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Studying Stem:

what are the barriers?

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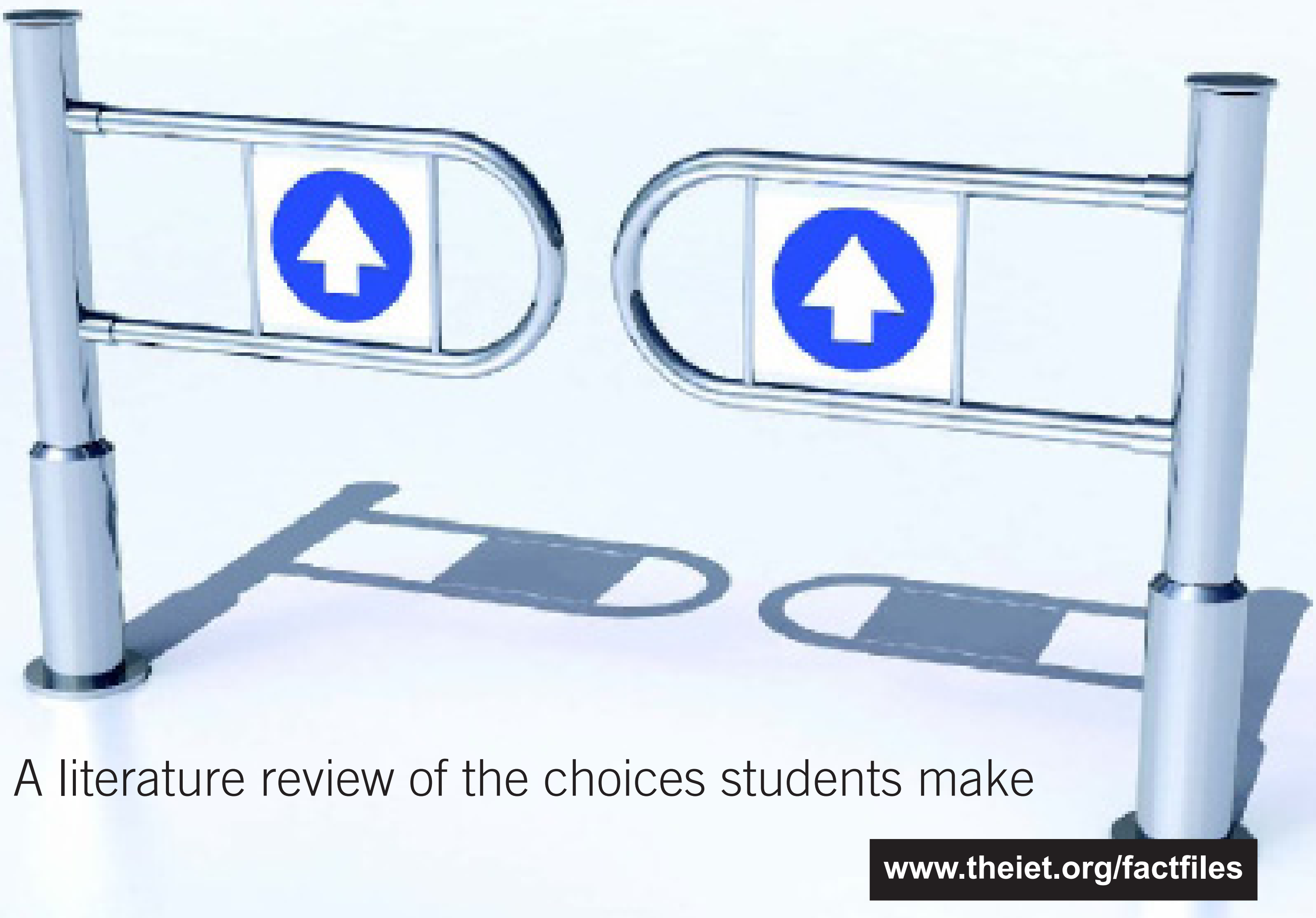

A literature review of the choices students make

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About This Factfile

The Institution of Engineering and Technology acts as a voice for the engineering and technology professions by providing independent, reliable and factual information to the public and policy makers. This Factfile aims to provide an accessible guide to the reasons behind the current decline in post-16 uptake of science, technology, engineering and mathematics (STEM) subjects.

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This report was commissioned by the IET Policy Department and carried out by an independent researcher, Dr Lyn Haynes. The views, conclusions and recommendations contained within this report do not necessarily reflect the views of the IET.

Contents

Executive Summary

The current decline in post-16 uptake of science, technology, engineering and mathematics (STEM) subjects is of great concern. A great deal of work has been done on why this is happening, and the IET commissioned this review of studies to identify the most commonly agreed upon 'switch-off factors'. Through this review we can reach conclusions as to why fewer young people are pursuing STEM studies at higher levels and therefore losing the chance to pursue STEM related careers.

The problem is well documented. Three global surveys (ROSE, PISA and TIMSS) indicate that 13-15 year-olds in developed nations display a positive relationship between self-efficacy and achievement in STEM, but do not place a high value on science and technology. In contrast, in developing countries a STEM related career is frequently seen to be the route to improving life for many in their country.

International research therefore shows this is far from a problem exclusive to the UK. Whilst the education system may play a major role, the issues are still being seen in different countries with very different education systems. Identifying the issues that lie outside of the education system is therefore the main focus on this work. This report identifies the following barriers, based on weighted evidence from a literature review of almost 300 reports and refereed journal publications, as the key issues to address.

The need for quality teaching for students to become and remain engaged in STEM

Inspirational teaching is time and time again identified as a key barrier to overcome. Likewise evidence suggests that the curriculum is not always seen as relevant.

The perceived difficulty of STEM subjects

Students do not believe they will achieve the same grades in STEM subjects as they might in others. Additional pressures mean that they may be discouraged from taking on subjects they are like to achieve lower grades in. The emphasis on achieving high grades overshadows the stimulating and worthwhile challenge that STEM offers.

The disillusionment of the transition from primary to secondary school

Pupils entering secondary school science report that the transition involves them becoming relatively passive recipients in the knowledge transmission process with less and less time devoted to practical work.

The negative views about success in STEM and negative stereotypes

The perception exists that anyone who enjoys or succeeds in STEM subjects is, or might be, a geek or nerd and the subject matter is not 'funky'. Such images are frequently reinforced by the media, peers and parents who are the major influencers when decisions pertaining to opting for STEM subjects or a career or not.

Perceptions of careers and opportunities in STEM

STEM subjects are seen as hard and unrewarding, with success in STEM being viewed as having connotations associated with being a "nerd" or a "geek". These same image problems extend into perceptions of careers, with students not perceiving STEM subjects as a passport to lucrative and interesting jobs.

Introduction

The current decline in post-16 uptake of science, technology, engineering and mathematics (STEM) subjects is of great concern triggering the need for an appraisal of the causative barriers, particularly amongst the 11-14 age group, in order to re-brand STEM to this age group, as well as their influencers. Some insight into the 'switch-off factors' might begin to throw light on why fewer young people are pursuing STEM studies at higher levels and/or careers.

This report considers the existing body of research to determine which barriers emerge as the key image and perception reasons for students being switched off STEM through not pursuing their study at higher levels or pursuing related careers. More specifically this report aims to identify:

- key barriers or 'switch-off' factors in the 11-14 age group, in order to elucidate/begin to understand the current trend of uptake;
- the future opportunities and current perceptions within the school context of science and technology, and the wider context of STEM pertaining to the value held and enjoyment of STEM;
- peer, parental and societal attitudes towards STEM.

This report will also make some suggestions pertaining to approaches to re-brand, re-image and re-imagine STEM in order to stem the current decline in post-16 uptake.

Methodology

Approximately 300 articles from peer reviewed journals, reports from learned societies and professional bodies in the private sector were consulted. The sources originated from university libraries and electronic journals in England, Australia and South Africa, as well as the www for government reports, etc. 124 sources were then entered into **EndNotes** based on their specific relevance. At least 62 of these publications have been cited in this report.

The Global Situation

The ROSE (Relevance of Science Education)[1] project, initiated by the Norwegians in 2001 and conducted in England in 2003[2], sought the views of 15 year-olds from 40 countries to map out attitudinal or affective perspectives that underpin the emphases of this report pertaining to science and technology (S&T). PISAA[A,3,4] and TIMSSB[B,5,6,7] projects include mathematics. Interesting disparities, conundrums and paradoxes emerge by superimposing these data sets.

Essentially the young people in developed countries display a positive relationship between the level of self-confidence in their ability (self-efficacy) and achievement in science, yet they tend not to place a high value on or interest in science and technology (S&T). The paradox alluded to lies with Japanese students[8,9,10,11,12]. While they are high achievers their self-efficacy and interest levels for science and mathematics were amongst the lowest. Generally they also undervalue STEM subjects and careers more than any other young people. Their disinterest is of great concern, particularly if this trend becomes more prevalent in developed countries.

The conundrum materialises from, amongst other developing nations, South African 15 year-olds whose TIMSS 2003[13] data placed them as the lowest scoring participating nation. Nevertheless while the students reported very high interest levels and self-confidence in their ability, they also tended to place high value on S&T.

Generally, children in developing countries articulate a much more positive view towards S&T than children in more wealthy countries. The latter (mainly boys and including English children) tend to portray scientists as "cruel and crazy", while most children in developing countries seem to consider scientists as "idols, helpers and heroes". Sjøberg[14] gives a tentative explanation for these observations: In developing countries, education is a "luxury" and a privilege, a resource that only a few children have access to. The motivation to learn and to study is high. This is particularly the case for girls, since the access to education is often denied them[15]. In developing countries a STEM related career is frequently seen to be the route to improving life for many in their country[16].

The global consensus is that enrolment for STEM studies and/or careers has been in decline for more than a decade. Even in Uganda, where the outcome of the ROSE project shows young people to display positive attitudes regarding the uptake of STEM, the Programmes Director of the newly formed Agency for Science and Technology Advancement (ASTAU) reports the rising concern about post-compulsory enrolment[17]. Few nations appear not to have had to confront this problem, yet India[18] discloses that graduate and post-doctoral students experience difficulty in finding STEM-related employment. Recent reports from ACME suggest that the situation for mathematics has turned the corner at tertiary level[19].

When do students lose interest?

As early as the late 1960s research indicated that one third of students made the decision whether or not to study science by the age of 12[20], while Lindahl's evidence[21] from Sweden this century suggests this happens when pupils are 12-13 years-old. In England a lack of enthusiasm compounded by the perception that science is difficult was detected by the time pupils reached Year 5 (10-11 year-olds)[22].

Jenkins and Nelson reckon that disengagement has occurred by the time the students embark on their GCSE courses aged 14-15. Despite the above, Robinson[23] found that his 5-6 year-old kindergarten pupils would have preferred a more positive science learning-environment than that on offer. According to Lindahl[21], "If so many decide their future so early, and science is so unfamiliar to them, perhaps it is not strange that they do not choose science". Consequently, the 'switch-off' factors effecting 11-14 year-olds' decisions regarding the uptake of STEM subjects and careers are being explored.

Learning and teaching methods, the curriculum, and assessment, are all highly influential in the formation of student attitudes towards science, as is the quality of the teaching that they experience. (Gilbert, 2006, p7)

Why do students lose interest?

Throughout the literature this is seen as a complex, multifaceted problem including teacher qualifications, recruitment and retention; the content of the science curriculum, the way science is taught and/or assessed; the alleged difficulty of the physical sciences; the influence exerted by the media, parents, students' peer groups within and outside school; careers' advisers; the nature and the extent of students' interaction with science[24,25] both in and out of school. Narrowing this list down to a few major 'switch-off' factors is an onerous task.

'Switch-off' factors

Teaching

Approaching this from a positive perspective, one of the most frequently cited reasons for inspiring young people to enjoy STEM subjects is good teaching[26,27,28,29,30,31,32,33], and his/her role and personality in the approach to delivering school science and its curriculum. The latter is oft-quoted as being irrelevant to life outside school, the subject matter as boring and over-prescriptive[34,35], the nature of the curriculum imposes constraints on teachers[36,37] and its assessment[38,39,40,41,42]. The situation for mathematics[43,44,45] is not dissimilar. Teacher qualifications[46,47], recruitment[48,49,50] and retention[51,52,53] are also raised frequently issues. Therefore the strongest direct influence on positive attitudes toward science is that of high quality, inspirational teaching[31].

Investigating content relevance and its boring nature fur ther, the curriculum is seen by students as being irrelevant to life outside school[54,55,56,57,58,59,60,61]. Lyons[56] refers to the content as being 'decontextualised'. For example, young people detect little relevance of the Haber process and Surds to the interests of their age group, or a working life[62]. The new 2006 GCSE science specifications for England and Wales attempted to address this issue with the 'How Science Works' strand. One should appreciate that the public is more interested in the product than how it works, and this is underpinned by the media[63]. Braund and Reiss[64] state that the current system is still outdated and that laboratory-based school science teaching needs to be complemented by out-of-school science learning that draws on the actual world (e.g., through fieldtrips), the presented world (e.g., in science centres, botanic gardens, zoos and science museums), and the virtual worlds that are increasingly available through information technology.

Issues that are meaningful and relevant to students "are dependent on the culture and the material conditions in the country", but these are constantly changing, as Schreiner[65] reminds us.

The science curriculum content is seen to be boring[66,67,68] because so much subject matter is repeated across the Key Stages. The teaching is boring because it is often perceived as 'knowledge transmission of correct answers'[69,70] without time nor room for creativity, reflection or offering opinions. Fensham[69,70] reinforces the need to present students with intellectually challenging material to engage their interest and commitment.

Associated with ‘boring’ is the perception that anyone who enjoys or succeeds in STEM subjects is, or might be, a geek or nerd[71,72,73,74] and the subject matter is not ‘funky’[75]. Such images are frequently reinforced by the media.

An approach to reversing the decline in STEM uptake would be to change the image of people working in STEM related jobs and develop a curriculum that is accordingly relevant and interesting, while being exciting to teach and assess. Schreiner’s[76] suggestion begins to address these.

In addition to computers and oil pumps, the physicist and the engineer develop methods for utilising alternative energy sources, they develop technologies for eliminating landmines, create methods for more animal friendly food production, devise solutions for protection against deadly weapons, invent new instruments for treating diseases and so on.

Appropriate and stimulating materials could be created along the lines suggested above that draws attention to STEM, including engineering and its real life applications that complements the curriculum, while using carefully selected young or renowned role models to alter the current public image and make this a sought after career path to contemplate.

Perceived degree of difficulty
Another commonly cited reason in the extensive body of literature associated with switching young people off science is that STEM subjects are perceived to be more difficult to achieve good grades than in other subjects. Therefore they are assumed to be more difficult. Such an attitude is not restricted to the students, but also perpetuated by most influencers. The alleged difficulty of the subject is critically linked to self-efficacy and interest levels in the subjects. Year 9 students (13-14 years-old) view science as being more difficult than English and mathematics[77].

The current education rationale that compares and publishes schools’ performance in England and Wales requires students to achieve the best possible grades. Even though GCSE has been reported not to be so difficult[78] by some GCSE students, STEM subjects are believed to be more difficult than the arts to achieve good post-16 grades[79,80,81]. Pressure can also originate from the school for potential underachievers not to opt for STEM subjects because of the knock-on effect on the league tables. This perception of the arduous nature of STEM subjects has been corroborated: it is more difficult to achieve good post-16 grades in STEM than the arts and humanities[82,83,84].

Unfortunately the concept of ‘difficult’ is seldom equated with being a positive challenge to pupils older than 10-11 years[85] or having social status as portrayed by the French “BacS” (the scientific Baccalauréat) “that remains the most prestigious option for sixth formers and attracts many academically gifted pupils destined for nonscientific careers/higher education”[86]. ‘Challenging’ and ‘interesting’ could be presented to young people as mutually inclusive concepts and incorporated into material produced to address the current issue with the uptake of STEM. At the same time such engagement could develop their confidence and competence (self-efficacy).

Possibly the approach to STEM should be marketed at school and in society as being an enticing, stimulating and worthwhile challenge, thus negating the uninteresting and esoteric field. Careers in STEM need to be re-imaged as stimulating and dynamic as opposed to being a dull job at the end where a person’s talents and abilities are not fully utilised.

Fensham[87] suggests that the decline in post-16 uptake of STEM might be part of a ‘marginalisation’ process; an aspect of adolescent rebellion against school in general and not just STEM and that it could lend ‘street cred’ to a decision not to take STEM subjects, rather than avoiding them on grounds of being too difficult.

A public awareness campaign could be initiated to raise the image of STEM subjects and careers, and change the impression of being difficult and ‘out of reach’ for most people.

The transition from primary to secondary school
This barrier was reported by many, including Qualifications and Curriculum Authority (QCA), as being students’ single most negative experience of science, and thus engendering a negative attitude towards STEM around the age of 11-12. There are reports of student-disillusionment with science in the secondary school. In particular, suggests Reiss[88], children expect secondary schools to provide distinctive equipment and other facilities for science in secondary schools. In the mind of the child, it seems, the act of lighting a bunsen burner assumes the status of a rite of passage into the realm of ‘real’ science. Many pupils commented that the very different (less nurturing) teacher-pupil relationship made the subject appear to be less favourable than at primary school[89]. These reasons point to a management of expectations of a preconceived image that they carry with them to the secondary school.

Lyons[90] reports that pupils revoke the transition as it involves becoming relatively passive recipients in the knowledge transmission process with less and less time devoted to practical work[91]. QCA[92] addresses the pupils’ disappointment (to a limited extent) in calling for more hands-on science to ease this passage. Secondary science was perceived as new, strange and difficult all at once, according to the students in Lindahl’s[93] research. While Campbell and Keegan[94] report that science was seen by Year 7 (11-12 years-old) pupils as being a global amorphous subject that was beginning to become serious. By the time students reach Year 10 (14-15 years-old) science is accepted as being part of the curriculum and the pupils become embroiled in GCSE and ‘resigned to the necessity of science’. This could explain the improved attitude towards STEM from the age of 15 frequently alluded to in the literature.

This ‘switch-off’ factor subsumes curricular issues, poor teaching and perceptions that STEM is difficult, calling for a different mechanism for the presentation and delivery of science and mathematics in primary school. This also indicates to a need for the way in which the students' expectations of secondary school are prepared. There are currently many programmes whereby the students are taken to possible secondary schools for an induction day. Many science departments offer the young people a 'whizz bang' display of fun activities, thus setting their expectations for a highly experimentally based science programme.

Schools need to make the primary-secondary school transitional-students appreciate that science, like any other subject, is not all 'fun and games'. Neither are STEM subjects realistically any more difficult than objects subjects, if one perseveres. The transitional students should also be prepared for the subject-specific teaching at secondary school, and how this affects teacher-pupil relationships.

Young STEM ambassadors could be utilised to ease the students through this currently disappointing 'rite of passage'. Secondary school science teaching styles should aim to become less 'knowledge transmissive' and involve the students more frequently. The 2008 Key Stage 3 Science curriculum is designed to adopt this strategy.

Gender

While gender is still frequently highlighted as a cause for the discrepancies in post-16 uptake of physical STEM subjects it is not one of the top three barriers to post-16 uptake. In England and Wales girls currently outperform boys in GCSE sciences and more girls enter the sciences, but mainly entering the medical and biological fields. What is not accounted for is that males and females have different interests and focus on different things[95], and these are not addressed through the current curricula. There are still disparity issues surrounding ethnic representation in STEM in the UK[96].

There exists a plethora of gender specific engagements projects, though they appear to cater more for those who are already interested in STEM.

An overarching issue fundamental to these 'switch-off' factors is the manner in which young people are advised about careers.

Perceptions about careers and future opportunities

A crucial factor driving this concern for the declining uptake of STEM subjects and careers post-16 is the political capital and its ultimate success outlined in Science and innovation investment framework 2004-2014[97]. In spite of this agenda government response to some projects has appeared to be slow or non-existent[98]. Is the current emphasis on making science more student friendly and raising standards, designed to enable young people to leave compulsory education as scientifically literate citizens or to produce a workforce to sustain the political agenda?

It seems that 'the problem' is not a general decline in interest in and respect for S&T as such, but rather a decline in the willingness to opt for S&T related studies and careers. Our contention is that the reluctance of young people in many of the more economically developed countries to enter S&T fields has more to do with the perceived values and images of S&T than with a lack of respect for S&T or lack of knowledge.
Schreiner 2007

Surveys revealed that some older pupils think it likely that they will do at least one STEM subject at A level, yet few see themselves going into a STEM-related career[99]. For some pupils the future and careers is a hazy non-reality, often coinciding with the point when the imagery and attitudes towards STEM are low or still deteriorating. They do not "see scientists as people they could grow up to be"[100,101]. Some teachers reported that pupils do not perceive science subjects to be a passport to lucrative, interesting and glamorous jobs. Neither are they aware that science subjects teach them life-long transferable skills that are as relevant in finance as in more obviously scientific jobs[102]. They just find other subjects and careers more exciting and accessible than STEM.

Students' perceptions of, and associations with, jobs in science are narrow and limited at best and misleading or incorrect[103,104]. They do not see ICT as being naturally linked to science. The imagery of ICT is very different from that of science, i.e. fast changing, contemporary, young and 'sexy'. Science could well borrow some of this imagery in order to re-brand itself. There is also a view that the current fashion is for arts-oriented subjects, with many parents feeling that specialising in STEM subjects would restrict the scope for other career choices at a later stage[105]. Thus a career in science has little appeal for either boys or girls, while a 'job in technology' has some appeal for boys.

How aware is the public about STEM (see, for example, Tulasiewicz, p33-35)[106]? It was reported that some young people and their parents were unaware of the shortage of trained personnel that the STEM industry is currently experiencing. What views about STEM emanate from the general populace? For example, the 2005 Eurobarometer survey[107] (age 15+) reveals that most Europeans are optimistic about scientific and technological progress. A small majority believes that the benefits of science are greater than any harmful effects it may have. Surveys with students reveal similar trends but their view about school science might be summed up as 'important but not for me'[108]. The general trend in Scottish society is that physics as a useful, important, relevant subject which may open many doors to future careers[109]. Nevertheless, many youth see STEM as having a poor image and little value in terms of a safe job with stable income and stimulating career about which they can be passionate[110].

Schreiner suggests that maybe young people, especially girls, although they appreciate the technology, would rather like to have an identity that conveys late-modern values. Such values might be self-realisation, creativity and innovation, working with people and helping others. If young people are not concerned about further national economic growth, but desire an identity that is coherent with the late-modern post-material values, then school science could demonstrate to students that the S&T subjects play a crucial role in accomplishing exactly these values[111].

It is possible that some of student reluctance to pursue careers in science and technology may lie as much outside the school system in the wider society. Thus it is also perhaps time to revisit some of the outcomes traditionally associated with school science education and forge links between ‘school science’ and future job or career routes, making ‘school science’ more closely related to ‘real life’ in current time[112]. The need for current role models who are young, normal, fun and are scientifically literate becomes a necessity[113].

If these are some of the issues at hand, how do young people discover what is involved in pursuing a post-16 education in STEM-related subjects; what is their knowledge-base and who or what influences their decision-making?

56% of Year 9 students believed the way in which jobs and careers are portrayed in the media had influenced them in their subject options choice; 72% found the subject teachers’ information very useful; 45% sought advice from the school careers teacher; 50% used relevant websites; 38% referred to books; 34% watched TV; 27% referred to magazines/newspapers. Thus it would appear to indicate that the more able students turn to their subject teachers, who have specialist knowledge, for advice. Adapted from NFER 2007

The Influencers

Teachers are important resources for students making STEM study and career decisions. The teachers’ advice being valued more by girls114, but they are concerned that they unable to keep abreast of changes pertaining to careers information[115,116].

The **media** has been accused of characterising STEM rather negatively, perpetuating stereotypes, highlighting the alleged degree of difficulty associated with the subjects and attaining good grades, and that scientists are intellectually elite[117,118]. Nevertheless a significant number of young people admitted to being influenced by the media. A recent success story is the extremely influential ‘Food Dudes’ television programme. The key to the Food Dudes’ success is reported to be **peer pressure**, and the consequent behavioural changes. Research has shown that food advertisements on commercial TV in Australia do exert an influence on children’s eating habits[119]. (See also Lowe[120], Horne[121] and their colleagues.)

Students report that their peers often stress the ‘uncool’ aspects of STEM thus preserving negative stereotyping that is influenced by group norms[122,123,124].

Parental influence tended to be less negative and stereoscopic than their peers, though students preferred to make up their own minds and reflect on their self-efficacy before making the final decision. Girls tended to refer to other family members ahead of their parents for subject and career advice. The educational background, occupations and aspirations of the parents are important factors, introducing the concepts of cultural and social capital to this process[125,126,127].

In the Europe needs more scientists report[128] recommendation 25 states:

One of the problems with attracting and retaining people in SET is poor or non-existent *careers advice*. This is particularly pertinent for the 11-14 age group as well as for the 16-18 age groups where important choices are being made. Students very often have no insight into what scientists can do to contribute to the future of society. The EU needs to address this via policy and partnership initiatives.

As mentioned above, STEM teachers do not feel confident about acting as career guidance counsellors and many careers advisers have a humanities or social science backgrounds, with only one in ten holding a science degree[129].

Implications [for the Engineering and Technology Board (etb)]: The survey findings indicated that two-thirds of the Year 9 students had some degree of interest in SET careers. This suggests that there is a large group of young people who would welcome more information about the wide range of opportunities in that area, and help them decide which, if any, is the right one for them. NFER 2005

There is thus scope for industry and business partnerships to develop career advice strategies and campaigns that include the use of young practitioners to explain the nature and dynamics of the different fields in STEM and how they contribute to society. Reliance on the written format (brochures and websites) for students and generic careers advisors to provide information reduces motivation.

Conclusion

The major barriers to the uptake of STEM subjects, based on weighted evidence from a literature review of almost 300 reports and refereed journal publications are:

- The need for quality teaching for students to become, and remain, engaged in STEM
- The perceived difficulty of STEM subjects
- The disillusionment of the transition from primary to secondary school
- The negative views about success in, and 'unacceptable' stereotypes about STEM

These barriers are in some ways beyond the remit of this report, yet each of these points extends beyond school science and the classroom. They relate to the poor public image that STEM is uncool, boring and difficult. The barriers can be addressed outside school by changing the impressions held by young people and their influencers, mainly the media, parents and peers, and encourage many more students to opt for post-16 studies and maybe even a career in a STEM-related field. Juxtaposed to these barriers is the overarching need for an altered approach to, and better informed careers guidance service.

The central concern is "How can science be re-branded, re-imaged and re-imagined" to this clearly defined target group?[130] Whatever approach is decided upon in altering the public image of STEM it must be bold, creative and innovative in design. Its implementation and execution must be unique and dynamic if it is to compete with the overt messages in the world-outside-school, in which young people prefer to dwell.

Only by being aware of the values and priorities of the younger generation can we hope to show them that STEM studies may open up stable, meaningful jobs about which they can be passionate. It is evident that the target audience for re-imaging STEM should be pupils in primary school, before that declining motivation and interest in STEM takes hold, i.e. pupils younger than 11 years-old (as well as their parents, the media and other influencers). Any mechanism must also appeal to and be relevant for students up to the age where subject and career decisions are made (at 14, at 16, and again at 18 years-old).

The need for quality teaching for students to become, and remain, engaged in STEM
Inspirational teaching is time and time again identified as key barrier to overcome. Whilst a number of projects are working to attempt to address this, inspiration and innovation could be a key theme of any campaign. Likewise evidence suggests that the curriculum is not always seen as relevant. Whilst again it is beyond the scope of this work to address this directly, working to link everyday items and life with STEM can address a lack of inspiration.

Curriculum linked material that enables stimulating presentation and entices young people to explore STEM beyond school could be created. However ultimately it must be noted that the most necessary and effective means will be to ensure that younger pupils receive the best quality science[131], mathematics and technology teaching.

The perceived difficulty of STEM subjects
STEM subjects are perceived to be more difficult than other subjects in which to achieve good grades; therefore they are widely assumed to be more difficult. This alleged difficulty of the subjects is critically linked to self-efficacy and interest levels in the subjects. Year 9 students (13-14 years-old) view science as being more difficult than English and mathematics; thus it might be prudent to ascertain why this age group finds science more difficult.

Challenging out-of-school hands-on programmes could be developed that offer high-value prizes for the individuals, rather than their educational institutions, could encourage more young people to participate. The programme could be multidisciplinary providing them with an opportunity to engage with different aspects of STEM. At the same time the young people would be accepting a difficult challenge and have a reason to commit to the task. Such a task could benefit the influencers and alter their beliefs about the long-term value of not opting for the easier subjects. An added benefit of such programmes that self-efficacy would be enhanced through genuine participation.

The disillusionment with the transition from primary to secondary school
This 'switch-off' factor subsumes curricular issues, poor teaching and perceptions that STEM is difficult. Addressing this problem calls for a different mechanism for presenting and delivering science and mathematics in primary school. The way in which the students' expectations of secondary school are introduced needs to be revisited. There are currently many programmes whereby the students are taken to potential secondary schools for a day's induction. Many science departments offer the young people a 'whizz-bang' display many fun activities, thus setting their expectations for a highly experimentally based science programme, which the literature reports to be a major letdown[132]. The schools need to make the primary-secondary school transitional-students appreciate that science, like any other subject, is not all 'fun and games'. Attention should be brought to the fact that STEM subjects are realistically not any more difficult than objects subjects, if one perseveres, which can be rewarding.

Young STEM ambassadors could be utilised to ease the transitional students through this potentially disappointing 'rite of passage'.

The negative views about success in, and 'unacceptable' stereotypes about STEM
Associated with 'boring' and 'science' are perceptions that those who enjoy or succeed in STEM subjects are, or might be, geeks or nerds[133,134,135,136], and that the subject matter is not seen to be 'funky'[137]. Fensham[138] strongly suggests that the decline in post-16 uptake of STEM might be part of a 'marginalisation' process; an aspect of adolescent rebellion against school in general and not just STEM and that it could lend 'street cred' to a student's decision not to take STEM subjects, rather than avoiding them on grounds of being too difficult.

Overcoming these deeply ingrained and stereotypical images of STEM and scientists requires a bold, inspirational and positive visible public campaign (see the mini case studies in Appendix 1) though transformation will nevertheless take many years. The re-imaging campaign will need to be a totally new and different conceptual strategy, and thus cutting edge (see suggested approaches in Appendices 1 and 2).

The role that careers advice plays in the uptake of STEM post-16 is both critical and complex and requires a critical overview, as subscribed to in the Europe needs scientists report[139]. The concept that STEM careers can be creative, exciting, stimulating and stable needs to be posited firmly within the public domain. Some suggested re-branding, re-imaging and re-imagining approaches are documented in Appendices 1 and 2.

Appropriate and stimulating material could be produced that can draw attention to STEM, including engineering, and its real life applications in a way that complements the curriculum. The use of carefully selected young or renowned role models could alter the current public image and make this a worthwhile career path to contemplate, while simultaneously challenging the entrenched stereotypes.

In conclusion, the use of dynamic, futuristic-orientated outside-school-science approaches that bring attention to and highlight the positive values, aspirations and opportunities available in the world of science, technology, engineering and mathematics is recommended if the current trend in the uptake of post-16 STEM is to be reversed.

Endnotes

A Programme for International Student Assessment of the OECD in 56 countries, cycle 3 in 2006 which placed its main emphasis on scientific literacy

B Trends in International Mathematics and Science Study involving 8 and 13 year-olds

1 http://www.ils.uio.no/english/rose/about/rose-brief.html

2 Jenkins, E.W. and Pell, R.G. (2006)

3 Jenkins, E.W. (2006)

4 OECD (2006)

5 Thomson, S. and Fleming, N. (2004)

6 Papanastasiou, E.C. and Zembylas, M. (2004)

7 Kato, A. and Yoshida, A. (2003)

8 Gouthier, D. (2005) p3

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Appendix 1: Examples of successful international pro-STEM initiatives

1.1 Food Dudes

A successful campaign that has had international success in "weaning children onto [eating] foods they almost universally dislike on first taste"140 they refer, of course, to vegetables and fruit. The programme was designed by psychologists at the University of Bangor, Wales, as an initiative to encourage and maintain healthy eating habits in children. The Food Dudes model utilises a communication medium (a website http://www.fooddudes.co.uk) proven to attract an audience (because it has been professionally compiled with clear and specific intentions) and aims to effect behavioural changes on the thinking of viewers/consumers.

Such an approach could be emulated elucidating what STEM is , what it can do for everyone, the risks that are associated with the pursuit of STEM, the range of STEM related careers as being fun, sexy and offering job security; the need to be passionate about science; how to be cool and funky and be in to STEM. Osborne and colleagues suggest that an approach be adopted in a pro-STEM campaign that highlights what kinds of careers will be by-passed if students decide too young to exclude STEM from one's life path.

1.2 Sleek Geeks in the media

The current public image of STEM is not fun, cool or funky: address this issue and here by re-image and re-brand science in the public's domain, including the young public; through this a re-imagining process can begin. Use role models that are young (really young), contemporary, sexy and if possible, well known. The Australian pro-STEM campaign model includes Dr Karl Kruszelnicki (2002 Ig Nobel winner for the Belly Button Lint Survey; a radio, TV and web141 presenter) and The Sleek Geek Eureka Schools competition. Dr Karl is funky and an all-round science guru, as well as being a very cool nerd, well received by young people and adults alike.

1.3 Young Scientists of Australia

Australia also has an excellent and engaging organisation, Young Scientists of Australia (YSA: www.ysa.org.au), for those with an interest in STEM, for the 14-24 age group. The author observed the way the Sydney Chapter operates actively as a social, friendship group with a shared passion for things 'sciency' and it's very cool to be a member. This is a model worth emulating in the UK and Europe that would be cost-effective, driven by the energy and inspiration of the youth who would themselves be trying to engage potential new 14 year-old members; and they would set the agenda as chief stakeholders.

1.4 The Smallpeice Trust

A successful and engaging initial programme could be followed up by hands-on activities using the long summer holidays as suggested in the House of Commons 2002 report, similar to some programmes in the United States. The Smallpeice Trust (http://www.smallpeicetrust.org.uk) operates summer holiday residential programmes that students do not consider as being an extension of school, but an interesting opportunity to learn about and engage with aspects of engineering and STEM.

1.5 Careers & Training Expo

South Africa operates a successful careers programme (Careers & Training Expo) at venues around the country, involving young professionals who introduce the students to some careers. Delegates at the Expo each receive a work book (which is essentially an aptitude guide/test) prior to attending "The Working World Extravaganza". The programme is financed by banks, industry and other corporate sponsors, plus government departments, presenting a wide range of careers, not just STEM. (The 'workbook' could be substituted by an 'electronic book' for any similar campaign programme.)

Appendix 2: Suggested re-branding approaches

Any out-of-school strategy to re-brand, re-image and re-imagine STEM to engage young people should aim to meet the target audience on their own ground. The strategy should be 'delivered' within their own normal comfort zone and utilise their favourite media: television, the internet, console games, MP3 or 4 players and mobile phones. The technology is easily accessible and operable for most pupils in the UK . Any 'message' about the positive image of STEM must be overt, but fun and attractive out side of school science, i.e. not sad-geeky, nerdish, boring, unsexy or too academic (or a perpetuation of the mad scientist image).

In any planned undertaking, engage members from the target audience (9-12 year-olds) inconsultation to develop the idea. Use of 13-15 year-olds to assist with the development of the material that would engage the younger audience, is well worth considering. It is important that any consultation is not a series of hoop-jumping questionnaires and focus group interviews to underpin what the adults have already developed, as happened with the Science Year pre-delivery research. Young people can create and develop viable products if invited to: the recent London 2012 logo debacle is testament to this under-utilised resource. Science Year appears not to have been successful in reaching, and drawing in, those who were not interested in science[142,143,144] the prime target audience for any new campaign.

Any campaign action and its product must be widely and boldly advertised; use road side billboards, internet ISP welcome pages, children's TV programmes with a news interview. Forget about using newspaper advertisements and sending and fliers to schools as they are expensive and the paper is only infrequently recycled. The campaign will need to apply some of the market strategies regarding the success of advertising, with the re-investment being in people. It will be valuable to recall that this investment is about recruiting minds of people and keeping them interested. Long-term follow-up will be essential with material that's new and constantly evolving and listening closely to the younger student voice.

Engineering is very much under-represented in the current school education system, so the introduction of the Engineering Diploma 14-19 is a means to address this problem. But, the young people at 14, opting to opt for, or reject, this diploma will still have little knowledge about engineering. Some of the suggestions about raising the profile of engineering suggested by NFER[145] are already in operation, but are mainly school-linked. A need for quality career guidance is even more critical now, and it too should adopt a new image and approach.

[140] Coghlan, A. (2007)

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