In 2013 it followed this line of inquiry further with the report Closing Doors, which investigated the gender imbalance in physics alongside the gender imbalance in five other subjects, choosing six subjects overall: three with a female and three with a male bias (Institute of Physics, 2013). The study showed that there were a number of factors that made it less likely for girls to take physics at upper secondary level:

- Attending a co-educational (mixed gender school)
- Attending a school without a sixth form (upper secondary 16-18 education)
- Attending a state school
- The “whole school” environment and the attitude toward gender across the school

The attitude of the wider school and of individual teachers can be key, especially as female students are already immersed in a culture that has highly gendered expectations for education and careers. There may be issues of confidence and perceived competence: “Girls especially are more likely to take a subject post-16 if they think the teacher is interested in their education as an individual, yet conversely girls are much less likely to think this is true compared with boys.” (Institute of Physics, 2014). Other evidence has shown that girls more than boys may base their subject choice at upper secondary level on how “useful” they are and on the perceived potential for future careers (MacDonald, 2014), making the need to link careers information in to physics teaching even more important.

In England, teaching the separate sciences (biology, chemistry and physics) at GCSE has been shown to lead to relatively larger improvements in A Level outcomes for students from more deprived backgrounds compared with other students. Unfortunately, the separate sciences at GCSE are less widely available in areas of higher deprivation where their availability could have the most impact (Department for Education, 2010).

d. Initiatives supporting physics

It has been shown that schools engaging with initiatives aimed at improving engagement and attainment in the sciences and maths have a greater proportion of pupils taking these subjects, although this may be due to an existing focus on science. Such initiatives are widely available to schools, but with great regional variation – there are very few universal initiatives and some schools do not engage at all (Department for Education, 2010).

4. New technology in the classroom

New classroom technologies are emerging all the time, and the use of them is something that varies not only from school but from teacher to teacher. There is some evidence to show that using technology, from iPads and other tablets or computers, to aids for teachers such as interactive whiteboards, to software for analysing or recording experimental data, can increase student engagement and/or enjoyment. As children use technology more and more in their home life, it makes sense to engage with technology at school as well, but for many teachers this means learning new skills and making the time to learn new methodologies, which can be a challenge in terms of time or availability of training.

Some classroom technologies are supported by education teams, such as Apple Education (http://www.apple.com/uk/education/) or Lego Mindstorms (https://education.lego.com/en-gb/lesi/middle-school/mindstorms-education-ev3) who help to disseminate the methodology to schools – but of course schools must already have bought in to the technology. Some local authorities and individual schools in the UK have taken uniform measures to include technology in the classroom, for example providing iPads for every student which remain the property of the school (and the school retains administrative powers over what apps can be added) but this is not representative of all UK schools.

a. Variance/issues in uptake

In 2004 the Department for Education set a target to bring all school laboratories up to a satisfactory standard by 2005/6 and to a good or excellent standard by 2010. Reports since then have suggested that around a quarter of secondary schools' laboratory facilities remained either unsafe or unsatisfactory in 2005, and that the 2010 target will not be met until at least 2021 (Department for Education, 2010). This is indicative of the huge variation between schools in the standard of facilities, and sadly this variation is also seen in terms of schools technical facilities, the technical knowledge of school staff (teachers, technicians, and other support staff), network access, and use of computers, tablets and other devices.

Networking and IT support is another area in which Scotland has a markedly different approach to England, Wales, and Northern Ireland. The Education Scotland website outlines this as follows:

"Digital literacy, the effective and creative use of ICT, is key to developing the skills for learning, life and work needed by young people in the modern world. Schools must find new ways of thinking about how to use ICT so that it is at the heart of teaching and learning - not using computers to do the same things more efficiently, but changing the process of learning through digital media itself."

Scottish schools are all connected to a centrally maintained "intranet" called Glow, a "digital learning environment" which allows students and teachers to access programmes and resources to help with teaching and learning (http://connect.glowscotland.org.uk/start-here/). This system is shared through the Local Authorities in Scotland and was developed to support the delivery of Scotland's Curriculum for Excellence. However, despite Education Scotland's stated goals for engaging students with digital learning, the uptake of this kind of technology is still inconsistent and often, when successful, it is driven by individual teachers or departments.

b. Do students and teachers enjoy using new classroom technologies?

As part of the implementation of Glow and Scotland's wider policy on ICT in schools, the Scottish government has published a number of reports into ICT use and its effects. One, conducted by Young Scot, sought responses from 11-15 year olds about their experience of ICT in the classroom: it showed that respondents felt positively about the level of interaction allowed by digital learning methods, such as using tablets and interactive whiteboards, as well as accessing revision games and activities, accessing support for dyslexic learners, and accessing information quickly (Young Scot, 2015). It also allowed respondents to point out their frustrations with digital learning, including unreliable technology which could derail a lesson, teachers' lack of knowledge on how to use the technology, misuse of technology by other students becoming a distraction, and a lack of available resources that use the technology.

Initial use of new technology or more interactive forms of ICT usually raises the interests of students immediately, but that interest can wane quickly through frustration with unreliability or simply with familiarity once the students become used to it (Young Scot, 2015) (Dillon, 2010). Students engage with technology in their home life and since it is likely that access to technology varies with socio-economic status, school could become a leveller in that regard.

c. Are classroom technologies effective?

Of course there is no single answer to this question, as new gadgets/software which might be termed "classroom technologies" continue to proliferate (as does technology generally). Case studies of the use of such technology can be highly variable and what works in one area or one type of school may work differently elsewhere. Assessing the success of new technology or ICT solutions often uses existing measures of attainment, whereas "technologies provide new opportunities for learning and new ways of working so that traditional assessment methods may no longer be appropriate" (Dillon, 2010). Instead, it may be better to ask what approaches work best when selecting or implementing new tech to support current learning, as new ways of working will need to reach a tipping point before assessment methods are seen as requiring change.

An example of how classroom technology can be adapted to pedagogy is explored in a study of the use of interactive whiteboards (IWBs) at schools in London (Moss, 2007). The researchers found that IWBs "adapt well to the kind of whole class teaching environment favoured in secondary school core subjects" however, they found that use by teachers varied and they observed that teacher CPD is most likely to be successful when it "supports individual teachers' exploration of their current pedagogy, and helps identify how IWB use can support, extend or transform this".

A review of the literature on ICT and teacher methods from 2004 (Cox., 2004) emphasise in its key findings that appropriate pedagogical approaches are crucial for the success of classroom technology. They also found that "the evidence shows that when teachers use their knowledge of both the subject and the way pupils understood the subject, their use of ICT has a more direct effect on pupils' attainment. The effect on attainment is greatest when pupils are challenged to think and to question their own understanding, either through pupils using topic-focused software on their own or in pairs, or through a whole-class presentation."

Teachers also use technology to present and discuss students' work, to facilitate work in small groups, to facilitate whole class discussions, and in some cases to facilitate individual work. Use of ICT is less impactful for teaching and learning "where teachers fail to appreciate that interactivity requires a new approach to pedagogy, lesson planning and the curriculum. Some teachers reorganise the delivery of the curriculum, but the majority use ICT to add to or enhance their existing practices" (Cox., 2004).

5. Conclusions

The UK education systems are incredibly varied and through both direct and indirect government policies secondary schools in England are diverging further from the central National Curriculum model, whilst Scotland, Wales, and Northern Ireland are all now taking greater control of what schools in those nations teach – Scotland being the most distinct from the other nations with an entire curriculum and structure for education of its own. This greater variance produces wider choice for parents and for children, however it means that the system is vulnerable to producing inconsistent outcomes for pupils making comparison difficult. Whilst for now the qualifications taken at secondary level remain the same in general some consistency is assured – not least assuring employers that they understand what level of knowledge and capability these qualifications are expected to signify - upcoming changes to the GCSE qualifications in England, along with a widening of vocational learning options, mean that this consistency is not certain to continue.

With respect to physics, the changing focus of science education over past decades has led to a generally held view that developing an understanding of how science works through investigation is at least as important as developing a knowledge base, but this has always been challenged by the nature of assessment and is facing further challenges with current political approaches to education, in England at least. It seems that the answer for the HE institutions and industries that want entrants with a physics background is some combination of the two. Physics teaching, more so than the other sciences at secondary level, runs the risk of being seen as dull, difficult, and even useless, by students (Dillon, 2010). This is not a new situation, but it may be exacerbated by changes in the role of teachers - for example reporting being a greater part of their workload – and by the continued dearth of physics specialists amongst the population of science teachers. From the IoP's research we know that the single biggest factor affecting the uptake of physics in terms of school provision (ignoring societal issues external to the school environment) is the quality of physics teaching.

Can physics teaching in UK schools be improved through the introduction of new classroom technologies? In many ways ICT, from hardware for teachers to use in directing the classroom to software applications for students to do work using real life data, can streamline the teaching workload and provide novel ways of engaging with students. Having said that, there is one major barrier to be overcome when desiring to implement new technologies for the classroom, and that is the time and effort it takes for a teacher to feel confident to incorporate the new technologies into their schemes of work and within their existing pedagogical approach. Under pressure to produce better results with less financial resource and an increased requirement for evidence and reporting, teachers will not engage with and include new technologies unless it is clear that the benefit to them and their students will outweigh the time they will need to spend in understanding and implementing the technology.

Of course, it is not only teachers that can bring novel technologies into the classroom, and there are many external education providers active in the UK that can be brought in to schools to deliver sessions using these technologies. Whilst this can have a genuine positive impact on students attainment and engagement, it is not something that would be available to all students – further highlighting a risk of inequality in the UK education system.

a. Recommendations

The following recommendations are suggested for any development of teaching activities using space contexts and new technologies for the classroom:

1. Clear links are made between the activity and the curriculum: the link to useful learning for the curriculum should be the driver for the activity in the first instance. Whilst working across diverse physics curricula (eg across nations in the UK) it would be wise to link to topics that are common to these curricula. In addition to this, working with teachers who have in-depth knowledge of a specific curriculum is to be recommended, to allow them to further develop any activities from the common topics across curricula to specific examples or requirements within their own curriculum.
2. The format of any written resources for the activity for uptake must be carefully considered, with outcomes for learning made clear in the activity summary, as this is the selling point for teachers that will persuade them to invest the time in implementing the activity.
3. Where possible, face-to-face training of teachers is the best way to pass on the knowledge needed for teachers to take on new methodologies. This allows teachers to see the activity in action and build their own confidence in using new technologies in the classroom. It also allows them to question the trainer and other teachers, and to share their own knowledge with their peers, which is an opportunity teachers in the UK have less and less often these days.
4. As the proportion of science teachers in the UK that are physics specialists is so low, it must be remembered that most physics teachers have a background in a subject other than physics. This may affect their confidence, or even their capability, in teaching some physics topics, especially at higher levels or with gifted and talented students. For this reason, it would be useful to look at building in activities that support non-specialist physics teachers to develop their abilities and confidence in teaching physics.

5. Since the landscape for education in the UK is constantly evolving, and since new technologies are being developed or created all the time, it would be wise to consider how to "future-proof" any resources developed for supporting physics teaching using new technologies. For both of these reasons it would be ideal to be able to revisit the resources regularly to update them as necessary, or review them on a regular basis.
6. Students value "genuine learning experiences" (Dillon, 2010) over contrived experiments, and this supports understanding of science. Projects involving real data or examples can give a real-world context to science and raise students' investment in the activity, so the real-world context and links to cutting edge science should be included.
7. The contexts of socio-scientific issues, careers, and the usefulness of science are useful for engaging with groups that are proportionally underrepresented in physics, be it by socio-economic status, gender, or ethnicity. These contexts should be explored in activities developed for the classroom where possible.
8. Students enjoy the experience of using technology in the classroom when it raises interactivity, but find it frustrating when technology is unreliable or when the teachers' knowledge of the technology is poor. Teachers should be trained and confident to deliver content with technology and should use opportunities to interact with students using technology.

Appendices

1. Glossary

A Level	Shortened name for the GCE A Level (General Certificate of Education Advanced Level), examined qualification for mainstream subjects usually taken at age 18
AS Level	Qualification that can be taken at the end of the first year of A Level study, introduced in 2000, but removed as a requirement in 2015
BIS	Abbreviation for the Department for Business, Innovation and Skills, UK government
DfE	Abbreviation for the Department for Education, UK government
DfES	Abbreviation for the Department of Education and Skills, predecessor to BIS and DfE
Estyn	The Welsh schools inspectorate, equivalent of Ofsted
Education Scotland	The education body for Scotland, including the remit for schools inspections equivalent to Ofsted.
GCSE	General Certificate of Secondary Education, examined qualification for mainstream subjects usually taken at age 16
Higher Education (HE)	University level education
IT	Information Technology – broad term including computers and their use
ICT	Information and Computing Technology, similar in meaning to IT
Further Education (FE)	College or Sixth Form (VI form) education at Level 3.
NQF	National Qualifications Framework (England, Wales, Northern Ireland)
Ofsted	The Office for Standards in Education, Children's Services and Skills. Ofsted is a non-ministerial department that inspects schools in England to assess their standards against a set framework
SCQF	Scottish Credit and Qualification Framework
Science capital	A term used to refer to a level of familiarity with science, such as having science-related qualifications, understanding, knowledge, and social or familial contacts in science
SEN	Special Educational Needs
SES	Socioeconomic status: a term to describe someone's financial and social standing
Sixth Form	Upper secondary level – ages 16-18. The term comes from when year groups were called "forms", the sixth form was the last two years of school, with ages 16/17 in the lower sixth and 17/18 in the upper sixth
STEM	Science, Technology, Engineering, and Maths. An acronym commonly used in education and careers guidance

2. List of physics education projects/organisations

ESERO-UK — The UK ESERO (European Space Education Resource Office), situated at the National STEM Centre in York. ESERO-UK is funded by the European Space Agency (ESA) and DfE and its goals including supporting STEM education and promoting the role of ESA's education work https://www.stem.org.uk/esero/about-us

ESA — The European Space Agency

Institute of Physics — Learned society of physicists with remit to support physics education at all levels and physics professionals http://www.iop.org/

STFC — The Science and Technology Facilities Council, one of the UK's six research councils. STFC has a remit to fund research in the physical sciences and engineering in the UK and does so through university research groups and its own research facilities/laboratories at various UK sites.

Stimulating Physics Network — An initiative of the IoP. The Stimulating Physics Network (SPN) exists to support physics teachers in England and Wales and to raise the uptake of A Level physics http://www.stimulatingphysics.org/

The Ogden Trust — A charitable trust set up by Sir Peter Ogden, the founder of Compuserve, which seeks to encourage and promote the teaching and learning of physics and works with schools, teachers and universities http://www.ogdentrust.com/

3. National Qualification Framework Levels

The table below is from the National Careers Service for England website: https://nationalcareersservice.direct.gov.uk/advice/courses/Pages/QualificationsTable.aspx accessed 01/03/2016

Level	Qualification examples
Entry (levels 1-3)	Entry Level Award, Certificate, Diploma English for Speakers of Other Languages (ESOL) Skills for Life Functional Skills (English, maths, ICT) Essential Skills
1	GCSEs (grades D-G)[1] Award, Certificate, Diploma (City & Guilds, CACHE, OCR, BTEC/Edexcel/Pearson[2]) English for Speakers of Other Languages (ESOL) NVQ Level 1 First Certificate Functional Skills Essential Skills Music (grades 1-3)
2	GCSEs (grades A*-C)[1] O Levels (grades A-C) Award, Certificate, Diploma (City & Guilds, CACHE, OCR, BTEC/Edexcel/Pearson[2]) English for Speakers of Other Languages (ESOL) NVQ Level 2 National Certificate/Diploma Intermediate apprenticeship[3] Functional Skills Essential Skills Music (grades 4-5)
3	A Levels (grades A-E) AS Levels Award, Certificate, Diploma (City & Guilds, CACHE, OCR, BTEC/Edexcel/Pearson[2]) English for Speakers of Other Languages (ESOL) Access to Higher Education Diploma Foundation Diploma (Art and Design) NVQ Level 3 Advanced apprenticeship[3] National Certificate/Diploma International Baccalaureate (IB) Diploma Music (grades 6-8)
4	Higher National Certificate (HNC) Certificate of Higher Education (CertHE) Higher apprenticeship[3]
5	Higher National Diploma (HND) Diploma of Higher Education (DipHE)

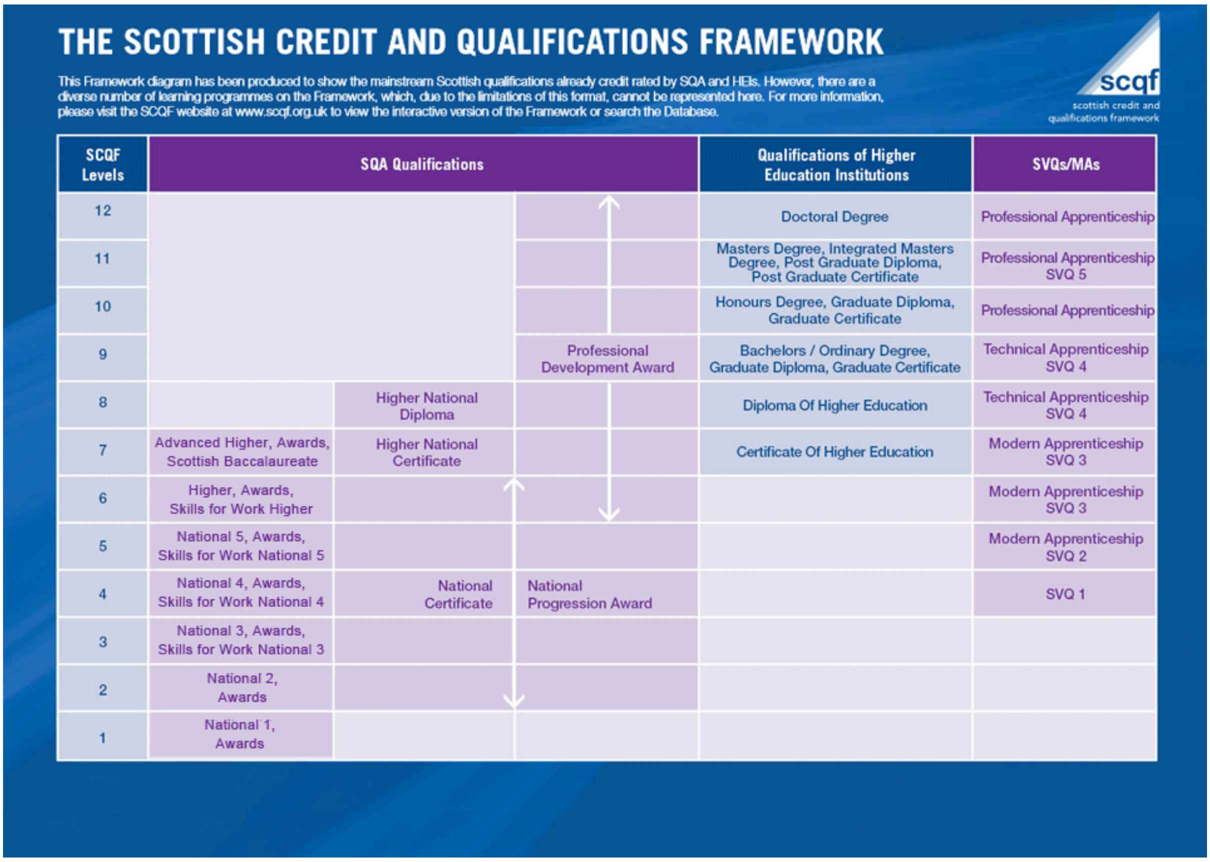
	Foundation Degree NVQ Level 4
6	Degree with Honours (eg BA Hons, BSc Hons) Degree apprenticeship[3] Graduate Certificate Graduate Diploma Ordinary Degree (without Honours)
7	Postgraduate Certificate Postgraduate Diploma Master's Degree (eg MA, MSc, MBA, MPhil) Integrated Master's Degree (eg MEng) Postgraduate Certificate in Education (PGCE) NVQ Level 5
8	Doctorate (eg PhD, DPhil, EdD, DClinPsy)

[1] A new grading system for GCSE exam results is being introduced from summer 2017. Eventually, all GCSE exams will be graded from 1 to 9 rather than the current A* to G, with 9 the highest grade. Grade 4 will be equivalent to grade C on the previous system

4. Scottish Qualification Framework

Taken from the Scottish Credit and Qualifications Framework website

[http://www.scqf.org.uk/framework-diagram/Framework.htm accessed 01/03/2016](http://www.scqf.org.uk/framework-diagram/Framework.htm)



THE SCOTTISH CREDIT AND QUALIFICATIONS FRAMEWORK

This Framework diagram has been produced to show the mainstream Scottish qualifications already credit rated by SQA and HEIs. However, there are a diverse number of learning programmes on the Framework, which, due to the limitations of this format, cannot be represented here. For more information, please visit the SCQF website at www.scqf.org.uk to view the interactive version of the Framework or search the Database.

scqf scottish credit and qualifications framework

SCQF Levels	SQA Qualifications			Qualifications of Higher Education Institutions	SVQs/MAs
12				Doctoral Degree	Professional Apprenticeship
11				Masters Degree, Integrated Masters Degree, Post Graduate Diploma, Post Graduate Certificate	Professional Apprenticeship SVQ 5
10				Honours Degree, Graduate Diploma, Graduate Certificate	Professional Apprenticeship
9			Professional Development Award	Bachelors / Ordinary Degree, Graduate Diploma, Graduate Certificate	Technical Apprenticeship SVQ 4
8		Higher National Diploma		Diploma Of Higher Education	Technical Apprenticeship SVQ 4
7	Advanced Higher, Awards, Scottish Baccalaureate	Higher National Certificate		Certificate Of Higher Education	Modern Apprenticeship SVQ 3
6	Higher, Awards, Skills for Work Higher				Modern Apprenticeship SVQ 3
5	National 5, Awards, Skills for Work National 5				Modern Apprenticeship SVQ 2
4	National 4, Awards, Skills for Work National 4	National Certificate	National Progression Award		SVQ 1
3	National 3, Awards, Skills for Work National 3				
2	National 2, Awards				
1	National 1, Awards				

5. References

Bolton, P. (2015). *Grammar School Statistics.* London: House of Commons Library.

Cox., M. e. (2004). *ICT and Pedagogy: a review of the research literature.* London: Department for Education and Skills. Retrieved from file:///C:/Users/Kierann%20Shah/Downloads/ict_pedagogy.pdf

Department for Education. (2010). *Education the next generation of scientists.* London: National Audit Office. Retrieved from https://www.nao.org.uk/wp-content/uploads/2010/11/1011492.pdf

Department for Education. (2016). *Training New Teachers.* London: National Audit Office. Retrieved from https://www.nao.org.uk/wp-content/uploads/2016/02/Training-new-teachers.pdf

Dillon, J. O. (2010). *Good Practice in Science Teaching: What Research Has To Say.* Maidenhead: Open University Press.

Drake, R. (2015). *Schools, pupils, and their characteristics: January 2015.* National Statistics. London: Department for Education. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/433680/SFR16_2015_Main_Text.pdf

Ford, M. (2008). Disciplinary authority and accountability in scientific practise and learning. *Science Education, 92*(3), 404-23.

Homer, M. R. (2013). Sources of differential participation rates in school science: the impact of curriculum reform. *British Educational Research Journal, 39*(2), 248-265.

Institute of Physics. (2013). *Closing Doors.* London: Institute of Physics.

Institute of Physics. (2014). *Raising Aspirations in Physics: Recommendations from a review of research into barriers to STEM participation for students fro disadvantaged backgrounds.* London: Institute of Physics. Retrieved from http://www.iop.org/publications/iop/2014/file_64463.pdf

Institute of Physics. (2015). *The Institute of Physics Strategy 2015-19.* London: Institute of Physics. Retrieved from http://www.iop.org/publications/iop/2015/file_65148.pdf

MacDonald, A. (2014). *Not For People Like Me.* Bradford: WISE Campaign. Retrieved from https://www.wisecampaign.org.uk/uploads/wise/files/not_for_people_like_me.pdf

McNally, S. (2015). *Schools: the evidence on academies, resources and pupil performance.* London School of Economics and Political Science. London: Centre for Economic Performance.

Miller, P. (2011). Free Choice, Free Schools and the Academisation of Education in England. *Research in Comparative and International Education, 6*(2), 170-182.

Moss, G. e. (2007). *The interactive whiteboards, pedagogy, and pupil performance evaluation.* London: Institute of Education.

NESTA. (2005). *Real Science: Encouraging Experimentation and Investigation in School Science Learngin.* London: NESTA. Retrieved from https://www.nesta.org.uk/sites/default/files/real_science.pdf

Northern Ireland Statistics and Research Agency. (2015). *School Enrolments in Northern Ireland.* Belfast: Department of Education, Northern Ireland.

OECD. (2015). *Education at a glance: OECD Indicators.* OECD Publishing. Retrieved from According to the latest data* made available publicly there are 3329 state secondary schools in England, 361 in Scotland, 207 in Wales, and 208 in Northern Ireland

Smithers, A. a. (2008). *Physics in Schools IV: Supply and retention of teachers.* London: The Gatsby Charitable Foundation. Retrieved from http://www.gatsby.org.uk/uploads/education/reports/pdf/16-physics-in-schools-supply-and-retention-of-teachers-june-2008.pdf

Young Scot. (2015). *The Views of Young People on Digital Learning and Teaching.* The Scottish Government. Retrieved from http://www.gov.scot/Resource/0049/00495091.pdf