Attitudes Towards Science: An Update

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Abstract
This paper provides an update on recent research about attitudes of school students towards science. It builds on, and adds to, the review conducted by the author and colleagues and published in 2003 (Osborne, Simon, & Collins, 2003). The significance of this topic to the field is shown by the fact that this paper has been one of the ten most downloaded article on the IJSE website in 2007 (Lee, Wub, & Tsaic, 2009 (in press)). Since the publication of this article a number of important pieces of research have been published which are presented and discussed here. These findings provide new insights into the nature of the problem in contemporary contexts and possible methods of addressing an issue that is of concern to all developed countries.
Introduction

The issue of attitudes to science remains one of enduring focus. In a recent analysis of the trends in research in science education using a citation analysis, Lee et al. (2009 (in press)) argue that research on the conative dimension of learning has been one of the principal foci of the published body of work in the leading journals in the field. Indeed, they show that a paper reviewing what is known about attitudes towards science, published by two of the authors of this paper, is one of the ten most highly-cited papers between 2003-7. The interest in this domain of work is perhaps unsurprising. The past decade has seen the publication of a number of reports in the developed world raising anxiety about the future supply of scientists and technologists. These began with the Robert’s Report on ‘the supply of people with science, technology, engineering and mathematical skills’ (Roberts, 2002) in the UK, then ‘Europe Needs More Scientists’ (European Commission, 2004), followed by the report ‘Rising above the Gathering Storm’ (National Academy of Sciences: Committee on Science Engineering and Public Policy, 2005) in the USA, all of which have been followed by yet another UK report whose title bluntly proclaims the issue as being one of economic competitiveness – ‘The Race to the Top: A Review of the Government’s Science and Innovation Policies’ (Lord Sainsbury of Turville, 2007). Finally, there has been an Australian Report on ‘Opening up pathways: Engagement in STEM across the Primary-Secondary school transition.’ (Tytler et al., 2008). Whilst the premises of some of these reports are questionable and their production can be seen as an attempt by the scientific community to advantage both their significance and funding by government, they articulate a widely felt concern that there is a problem with student interest in studying science, technology, engineering and mathematics – otherwise known as STEM subjects. Policy makers who have been persuaded by such reports that there is an issue to be addressed have looked to research in science education for evidence to inform the decision making process about what, if anything, should be done.

Since the publication of our original paper – much of it based on work conducted in the 1990s, substantially more work has been undertaken which provides important insights into the domain. Given its importance to policy makers and to researchers, we felt that it would be of some benefit to present the main features of the work in an additional paper. These are:

- A body of work critically examining the range of extant instruments for measuring attitudes towards science. This has examined issues of theoretical grounding, validity and reliability and found them wanting in one or all of these respects. This work has in turn led to the re-evaluation of existing instruments or instruments which has a more rigorous foundation.
- A growing body of research which points to the fact that an interest in science (or not) is largely formed for the majority of young people by age 14.
- A revisiting of the issue of poor uptake of physical sciences by young girls and a deeper understanding of the nature of the issue if not its solution.
- A rising body of work grounded in theoretical construct of ‘identity’ which has been used as an analytic lens to construct explanatory hypotheses for students’ choices.
- A number of surveys of student attitudes towards science which have provided datasets which have served the valuable function of producing generative questions for the field which need further exploration.

In this paper, we will briefly present, under the themes outlined above, what we consider to be the main points of interest for the field. Many of these issues are explored in more substantive detail in two forthcoming publications (Osborne & Tytler, submitted) and (Osborne & Simon, in press). No
significance should be read into the order in which we present these features and their salience. Their relevance to current concerns will be discussed in our conclusions where we turn to exploring an issue which the field is reluctant to examine or discuss – do we actually need more scientists?

The Measurement of Attitudes
The theoretical concept of an ‘attitude towards science’ has lead to many attempts at its measurement and there have been many attempts to define both the construct and the means of its measurement. What is meant by the construct has been the subject of some discussion – notably the distinction between attitudes towards science and scientific attitudes (Gardner, 1975). More careful elaboration is still needed. For instance, their measurement rests on the questionable assumption that there is a homogeneous entity called science when the reality is that there is a diversity of sciences. Without such sound theoretical foundations, instruments lack construct validity (Messick, 1989). One means of attempting to establish construct validity is to use a panel of experts and ask them individually what aspects they think the items are attempting to test. However, this has been criticized by Munby (1982) as it rests on an assumption that the meanings attributed to the items by the experts will be the same as that attributed by the participants. The latter is essentially what is termed face validity – that is whether the construct which is operationalized in the items written to assess it has the same meaning for the participants as it does for the researchers. The only means of testing this is to conduct interview studies with a selection of participants to explore what they understood the item to be asking and what were the reasons for choosing the response they did - something which has rarely been conducted in designing and validating any instrument.

Evidence that the field has had problems in developing instruments which meet the criteria of both validity and reliability comes from a recent comprehensive review conducted of 66 instruments for measuring attitudes by Blalock et al. (2008). 20 of these measured attitudes towards science and were assessed against the criteria of: the extent to which they were theoretically grounded; what tests had been undertaken of their reliability; the measures that had been used to establish their validity; how the dimensionality of the instrument had been used in reporting the scores; and the extent to which the instrument had been tested and developed prior to its use. Using these criteria, the authors reported that the highest scoring instrument was that developed by German (1988) where ‘reliability estimates were in the 0.90s, and various methods of validity evidence were given including content, discriminant, convergent, contrasting groups, and exploratory factor analysis’ (Blalock et al., 2008:970). The factor analysis used supported a one-dimensional structure, and total scoring was used appropriately. Yet this instrument has only been used in a single study. In contrast, instruments which score poorly on their criteria e.g Moore and Sutman’s Scientific Attitude inventory (Moore & Sutman, 1970) has been used in 13 additional studies. What Blalock et al. point to is the tendency for researchers not to use existing instruments, but rather, to reinvent the wheel each time by designing one anew, and then, not subjecting it to the kind of development required of a good psychometric measure. Hence, their work offers an important critique of work in this field which has not met the normative standards one might expect of psychometric research.

Fortunately, some recognition of these criticisms can be found in more recent work. For instance, the instrument developed by Kind et al. (2007) does define the constructs that it is attempting to measure and establishes its reliability and validity through the use of a factor analysis which demonstrates that the factors correspond to the theoretical constructs it seeks to measure and that they are internally
consistent. Likewise, Owen et al. (2008) have re-evaluated one commonly-used instrument – the Simpson-Troost Attitude Questionnaire (Simpson & Troost, 1982) which consisted of 59 items. Using a sample of 1812 participants split into two groups – half of which were used for exploratory factor analysis and half for confirmatory factor analysis – they were able to reduce the instrument to a five factor model using only 22 items which they identified as measures of the extent to which the science class was motivating; the level of effort the student applied to their own learning; the influence of family models; the extent to which it was enjoyable; and a measure of the influence of their peers on their liking for science. In doing so, they have addressed many of the criticisms that might be made of earlier work and have refined an existing instrument. In coming to a view, either about existing instruments or developing their own, researchers therefore do need to ask:

- Whether clear descriptions have been articulated for the constructs that one wishes to measure.
- Whether separate constructs have been combined to form one scale and whether there is evidence that these constructs are closely related which would justify such an action.
- Whether the reliability of the measure has been demonstrated by confirming the internal consistency of the construct (e.g., by use of Cronbach’s α) and by confirming the unidimensionality (e.g., by using factor analysis).
- Whether validity has been demonstrated by the use of more than one method, which include the use of psychometric techniques.

Failure to do any one of these would mean that the work would not be meeting the standards now established in the field and weaken the significance and value of the findings. In short, the field has moved on and work which fails to meet these standards is of questionable value.

**Engaging Young People with Science**

Student interest in science at age 10 has shown to be high and with little gender difference in either interest (Murphy & Beggs, 2005; Pell & Jarvis, 2001) or aptitude (Haworth, Dale, & Plomin, 2008). The latter is particularly noteworthy as it is based on an extensive set of data collected from the Twins Early Development study which has studied the development of 2674 twins over the past ten years. However, emerging from a growing body of research in the past decade is the finding that, by the age of 14, for the majority of students, interest or not in pursuing further study of science has largely been formed. Moreover, in the case of girls, their attitude is significantly more negative, particularly towards the physical sciences (Scantlebury & Baker, 2007; Schreiner, 2006a; Schreiner & Sjøberg, 2004).

Of particular note is a recent analysis of data collected for the US National Educational Longitudinal Study conducted by Tai et al. (2006). These researchers showed that by age 14 students with expectations of science-related careers were 3.4 times more likely to earn a physical science and engineering degree than students without similar expectations. This effect was even more pronounced for those who demonstrated high ability in mathematics – 51% being likely to undertake a STEM related degree. Indeed Tai et al’s analysis shows that the average mathematics achiever at age 14 with a science-related career aspiration has a greater chance of achieving a physical science/engineering degree than a high mathematics achiever with a non-science career aspiration (34% compared to 19%).
Further evidence that children’s life-world experiences prior to 14 are the major determinant of any decision to pursue the study of science comes from a survey by the Royal Society (2006) of 1141 SET practitioners’ reasons for pursuing scientific careers. It found that just over a quarter of respondents (28%) first started thinking about a career in STEM before the age of 11 and a further third (35%) between the ages of 12-14. Similar evidence came from a study by Maltese and Tai (2008) based on analysis of interviews with 116 scientists and graduate students. This study found that 65% claimed interest in pursuing science prior to middle school and a further 30% during middle and high school. An interesting gender difference arose in this study with females more likely to ascribe school or family-related interest compared to males who tended to claim intrinsic or self-related interest in science.

Likewise a small-scale longitudinal study conducted following 70 Swedish students from Grade 5 (age 12) to grade 9 (age 16) (Lindahl, 2007) found that their career aspirations and interest in science was largely formed by age 13. Lindahl concluded that engaging older children in science would become progressively harder. Similar data can also be found in the work of Bandura et al. on children’s aspirations and career choices (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001).

Taken together what emerges is a very clear picture that the critical phase for engendering an interest in young people in science is the age of 10 to 14. Hence, these data demonstrate the importance of the formation of career aspirations of young adolescents, long before the point at which many make the choice about which subjects to specialize in. These findings would suggest that efforts to engage school students with science would be productively informed by: (a) understanding what are the formative influences on student career aspirations between the ages of 10 and 14; and (b) understanding better how to foster and maximize the interest of this cohort of adolescents, particularly girls, in Science, Technology, Engineering and Mathematics (STEM) related careers. Given the considerable sums of money invested in outreach activities, curriculum development and supporting the teaching of science in schools, the evidence discussed above has important implications for policy makers. It also points to the need to ensure that the teaching of science in middle schools is of the highest quality and that considerable effort is needed to inform students of the potential career pathways afforded by the study of science.

Gender

Gardner comments that ‘sex is probably the most significant variable related towards pupils’ attitude to science’. This view is supported by Schibeci’s (1984) extensive review of the literature, and more recent meta-analyses of a range of research studies (Becker, 1989; Brotman & Moore, 2008; Murphy & Whitelegg, 2006; Weinburght, 1995) covering the literature between 1970 and 2005. All four studies summarize numerous research studies to show that boys have a consistently more positive attitude to school science than girls – a finding confirmed by the data emerging from the ROSE study (Sjøberg & Schreiner, 2005) and other recent work (Haste, 2004; Jones, Howe, & Rua, 2000). Despite a large number of interventions undertaken in the 1980s and 1990s to engage more young women with the study of science, Jones et al (2000) were forced to conclude ‘that the future pipeline of scientists and engineers is likely to remain unchanged’. However, it would be better to say that the real difference is in attitudes to the physical sciences and engineering (OECD, 2006). Indeed, one of the weaknesses in the extant data is the tendency to measure attitudes towards science as a homogeneous construct rather than measuring attitudes to the separate sciences (Murphy & Whitelegg, 2006). Engaging young girls and young women with the study of science remains a chronic problem and a matter of concern.
It is chronic as, despite 25 years of efforts, little if any change has been achieved. It is a matter of concern because young women who choose to study science and mathematics in high school have an ‘increased likelihood of attending a university and a much broader range of programme options at the post-secondary level’ (Adamuti-Trache & Andres, 2008; Csikszentmihalyi & Schneider, 2000).

A useful review of nine explanatory hypotheses for women’s lack of engagement with science is offered by Blickenstaff (2005) who argues strongly against those that would suggest that there are innate genetic differences. In his review, he offers 8 other possible explanatory hypotheses which are:

1. Girls’ lack of academic preparation for a science major/career.
2. Girls’ poor attitude toward science and lack of positive experiences with science in childhood.
3. The absence of female scientists/engineers as role models.
4. Science curricula are irrelevant to many girls.
5. The pedagogy of science classes favors male students.
6. A ‘chilly climate’ exists for girls/women in science classes.
7. Cultural pressure on girls/women to conform to traditional gender roles
8. An inherent masculine worldview in scientific epistemology.

Examining each of these, he suggests that the problem is complex and not amenable to simplistic solutions. Nevertheless, some useful insights come from work that focuses on the context in which science is presented. For instance, the ROSE questionnaire presents 108 topics that students might like to learn and asks respondents to rate them on a 1 (‘not at all’) to 4 (‘very interested’) scale. Between English boys and girls there were 80 statistically significant differences. The top five items for boys and girls are shown in Table 1.

Such a stark contrast would suggest that the content of interest to girls is significantly under-represented in the curriculum (Haussler & Hoffmann, 2002) These data are also supported by other research which would suggest that girls would be interested in a physics curriculum for instance which had more human related content (Krogh & Thomsen, 2005). Indeed, further evidence to support this hypothesis can be found in a recent survey of student attitudes based on a sample of 327 fourteen/fifteen year-old boys and 256 girls which looked at how their perception of science was related to their personal, social and ethical values (Haste, Muldoon, Hogan, & Brosnan, 2008). Dividing the sample into those orientated towards science by positive responses to questions about employment in science and an expressed interest in technology, a factor analysis of the data was conducted. Haste et al. found four features which discriminated the sample. These she called ‘trust in the benefits of science’, ‘science in my life’, ‘ethical skepticism’ and ‘facts and high-tech fixes’. For girls, regardless of their inclination towards science, the consideration of ethical factors was a large positive explanatory factor of their interest in science whilst, in contrast, it was a negative factor for boys. Likewise, the perception of how science was relevant to their lives was a large contributing factor for girls positively inclined towards science but not for any other groups. In short, both the context, purpose and implications matter for girls and any attempt to present a decontextualised, value-free notion of science will reduce their engagement. Such data also strongly suggest that offering a homogeneous curriculum to all is a mistake – what interests girls being unlikely to interest boys and vice versa.
Table 1: The 5 top ranked items boys, and girls, would like to learn about in science. (Jenkins & Nelson, 2005)

<table>
<thead>
<tr>
<th>Boys</th>
<th>Girls</th>
</tr>
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<tbody>
<tr>
<td>Explosive Chemicals</td>
<td>Why we dream when we are sleeping and what the dreams might mean</td>
</tr>
<tr>
<td>How it feels to be weightless in space</td>
<td>Cancer – what we know and how we can treat it</td>
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<tr>
<td>How the atom bomb functions;</td>
<td>How to perform first aid and use basic medical equipment;</td>
</tr>
<tr>
<td>Biological and chemical weapons and what they do to the human body;</td>
<td>How to exercise the body to keep fit and strong;</td>
</tr>
<tr>
<td>Black holes, supernovae and other spectacular objects in outer space.</td>
<td>Sexually transmitted diseases and how to be protected against them</td>
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Further interesting work in explaining not only girls’ but also minority students’ response to science comes from work conducted in social psychology on how negative stereotypes can undermine student confidence (Aronson, Quinn, & Spencer, 1998). Starting from the premise that persistence in any endeavor is sustained by a faith that one will be viewed as an individual and be included in important relationships, Cohen and Steele have examined how such stereotypes erode this trust and reduce the likelihood of academic success (Cohen & Steele, 2002). Using two treatment groups – one of whom received critical feedback on a specific piece of work that simply documented its failings and how its remediation might be achieved versus a group who received such feedback but set in a context of explicating why the work failed to meet the high standards expected and a personal assurance of their capability. The subjects were then permitted to revise their work and resubmit it for further assessment. When they did, the performance of the latter group improved so dramatically that the average quality of their work proved superior to both the male subjects and the other females in the other experimental condition. The implication of this is profound. Student attitudes and performance can be manipulated by simple strategies that seek to address threats that are commonly perceived by groups who a minority in any classroom.

Identity
To understand student responses to science, there has been recent and increasing interest in exploring the construct of identity. This has been fruitful in exploring both the complexity of student responses to the science curriculum, and for making sense of the response of coherent groups such as indigenous or gender groupings. For instance, Aikenhead (2005) has argued that for many students, especially indigenous students, coming to appreciate science requires an identity shift whereby students come to consider themselves as science-friendly – that is ‘to learn science meaningfully is identity work’ (p. 117). Similarly, he argues (p. 64) that the persistence of status quo versions of school science in the face of the many existing critiques, e.g. Osborne and Dillon (2008), can only be explained by the strong discursive traditions held by teachers of science which are a product of their enculturation in their own schooling.
and undergraduate studies. Brown (2004) has examined the role of discourse in framing identity from a non-essentialist perspective for minority students identifying four distinct responses to the authoritarian socio-intellectual edifice that confronts most students in the science classroom – each of which demonstrates an attempt by students to negotiate and resolve what appears to be a clash of discourses. These range from developing an oppositional discourse which avoided the use of any scientific language, a maintenance discourse where, although there is some use of science specific discourse, they switch readily into non-science specific genres, to those who sought proficiency by engaging in extensive use of scientific language. What this suggest is that acquiring the language of science is a form of identity work and that students need a meta-linguistic rationale, however simple, for why the language of science is so foreign.

Indeed, there is widespread concern in many countries about gaps in performance in science and other subjects between majority/minority or indigenous/non-indigenous students (e.g. Thomson & De Bortoli (2008)). Aikenhead and Ogawa (2007) argue that school science tends to portray scientific ways of knowing as free from value and without context. This way of presenting school science, without multiple or contested views, tends to marginalize some students on the basis of their “cultural self-identities” (Aikenhead & Ogawa, 2007, p. 540). As Aikenhead argues (Aikenhead, 2001, p. 338) it is only a small minority of students whose “worldviews resonate with the scientific worldview conveyed most frequently in school science. All other students experience the single-mindedness of school science as alienating, and this hinders their effective participation in school science”. A further problem is the need to represent a broader range of future identities consonant with scientific work. McKinley (2005) identifies the difficulty experienced by Maori women scientists in managing inconsistent images of themselves — as women, as Maori, as scientists — and argues that competing legacies of science, knowledge, and culture have built strong cultural stereotypes of Maori women, who in interviews describe themselves as being discriminated against, prejudged and overlooked in their scientific roles.

In a similar vein, Johnson (2007) in the U.S. has described barriers to science-interested minority females’ continuing participation in STEM such as lack of sensitivity to their difference, discouragement, and a sense of alienation from school science. Johnson described how even a laudable activity like asking questions of students in lectures can advantage white male students who are more competitive and confident, and cause women to feel a loss of status, robbing them of the only opportunity to get to know their teachers on a personal level. In describing the experience of these women moving through undergraduate science, Johnson concludes:

> The first step in making science more encouraging ... is for scientists to recognize that science has a culture, and that certain types of students may find it challenging to understand and navigate this culture ... if scientists cannot let go of narrow, decontextualized presentations of science, they will have difficulty winning the respect of women who see their interest in science as inextricably united to their altruism. ... Science has a rich history of service to humanity. When scientists present their lectures with no allusion to this context, it may not be because they are uninterested in it but only because such ties are so obvious to them already (p. 819).

The evidence presented here demonstrates that contemporary youth is not a homogeneous population. Moreover, young people in today’s society see themselves as free to choose their form of address, religion, social grouping, politics, education, profession, sexuality, lifestyle and values (Beck & Beck-Gernsheim, 2002). This is a considerable transformation from 40 years ago when choice was much more
limited and expressed predominantly in terms of a young person’s choice of profession. Adolescence is a particularly significant time when young people are first confronted by the need to construct their sense of self. As has been well documented, this situation creates a state of insecurity or moratorium (Head, 1985). In some senses, this angst is not new, but the range of choices presented to contemporary youth is now much greater. Gee (2002), for instance, has argued for a fluid definition of identity as ‘the kind of person one is recognized as being at a given time and place’ (p99). The decision-making landscape that young people negotiate as they select their school subjects, decide who they want to be, and aspire to fulfilling futures is complex terrain making it difficult to define who they are and where subject choice becomes one important marker for defining who they are to others. Furthermore, analysis is complicated by the fact that the barriers that hinder young people’s decision-making are not always immediately apparent and will change over time, and change in degree, as students grow and develop (Alloway, Dalley, Patterson, Walker, & Lenoy, 2004; Engineering and Technology Board, 2005; Fouad, Hackett, Haag, Kantamneni, & Fitzpatrick, 2007; McMahon & Patton, 1997; Walker, 2007; Walker, 2006; Walker, Alloway, Dalley-Trim, & Patterson, 2006).

There is, however, a significant body of research on the impact of identity on the education-related choices of young people (Archer, Hollingworth, & Halsall, 2007; Archer, Pratt, & Phillips, 2001; Archer & Yamashita, 2003; Boaler, 1997; Connell, 1989; Francis, 2000). This shows that many of students’ choices—whether or not to continue, which subjects to continue with, who I will aspire to become—impact upon each student’s success or failure in fulfilling his or her aspirations. However, it should be noted that ‘choice’ is a highly constrained concept in the context of education, and experienced as limited or expansive depending upon a number of factors, including prior academic performance, school location, and prior choices of an equally constrained nature. For instance, Fouad, Byars-Winston and Angela (2005) found, in the U.S. context, that while race does not have an impact on students’ career aspirations, it impacts on the barriers that students encounter as they attempt to fulfil those aspirations.

The attraction of identity as a theoretical construct for interpretive and explanatory perspectives is that it goes beyond concerns such as curricula, intrinsic interest or career intentions, to frame aspirations and perceptions in terms of social relationships and self-processes instead (Lee, 2002). Identity theory understands that the self (or selves) is bounded by social structures, and that interactions shape the organization and content of self. Analysing decisions to participate in and choose STEM courses and careers through an identity framework, involves emphasising relationships with family, teachers, peers, and others, and identifying the degree of synergy, or disjuncture, experienced by young people between their everyday lives and the educational pursuit of STEM (See Archer, Hollingworth, & Halsall, 2007).

Two recent studies which have used the notion of ‘identity types’ have contributed to our understanding of how youth respond to science, school science and environmental issues. Haste (2004) conducted a survey of the values and beliefs that 704 eleven to twenty-one year old UK individuals held about science and technology. Her analysis identified four distinct groups of students: the ‘green’ who held ethical concerns about the environment and sceptical about interfering with nature, and were predominantly girls under 16; the ‘techno-investor’ who were enthusiastic about technology and the beneficial effects of science, trusted scientists and the government, and were mostly male; the ‘science oriented’ who were interested in science and had faith in the general application of scientific ways of thinking, and were mostly male; and the ‘alienated from science’ who were bored with science and skeptical of its potential, and who were predominantly female. Haste found that girls were not less
interested in science or science careers than boys, but focused on different things. They related more strongly to ‘green’ values associated with science (socially responsible and people-oriented aspects of science) than to the ‘space and hardware’ aspects which often dominate communication about science. She argues that the science curriculum needs to represent both these dimensions of science, and to acknowledge the value aspects and ethical concerns surrounding science and its applications.

Schreiner’s (2006b) study, conducted in Norway, administered a questionnaire which had been extensively validated to a sample of 1204 students drawn from 53 randomly selected schools consisting of equal numbers of boys and girls. From a cluster analysis of her sample, she identified 5 distinct student types each of whom had a different response to science. As with the Haste study, the categories were highly gender specific, similar to Haste’s, and showed different patterns of response to a range of items relating to the perceived value of school science and science, and their future aspirations.

Drawing on these data, Schreiner interprets the low recruitment into STEM subjects in wealthy, modern societies in terms of changing values of youth in late modern societies – an analysis which has a significant identity component.

To make sense of the data, Schreiner and Sjoberg (2007, p. 242) draw on three perspectives:

1. Issues that are perceived as meaningful for young people in a country are dependent on the culture and the material conditions in the country
2. An educational choice is an identity choice (see also Aikenhead, Calabrese, & Chinn, 2006)
3. Young people wish to be passionate about what they are doing and they wish to develop themselves and their abilities. They experience a range of possible and accessible options regarding their futures, and among the many alternatives, they choose the most interesting.

A major national project of early and modernist industrial societies has been a commitment to progress and growth. In this project scientists and engineers have been seen as crucial to people’s lives and well-being. Likewise, in less-developed countries, young people have a rather heroic image of scientists. In late modern societies, however, these values have changed. Many of these have a diminishing industrial base where material needs are satiated compared to previous generations. In this context the role and value of the scientist and technologist is diminished – especially when compared with the sports and media personalities that dominate the news media.

Schreiner and Sjoberg speculate that the main reason that young people, especially girls, are reluctant to participate in the physical sciences is because they often perceive the identities of engineers and physicists as incongruent with their own. There is an abundant literature (Boaler, 1997; Lightbody & Durndell, 1996; Mendick, 2006; Walkerdine, 1990) which argues that STEM subjects and careers have a masculine image that leads girls to reject identities connected with STEM. Schreiner and Sjoberg (2007) argue that, if this perspective is correct – and that the identities of youth in late modern societies are connected with late modern values such as self realization, creativity and innovation, working with people, helping others, and making money – then attracting more students into STEM pathways will require transforming the images of STEM work to address the ideals of contemporary youth, and updating the content and practice of school STEM subjects to make these values more apparent.
This research into the interactions of identity with the nature of science and school science is important in illuminating the complexity of the issue of response to school science and, that if we are to engage students with science in school, more thought needs to be given both to the complex and varied histories of students that attend our classes, and to the nature of the science curriculum. We cannot hope for a simple match, and the strong message is that if we are to enlist young people into science subjects or even science-friendly positions, then it will be necessary to present a richer version of the science and its value in school.

New Data Sets
One of the consequences of the importance assigned to the issue of ‘attitudes towards science’ by policy makers and politicians is that a large body of national and international work has been funded which has collected relevant or salient data. Good data sets commonly serve two functions – either they offer explanatory accounts of social phenomenon or, as is the case with much of the data on attitudes, they raise significant questions which generate testable hypotheses. Some of the data gathered from the ROSE study (Schreiner & Sjøberg, 2004) has already been referred to in this paper. One of particular interest is the plot of the regression line between the values of the UN Human Development Index, which is measured using a combination of indicators such as literacy rates, mortality rates, GDP per capita etc, and the national average score across all the interest items in the ROSE questionnaire for all countries which is shown in Fig 1 beneath.

Figure 1. Scatter-plot with regression line: HDI values (horizontal axis) and the national average score across all 108 items for what students might want to learn about (vertical axis) for all countries.

This scatterplot shows a very well-defined negative correlation of -0.85 between the two indices and a clear demarcation between developed economies and the developing world raising the question of what is it that might explain why youth in the Western world is less interested in the study of science? The phenomenon is even more surprising given that schools in the Western world have better facilities and better-trained teachers yet are clearly less successful at engaging students. Clearly the answer is deeply cultural. However, does any explanatory hypothesis lie in the values of the contemporary culture
in which western youth is situated where future employment (at least until now) has not been a major threat and where some of the issues of identity discussed previously are more to the fore? Indeed, some would argue that the nature of contemporary culture with immediate access to information has made students better at multi-tasking but less capable of extended abstract thought and application – the kind of thinking commonly required by the study of the sciences (Greenfield, 2009; Sefton-Green, 2007; Tapscott, 2009). Hence, their unwillingness to pursue a subject which might be perceived as challenging. Alternatively the explanation might simply lie in the multiple pathways afforded by the study of subjects other than science in the developing world.

Further data confirming this trend identified by Sjoberg and Schreiner comes from an analysis of the 1999 TIMSS study by Ogura (2006). As well as its focus on declarative knowledge, TIMSS also had a set of measures for students’ attitudes towards science.

Fig 2: Plot of data from the 1999 TIMSS study by country of students’ average science scores versus the percentage of students with a high score for their positive attitudes towards science.

The picture emerging from the recent TIMSS study is more complex and the relationship between attitude and attainment less clearly defined but it is notable that, with the exception of Kazakhstan, no countries where students achieve a high TIMSS score have a high positive attitude to science.
What these data point to is that students who achieve highly on such tests are less likely to have a positive attitude to science. Whether it is a product of the pedagogy specific to those countries or whether it is a product of the value placed on science by the youth in some countries is unclear. What is clear is that there is an issue which many countries have to address – their youth demonstrate comparatively high performance, compared to other countries, yet the subject fails to engage them. One thesis, as we have already suggested, would suggest that this phenomenon is a product of their cultural context. Another might point to the growing rise of assessment as a means of making schools accountable for the performance of their students. Such assessment is often high stakes and there is an increasing body of research emerging that suggests that such testing has little positive effect on student achievement (Cheng, Watanabe, & Curtis, 2004; Nichols, Glass, & Berliner, 2006) and leads to a narrowing of the curriculum and an emphasis on performance rather than master learning (Au, 2007). At the very least, the question arises of whether such testing is doing more harm than good – particularly when policy makers are keen that more students should pursue the study of science.

Embedded in the full data sets for the recent PISA study are student responses which measure student interest in the further study of science. In contrast to the reports raised by the scientific community, these data would suggest that the interest in the study of science is reasonable with over a third interested in the future study of science and a fifth interested in doing advanced science.
<table>
<thead>
<tr>
<th>Country</th>
<th>Australia %</th>
<th>UK %</th>
<th>USA %</th>
<th>Average (All Countries) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>I would like to work in a career involving science</td>
<td>39</td>
<td>34</td>
<td>45</td>
<td>37</td>
</tr>
<tr>
<td>I would like to study science after secondary school</td>
<td>34</td>
<td>33</td>
<td>45</td>
<td>31</td>
</tr>
<tr>
<td>I would like to spend my life doing advanced science</td>
<td>15</td>
<td>13</td>
<td>24</td>
<td>21</td>
</tr>
</tbody>
</table>

Whilst a distinction clearly exists between the aspiration and the reality, it is nevertheless an indication that the study of science continues to interest a significant proportion of the student cohort.

The Future Demand for Scientists
Much of the concern about science education has been generated by a concern that there will be insufficient supply to support future demands. Sufficient data and scholarly argument exists to question the validity of this premise. For instance, Teitelbaum (2007) points to the fact that the trends in unemployment for STEM related professionals tracks that for the population as a whole – a feature that would not be expected if there was a genuine shortage in the supply. Furthermore, the number of tenure-tracked positions in the life sciences in the US has remained virtually static during the past decade whilst the numbers of doctoral students graduating has increased by 50%. During this period the success rate for NIH Funded grants has decreased from a peak of 32% in the year 2000 to 23% in the year 2005 – hardly a data set that would support any thesis that there is a shortage of supply. Jagger’s analysis of PhD awards globally in 2002 and 2003 (Jagger, 2007) showed that 125,011 SET doctoral students were awarded during this period with one fifth of these in the USA. Given the growth in Chinese universities, there is no reason to suggest that it will not continue to expand. Likewise, a seminar held on the research on future skills demands by the NSF (National Research Council, 2008) questioned the arguments that suggested the supply chain was failing to fulfill societal needs. For instance, in responding to a specific question about whether there was a national shortage of scientists, one of the contributors – a management professor from MIT stated that:

‘none of the companies she has talked to has suggested that there is a shortage of qualified chemists or life scientists. She said that employers’ greatest concern “is not numbers, it is training”. She cite the example of managers who told her they could interview hundreds of candidates for an organic chemistry position but wish they knew how to identify those candidates who “can behave collaboratively” and have other broad competencies discussed at the workshop. She argued that the degree to which scientists have these other capabilities “really seems to be the problem”.(p27)

Both this report and others suggest that the kinds of skills demanded by individuals in the future will be a creative approach to problem solving, complex communication skills and an ability to synthesize from different domains of knowledge (Gilbert, 2005; Hill, 2008). Hill, in particular, argues that the developed
world is moving to a ‘post-scientific society’. By this he does not mean that we will no longer be dependent on advanced technologies but rather that much of the basic research will increasingly be either mechanized or undertaken at sites where it is cheaper to do (and where individuals might be better educated in a knowledge of science) such as the BRIC (Brazil, Russia, India and China) countries. Rather the advanced societies will increasingly depend on wealth generation from individuals who have:

- a core understanding of scientific and technical principles but an equally strong preparation in business principles, communications skills, multicultural understanding, a foreign language or two, human psychology, and one or more of the creative arts. Their education must emphasize making connections among ideas, people, organizations, and cultures, often across boundaries that no one has thought to try to cross before.’ (Hill, 2008)

Consequently a post-scientific society will actually need fewer scientists than are currently employed today. If Hill is right, it is questionable whether societies should encourage their youth to study science for its instrumental value for future careers as, by the time they graduate, these may not exist. The only defensible position from which societies might encourage the study of science for all its young people rests in the basic liberal notion that science is a distinct domain of knowledge which offers us the best explanations we have of the material world; that many of these represent outstanding intellectual and creative achievements; and that a knowledge of this domain and its epistemic values will enhance students’ individual capabilities and what they might offer to the world in their coming futures.
References


