Science Education International
Vol.22, No.4, December 2011 (Special Issue), 255-265

International Council of Associations for Science Education

English Secondary school students' perceptions of school science and science and engineering

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Abstract
Debates about school science, students' engagement with, and participation in Science Technology Engineering and Mathematics (STEM), and the supply of suitably qualified people for STEM related fields have been ongoing in England since the early 20th Century. Recent key policy documents and STEM related organisations have highlighted a skills gap in these fields that, if not addressed, could have significant implications towards the country's economic development and prosperity. A large body of literature exists which contributes to the understanding of why it is that young people opt out of post-compulsory STEM education and STEM related careers. However, even with a large knowledge base and a wide range of initiatives and projects that have been carefully designed with the underpinning aim of attracting more young people to STEM related careers (10 year Science and Innovation Framework-HMT, 2004) there still appears to be a problem. This paper presents data gathered from two studies undertaken by the authors in 2004 and 2010. Key findings from two surveys of school students' perceptions of school science and science and engineering in general, and from follow-up focus group interviews are reported. Data sets from both 2004 and 2010 reveal a large amount of congruence in the students' perceptions. While the majority of participating students state that they enjoy school science they also state that they would not consider study of STEM related subjects beyond compulsory education or a STEM related career. The paper situates key findings within existing literature and argues that there is some way to go before we can begin to piece together the large range of factors which influence student's decisions to opt out of STEM study and careers and to develop a clear and effective strategy for tackling the problem.
Keywords: School science, STEM careers, Qualitative, Survey, School students' perceptions

Introduction
Since the early twentieth century there have been debates about school science and the supply of suitably qualified people for Science Technology Engineering and Mathematics (STEM) disciplines (Smith, 2010) and the current climate is no different. STEM employers in England are anticipating a need to fill around 750,000 extra jobs over the coming years that will require numerate and analytical individuals with STEM based skills by 2014 (DCSF, 2009). A recent Confederation of British Industries (CBI) report 'Building for Growth',

(2011) reported that 43% of employers stated that they currently have difficulty in recruiting STEM skilled staff and more than half of the employers (52%) surveyed anticipated continued difficulty over the next 3 years. The report recommended that the Government needs to tackle these shortages by promoting science and mathematics in schools and supporting STEM-related apprenticeships.

A large number of initiatives and policy changes have been introduced over the last decade to engage the interest and enthusiasm of young people in STEM education, demonstrate the relevance of STEM knowledge and skills to everyday life, promote excitement about England's science and technology base, and highlight the range of careers it can offer (see STEM Directories http://www.stemdirectories.org.uk/). This extraordinary number of new and continuing initiatives from government, professional bodies, education-business partnerships and employers has sought to change the teaching and learning of STEM subjects and promote the choice of STEM courses.

This paper presents data from two studies conducted by the authors in 2004 and 2010. Questionnaire responses and focus group interviews provide the key data. The data provide an understanding of the students' perceptions of secondary school science and science and engineering more generally, and the influences on their understanding of science and engineering careers.

The national curriculum and relevant national initiatives

The first decade of the twenty-first century in England has witnessed a number of changes in the administration and delivery of science education. These changes constitute acts of parliament, a change in Government, curriculum change and a large range of projects and initiatives all of which have sought to positively impact on and direct the school-based science education of school students in England (see Table 1).

Table 1. Key Policies and Initiatives in Education Since 2004

2004	*Children Act 2004*
	Five Year Strategy for Children and Learners, formed the basis for the 2005 white paper, *Higher standards, better schools for all*
	Tomlinson Report, *14-19 Curriculum and Qualifications Reform*
2005	White Paper *14-19 Education and Skills* (rejected most of Tomlinson Report's recommendations
	White paper *Higher Standards, Better Schools for All*, led to 2006 Education and Inspections Bill
	Education Act 2005
2007	QCA published plans for a more flexible Key Stage 3 curriculum
2008	*Education and Skills Act 2008*, raised school leaving age to 18; Key Stage 3 SATs effectively abolished
	Education for All, final report of the Nuffield Review of 14-19 education and training
	51 Academies opened in September
2009	*National Curriculum*, report by Children, Schools and Families Committee
	Apprenticeships, Skills, Children and Learning Act 2009, created statutory framework for apprenticeships
	White Paper *Your child, your schools, our future*, wide-ranging proposals including removal of central government prescription of teaching methods and reduction in the use of private consultants to improve schools
2010	Diplomas scrapped
	QCDA scrapped
	White paper *The Importance of Teaching*, wide-ranging document covering teaching, leadership, behaviour, new school, accountability.

The table shows that the involvement of Government in the details and direction of school science has been significant over the last ten years. This 'top down' approach has reduced the opportunity for 'bottom up' developments grounded in actual classroom practice and the potential for teachers to develop their own courses, as occurred in a number of limited

instances, prior to the arrival of the first national curriculum in 1988. As the curriculum developed it was subject to a number of reviews culminating in the Department for Education review (DFE, 2011) which identified the reason for the review as:

> The national curriculum has come to cover more subjects, prescribe more outcomes and take up more school time than originally intended. It is our intention that the national curriculum be slimmed down so that it properly reflects the body of essential knowledge in key subjects and does not absorb the overwhelming majority of teaching time in schools. A slimmed-down national curriculum will also free up teachers to use their professional judgment to design curricula that meet the needs of their pupils. (pg. 1)

It remains to be seen how the initiatives to increase STEM uptake will mesh with the perceived need to direct more students into STEM. The statement above could be perceived to imply that direction has failed, or at least not produced enough of the desired outcome. There are also concerns that the increased involvement has led to the 'deskilling of teachers' begging the question of whether teachers will be able to make use of the increased time and flexibility promised in the recent review.

The secondary school curriculum, introduced in September 2008, aimed to provide an effective framework for exploring STEM subject study and careers and is supported by the programme of study for economic well being and financial capability. Its aims are to:

- expand their horizons for action by challenging stereotyping, discrimination and other cultural and social barriers to choice
- aim high
- build a positive and realistic view of needs and capabilities so that they can make effective learning plans, decisions and transitions
- be aware of changing career opportunities and develop the knowledge and skills to make informed decisions about learning programmes. (DCSF, 2009)

The Qualifications and Curriculum Authority (QCA) guidance for Personal, Social and Health Education (PSHE) also asked schools to offer:

- specific lessons as part of PSHE
- explicit, planned content in other curriculum subjects
- whole school and extended timetable activities
- specific projects and experiences.

Combined, these presented opportunities for explicit reference to be made to the real life application of subjects and to provide scope for partnerships between STEM subject teachers and those responsible for PSHE education and personal and career development in schools. Also important were the key STEM subject statements which identify work-related factors:

Science - discovering how scientific ideas contribute to technological change that affects industry and business, and pupils should experience science in the workplace where possible

Maths - a subject important for all members of a modern society and for its use in the workplace, business and finance, including tools for understanding economics and essential for participation in the knowledge economy

Design and Technology – offers the skills and understanding of economic, industrial and environmental issues together with ways to evaluate present and past D&T, and its uses and effects

ICT – offers understanding on how to apply skills purposefully in learning, everyday life and employment and should include the economic implications of its use

During the Labour Government of 2005 – 2010 a number of Departments were charged with responsibility for addressing a perceived skills gap in STEM-based fields. The Department for Innovation, Universities and Skills (DIUS) was involved in addressing skills shortages, science in society initiatives and the role and contribution of higher education to the STEM agenda. DIUS launched the 'Science So What? So Everything' campaign (2009) which utilised video clips, case studies and other information to improve young people's and the general public's perception of science (see http://sciencesowhat.direct.gov.uk). The same Government also introduced a network of National Skills Academies to deliver the skills required by industry. The Department for Business, Enterprise and Regulatory Reform (BERR) published 'Manufacturing: New challenges, New Opportunities' (2008) which announced the launch of the 'Manufacturing the Future' campaign to change public perception of manufacturing and to ensure young people's awareness of the career opportunities available. The STEM Subject Choice and Careers project (DCSF, 2006-2011) further sought to bring together all of these elements in one project that was offered to schools across the UK (DfE, 2011 - nationalstemcentre.org.uk).

Headline mathematics and science trends

Research published by the Department for Education, (DfE, 2011) reported details of headline mathematics and science trends for school students. In 2002, the Department (then DCSF) began to collect individual data on school students through the Schools Census. Linking this to the attainment data from the Key Stage tests resulted in the National Pupil Database which enabled detailed longitudinal analyses of school students' performance and factors which are associated with it. The data highlighted concern over the number of young people studying mathematics and science, continuing their studies at university, and following careers in these subjects and related areas. The report presents a comprehensive set of statistical analyses which offer a view of the trends in mathematics and science studies for post 16 pupils.

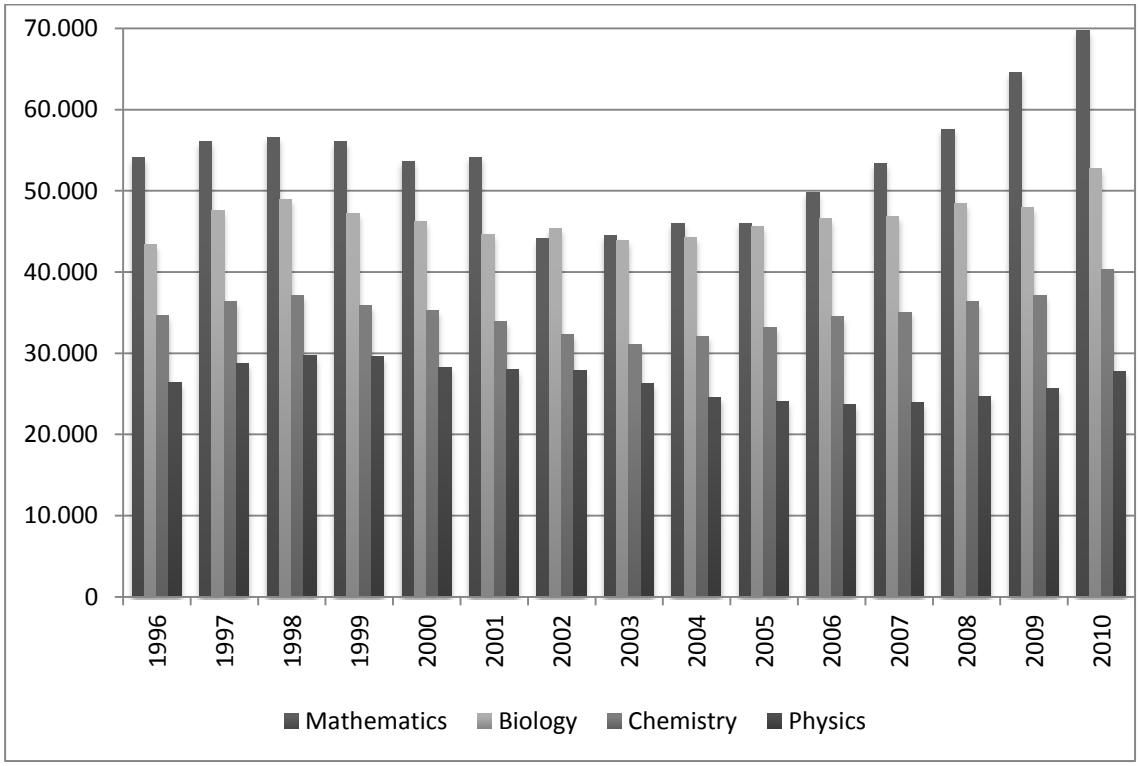
Provisional 2010 data show a continued increase in the number of entries to A-level mathematics since 2003. The data show entries reaching 70 thousand per year and indicate a recovery from the 18% fall in mathematics entries following curriculum changes in 2002. The 2002 decline was larger than the average across all subjects (-5%) but in the same direction. This might imply that the drop was to do with factors external to the mathematics classroom although issues within it may have amplified the trend. The number of A-level mathematics grades A*-B increased to 47 thousand in 2010, also continuing the trend of the previous 7 years. 2010 was the first year in which grades of A* were awarded and they were achieved by 17% of mathematics entrants. In Further mathematics this rises to 29%. This compares to an average rate of 8% A* grades across all subjects with figures for other sciences as: biology (8%), chemistry (9%), physics (11%). The data concerning candidate numbers indicate that mathematics is now the largest A-level course other than English. The data for Biology and chemistry also show steady increases since 2004, while physics increases slightly from 2007.

Current literature

The literature that focuses on young people's interest in school science and science and engineering prior to 2006 is quite extensive and includes a number of detailed studies (Osborne and Collins, 2000; Roberts, 2002; Planet Science, Institute of Education & the Science Museum, 2003; Nestle Social Research Programme, 2004; Bevins, Brodie & Brodie, 2005). The large majority of these studies are in agreement regarding their main findings which are broadly—that science is perceived as largely irrelevant to most people, physics is particularly difficult, males are more likely to be attracted to science and technology than females, there is a perceived lack of practical/investigation sessions in school science, and most school students' interest in science declines from the final year of primary schooling

through secondary school. Since 2006 the literature has thinned slightly but there is still concern about school students' interest in, and engagement with school science and science and engineering careers. Much of this literature confirms earlier findings. Jenkins and Pell (2006) reported findings from the ROSE project, a large comparative international survey of school students, from the perspective of students in England. The findings were largely congruent with findings from other data sets from industrialised nations taking part in the project. The authors stated that even though participating students hold positive views of science, engineering and society in general they are not '*reflected in their opinions about their school science education*' (executive summary). Most boys but, in particular, girls prefer other subjects to science.

Table 2. Science and Mathematics Entries to A-Level



Lyons (2006) compared three interpretive studies from Sweden, England and Australia which analysed students' narratives of school science. Despite the students' differing national contexts Lyons reported three emergent themes which have a high degree of congruence across all of the participating students. Firstly, the transmissive pedagogy of school science appeared to attract strong criticism from the students and left them cold and uninspired by the science content. This type of teacher-led approach was viewed by the students as ineffective in supporting the learning of scientific concepts. Secondly, the lack of relevance to students' everyday lives within much of school-based science was reported as a common theme from all three studies. Students indicated that there is no interplay between lesson content and their interests and aspirations. Thirdly, students perceive the physical sciences to be difficult subjects. Difficulty is explained within the three studies through a range of descriptions including intellectual challenge, difficulty with passive learning, irrelevance, and unfamiliar terminology and concepts.

Reporting on data from a five-year UK-based longitudinal study consisting of both qualitative and quantitative data Archer et al (2009) stated that students felt that school science bears little similarity to science practiced professionally. Similarly, Osborne (2007) suggests that

lack of interest in school science could also be influenced by a 'mismatch' between scientific values, teaching approaches, and the aspirations and developing identities of young people. Also, since science is represented as a body of unquestioned knowledge, without discussion and exploration of its nature, young people gain little opportunity to link it to their every day practices and aspirations.

Inappropriate pedagogy, lack of relevance and subject difficulty are just three of the main points emerging from studies of students' interest in, and engagement with science education. However, there are many other issues which cannot be ignored that may have significant influences on students such as ethnicity, gender, sociocultural background, and parental influence. We acknowledge that these issues exist but suggest they are beyond the scope of this paper and instead would point readers to the relevant literature (Royal Society, 2008; Gorard, 2007; Okpala, Okpala, & Smith, 2001). That said, there is one issue which is pertinent to this paper which has relatively less coverage in existing literature -'careers information'. Osborne (2007) reports that teachers view career information as being the domain of careers advisors and that *the compulsory nature of science means that there is less incentive for teachers to sell either careers in science, or careers from science* (p.107). Significant policy changes within education and in Careers Information, Advice and Guidance (CIAG) are currently ongoing in England and those changes include:

- the demise of Connexions careers services across England
- a move to an all age professional careers service due to start in 2012
- changes in the careers delivery in schools, making the school responsible for impartial guidance and removing careers education form the core curriculum.

Since many teachers are neither equipped nor motivated to provide effective careers information, advice and guidance future provision is uncertain. This can only reinforce the problem of school student interest in science and engineering.

While the aforementioned literature and other existing literature not reported within this paper identify an urgent need to address school students' interest in science others have suggested that the argument maybe a little over played. Smith (2010) suggests a different view of the perceived problem and argues that current concerns over the STEM agenda are not new and can be traced back over the last century at least. Reviewing key Government documents, focused on the position of science education and training from the last 90 years, Smith states that *concerns about the purpose of science education, how it is taught, who teaches it, and to which type of students, have a very long pedigree indeed* (p. 191). She argues that even after considerable debate and investigation we are still confused about the nature and purpose of the school science curriculum, the teaching of science in schools, and the recruitment of science undergraduates. Smith concludes by posing the question *When was there a 'golden age' for science education in the UK?* Whether or not there has been a 'golden age' remains up for debate. Our key concern is whether initiatives implemented through the 10 year Science and Innovation Framework (HMT, 2004) will have any positive long-term impact on science education and the science and engineering fields.

The reported literature describes some of the key issues central to school students' interest in, and engagement with school science as well as their perceptions of science and engineering, and careers in STEM fields. We now present key data from two studies conducted by the authors in 2004 and 2010.

Methods

Our research, both in 2004 and 2010 aimed to elicit secondary school students' perceptions of science and engineering - both classroom science (including Design & Technology) and

professional fields of science and engineering. Given the existing contexts of similar studies our specific aim was to gain a better understanding of why limited numbers of young people were choosing to study STEM related subjects beyond compulsory education. We designed and distributed a questionnaire to 50 schools across England for both studies. In 2004 responses provided data from 542 year 8 students (age 13 - 14). The questionnaire was followed up with focus group interviews conducted in four schools from South Yorkshire, the North West, Cambridgeshire, and London with 150 year 8 students. All of the students interviewed had completed the questionnaire.

In 2010 the same questionnaire was distributed and gained responses from 283 year 8 students. Focus groups in three schools with 27 year 8 students followed. Questionnaire data from both sets were analysed through the excel computer programme with data from all focus groups analysed through qualitative inductive methods based on open coding (Cohen, Manion & Morrison, 2011). Text units were arranged from transcripts and notes from the focus group interviews. Emerging codes were then organised into themes based on converging responses from pupils which lead to the identification of common patterns. We are aware that the data sets are different in size with the 2010 data sets considerably smaller than the 2004 data sets and that even though the participating schools are either the same or have similar characteristics, that the six year period between each study could have implications that impact on students' responses. Therefore, we acknowledge that any comparisons may be limited.

Questionnaire responses

Table 3 presents students' responses to statements from the questionnaire which attempted to gain an understanding of how students perceive school science.

Table 3. Students' Responses (by %) Which Focus on Classroom Science (2010 data in brackets)

	Item	SA	A	DK	D	SD
1	I enjoy learning about science in school	16(11)	53(62)	18(18)	11(8)	2(1)
2	I enjoy learning about science outside of school	6(3)	22(17)	22(27)	33(33)	17(20)
3	I find science difficult to understand in school	3(2)	17(16)	24(26)	41(42)	15(14)
4	My science teachers make science interesting	18(19)	42(51)	25(16)	11(11)	4(3)
5	My teachers tell me about things that are currently happening in science	18(8)	47(44)	21(34)	11(11)	3(3)
6	My teachers explain about careers in science	24(5)	4(17)	26(39)	37(31)	9(8)
7	I would like to study science at A-level	18(11)	21(20)	32(43)	14(13)	15(13)

Results in Table 4 show resonance with existing studies. Students register their enjoyment of learning science in school (69% and 73%) but are clear that that is where their interest halts with half (50% and 53%) stating that they do not enjoy learning about science away from school. The large majority of students do not find school science difficult to understand (56% and 56%) and believe that overall their teachers make science interesting (60% and 70%). This apparent contradiction with other comments about physics being seen as difficult is probably explained by the fact that students were questioned about 'science' rather than the three separate disciplines. Where the distinction between the three sciences has been made students tend to regard physics as more difficult than biology and less enjoyable. While most students agree that teachers explain about contemporary issues in science (65% and 52%) almost half state that teachers do not explain about related careers (46% and 39%). The work done through the ROSE project and by Osborne and Collins (2000) also shows that school students tend to enjoy classroom science and are positive about their teachers. However,

these studies also identify that these perceptions are not reflected in students' views of science as a career or further study options.

Table 4 shows students' responses in relation to statements concerning scientific careers and science and society.

Table 4. Students' Responses (by %) Which Focus on Scientific Careers and Science and Society (2010 data in brackets)

	Item	SA	A	DK	D	SD
7	I would like to study science at A-level	18(11)	21(20)	32(43)	14(13)	15(13)
8	I would like to study science at university	12(8)	16(13)	41(49)	16(21)	15(9)
9	I am considering a science related career	17(9)	13(12)	38(37)	19(28)	13(14)
10	I think science is important to the economic development of the UK	19(13)	51(49)	22(32)	5(5)	3(1)
11	I think science has a positive public image	8(5)	38(40)	41(47)	11(6)	2(2)
12	I think science offers a wide range of careers	18(15)	50(46)	24(33)	6(5)	2(1)
13	I think that scientists are generally well paid	10(16)	38(35)	44(44)	6(3)	2(2)
14	I think there are many more male scientists than female scientists	5(10)	19(21)	55(58)	17(7)	4(4)
15	I think most scientists are above the age of 40	4(4)	10(9)	49(58)	30(24)	7(5)

A relatively large number of students (39% and 31%) stated that they would like to study science at A-level which is reflected in the steady increase in numbers taking mathematics and sciences at A-level since 2004. Existing figures show that, of 781,511 A-level passes, 125,179 were in the sciences with 80,492 for mathematics and further mathematics and 28,262 for Design and Technology and computer studies and ICT. This means that 26% of all A-level subjects achieved in 2010 were either science or mathematics. The drop from 39% to 26% is perhaps understandable as students face the more demanding work at A-level compared with GCSE but it does beg the question of whether students are opting out of sciences and mathematics into other areas or simply opting out of A-level studies. Fewer students in the current study (28% and 21%) stated that they would like to go on to study science in university with a relatively high number (31% and 30%) stating that they would not consider studying science beyond the age of eighteen. Not surprisingly, the largest responses to statements 8 and 9 are given as 'Don't Know' (again, it is worth noting here that focus group data reveals students' lack of awareness regarding science and engineering careers). Most students (70% and 62%), reassuringly, believe that science is important to the economic development of the UK. However, their lack of enthusiasm for opting to take a scientific based career seems to indicate that either they have little understanding of the perceived skills deficit or little interest in the problem-a mixture of both would seem likely.

It is, perhaps, not entirely surprising that the remainder of the results in the section (11, 13, 14 and 15) are dominated by 'Don't Know' responses. Given the students' response to statement 6 that their teachers do not engage in discussion about scientific careers, it would be unreasonable to expect the students to make an informed response to these statements. Moreover, it appears to evidence an overall lack of knowledge and understanding of STEM-based careers.

Focus groups

Data from focus groups revealed a number of interesting issues. However, for the purposes of this paper we will report on the four most dominant emergent issues:

- pedagogy
- relevance
- careers information, advice and guidance

- career choice

Of the 27 students involved in the 2010 focus groups only four stated that they did not enjoy school science. These four students did not differentiate between the main science subjects and indicated that they are dissatisfied with a lack of practical/investigation activities which seem to give way to an inordinate amount of writing. The remaining 23 students stated that they did enjoy school science and agreed that practical/investigation sessions are the most enjoyable form of learning school science by far, with group work and discussion also cited as being effective approaches to learning science:

> I like it when we're not writing, it's good if we get to do practical work or run around the classroom like recently when I got to be a squirrel and run around collecting nuts. But I could only collect green nuts cause I was a red squirrel (Year 8 student, 2010).

Data from the 2004 students show that the majority of students indicate that biology is preferred to physics or chemistry as it is perceived as less complex. Most students from the 2010 cohort also state that they prefer biology as physics is too hard and has little relevance to their everyday lives. The large majority of students from 2004 said that they prefer to be engaged in practical/investigation sessions in comparison to more teacher-led approaches such as teacher demonstrations and copying text:

> It's better to do practical lessons they're more fun and help you to find out better about things for yourself. I don't like copying notes or watching the teacher do experiments (Year 8 student, 2004).

The above comments are largely consistent with existing research (Osborne & Collins, 2000; Lyons, 2006) which also highlights students' dissatisfaction with some teaching approaches, a lack of relevance, and perceiving physics as difficult.

A large number of students from both cohorts suggested that a more informed knowledge of the wide range of science and engineering professions, practice and environments would enable them to assess the relevance and applicability of science and engineering much better. However, they felt that their experience of CIAG was poor and that they had received little or no CIAG. The large majority of students from both cohorts expressed their enthusiasm for gaining a greater awareness of the day-to-day operations and duties of science and engineering professionals and career routes. Students appeared keen to enhance their understanding of the range of activities involved across science and engineering professions:

> It would be good to ask them (practising scientists and engineers) questions about their jobs and find out what they do, how they do it, how much they get paid...things like that...and how they learned to do it (Year 8 student).

As Osborne (2007) points out teachers may not be motivated nor equipped to pass on quality CIAG to teachers which may add to the problem of students' lack of knowledge about STEM careers.

Students from the 2010 cohort were asked if they were considering careers in STEM related subjects and only nine recorded a definite yes. The remaining 18 were either uncertain or not considering a career in STEM. Of those students wishing to take up a career in STEM fields six wanted a career in medicine, either as a General Practitioner or nurse, two were interested in veterinary services and one was uncertain, although she indicated an area in mathematics would be her preferred option. Of the 150 students interviewed in 2004 only a third stated that they were considering careers in STEM related subjects which were identified, in the main, within the medical professions with only a handful in engineering.

Conclusions

This paper reports data from two studies in 2004 and 2010 and even though there are differences in sample sizes the data indicate a great deal of congruence between both student cohorts. It would be incorrect to state that young people's interest in, and engagement with

science has not changed in the years between 2004 and 2010 as statistics show a steady increase in science and mathematics A-level entries with the most significant rise being in mathematics. However, what is stark is that while we have enjoyed the highest numbers ever of people attending higher education the physical sciences have suffered. Also, students who participated in the 2010 study have reiterated similar perceptions of the participating students from 2004 and findings from existing studies; that a lack of practical/investigation sessions still exists; students are still not seeing the relevance of some subjects and topics, particularly physics; provision of careers information, advice and guidance is not effective; and that the majority of students are not considering STEM related careers. Therefore, it would appear that the range of policy changes and initiatives that have been designed, for the most part, based on evidence and careful planning have had little impact.

It is our intention to revisit the 27 year 8 students who participated in the 2010 focus groups when they reach year 10 to ascertain whether or not their perceptions have changed in any way over the two-year period. At this stage we feel it unlikely. Our analyses of the data gathered across the two cohorts of students together with findings from existing studies supports our pessimism, although a deeper investigation in to the students' reasoning and decision making may reveal greater understanding than we have gained from the two reported studies. For us, the key dilemma is still that a large number of young people suggest that they enjoy school science and that it is important to the economic development of the country yet they choose not to study it beyond compulsory education. Continued research in to the many issues that can influence school students' perceptions of school science and science and engineering in general is crucial. Parental influence, socioeconomic status, teaching approaches, gender, ethnicity and culture are just a few of a long list of factors which need to be understood further in order to reach a clear understanding of why young people are opting out of STEM study and careers.

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