Chapter 41
Student Attitudes and Aspirations Towards Science

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Students' attitudes towards science have been a topic of enduring interest in the field of science education for over 40 years – but why? After all, there is no sense in which people are concerned about students' attitudes towards the learning of English or history. So what is it that drives the interest in this topic? The brief explanation is that compulsory science education bears a dual mandate (DeBoer 1991; Millar and Osborne 1998). On the one hand, school science is charged with educating the next generation in and about science – an education which essentially requires developing an understanding and appreciation of the explanatory hypotheses that science offers of the material world, how these came to be and why they matter. On the other hand, school science has a responsibility to educate the next generation of scientists. Whilst there are overlaps between the two goals, the former requires a broad overview of the domain. The latter requires a foundational knowledge of the discipline and its major concepts. And it is the supposed failure of school science to engage sufficient students in studying science for a future career that has pushed students' attitudes to the fore as a matter of concern for society and policy makers. Most advanced societies look to science and technology to sustain their economic lead, particularly in the context of threats to the dominance of the Western world posed by the developing economies of Brazil, Russia, India, and China. Looked at in this manner, science education is seen as a pipeline which supplies the next generation of scientists, albeit a leaky one. Sustaining the throughput of this pipeline is very much dependent on the attitudes that school science and science engenders in its students. Given a mounting body of data which suggest that students' attitudes in advanced societies are either negative or declining (Tytler, Osborne et al. 2008),

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there is a considerable interest in their measurement and any causal insights which might inform ways or remediating what is perceived to be a problem. This is true, for instance, in the UK (HM Treasury 2006), the USA (National Academy of Sciences: Committee on Science Engineering and Public Policy 2005; National Commission on Mathematics and Science Teaching for the 21st Century 2000), Australia (Tytler, Osborne et al. 2008) and Europe (European Commission 2004).

Meaning and Assessment of 'Attitudes'

Before discussing what the research findings reveal about student attitudes or what might be their causal factors, it is important to explore what is meant by the first construct in the title of this chapter. Perhaps the most important distinction here is that drawn by Leopold Klopfer (1971) between 'attitudes towards science' and 'scientific attitudes'. The latter are a set of attitudes which are the product of working in science and which are a commitment to evidence as the basis of belief, a belief in rational argument and a scepticism towards hypotheses and claims about the material world. Such values are represented by Robert Merton's (1973) attempt to define the principles that are inherent to science, commonly known as CUDOS: results are the property of the community not the individual (communalism); results are not specific to a context but universally valid (universalism); scientists should maintain a neutral or disinterested perspective about the acceptance of their findings (disinterestedness); research claims must be novel (originality); and all claims should be subject to criticism (scepticism). Merton's analysis has been substantively challenged by the body of work undertaken in the social studies of science, including Harry Collins and Trevor Pinch (1993) and Helen Longino (1990), who have questioned the validity of each of these claims in the light of the historical record and contemporary studies of scientific practice.

However, it is the first of these two constructs, 'attitudes towards science', which is the focus of this chapter and the body of research discussed here. Attitudes towards science is a complex concept which, at one time or another, has embodied the following concepts:

- The display of favourable attitudes towards science and scientists
- The display of favourable attitudes towards school science
- The enjoyment of science learning experiences
- The development of interests in science and science-related activities
- The development of an interest in pursuing a career in science or science-related work

It is necessary to distinguish between attitudes towards *doing* school science and attitudes towards science *in general*. It is the perceptions of school science, and the feelings towards undertaking a further course of study, which are likely to be most significant in determining students' decisions about whether to proceed with further study of science beyond compulsory courses. Students' attitudes to science more generally can be quite different from their attitudes to the science that they experience at school (Lindahl 2007).

The construct is further complicated by the fact that what is commonly measured is an attitude towards a unitary concept of 'science', whereas secondary schooling differentiates the object (which is the focus of the attitude) into three (physics, chemistry and biology), if not four sciences (earth sciences as well) which students like differentially according to research (Havard 1996; Lyons 2006; Osborne and Collins 2001). In attempting to measure one or more of these constructs, studies have incorporated a range of components in their measures of attitudes towards science, including:

- Perceptions of the quality of the science teacher
- Anxiety towards science
- The value of science
- Self-esteem at science
- Motivation towards science
- Enjoyment of science
- Attitudes of peers and friends towards science
- Attitudes of parents towards science
- The nature of the classroom environment
- Achievement in science
- Fear of failure in a course

The two key constructs in developing and assessing an instrument for the measurement of attitudes are the instrument's reliability and its validity. The latter is essentially dependent on a well-developed theoretical argument for the constructs that are to be measured. Without some careful elaboration of what is being measured and why those particular constructs might be considered important, it is likely that disparate items could be put together in a unitary scale for which there is no theoretical justification. The problem of interpreting the significance of a unitary construct synthesised from these multiple components of attitudes towards science has been clearly identified by Paul Gardner (1975), who comments:

> An attitude instrument yields a score. If this score is to be meaningful, it should faithfully reflect the respondent's position on some well-defined continuum. For this to happen, the items within the scale must all be related to a single attitude object. A disparate collection of items, reflecting attitude towards a wide variety of attitude objects, does not constitute a scale, and cannot yield a meaningful score. (Gardner 1975, p. 12)

And, if there is no single construct underlying a given scale, then there is no purpose served by adding the various ratings to produce a unitary score. As Gardner (1975) argues, weight, length and height can all be measured meaningfully, but adding these three variables together to form some kind of 'dining table index' simply produces a meaningless, uninterpretable variable.

Establishing the validity of an instrument, however, is not a simple task. Construct validity is reliant on the extent to which the items being measured have a good theoretical foundation so that it is clear what it is that the instrument is attempting to measure (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 criticised by Hugh 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 operationalised 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 understand the item to be asking and the reasons for choosing the response that they did. However, a not unreasonable argument here is that items of the nature ‘you have to be clever to do science’ or ‘I often do science experiments at home’ are really only open to one interpretation and, hence, do not require validation using such methods; this might explain why it is difficult to find attempts at such validation in the literature.

Reliability is generally sought by using the psychometric principle of writing several items which are attempting to measure an underlying unitary construct such as ‘interest in science’. A good instrument needs to be both internally consistent and unidimensional (Gardner 1975). Internal consistency is commonly determined through the use of a measure known as Cronbach’s alpha coefficient and is often quoted in much of the research literature on the measurement of attitudes. Essentially what this does is measure the extent to which individuals who score highly on any given item also score highly on the other items thought to be assessing one specific construct. However, it does not follow that scales which are internally consistent (i.e. all the items have a Cronbach alpha in excess of 0.7) will be unidimensional. This is because a scale might be composed of several clusters of items, each measuring distinct factors. In this situation, as long as the responses to every item correlate well with the other items, a high Cronbach alpha will still be obtained even though what is being measured is not a single unitary factor. Hence, it is important that the unidimensionality of scales is tested by using an appropriate statistical technique (e.g. factor analysis) that is capable of resolving the underlying factors. If a scale does measure what it purports to measure, then all the variance in responses should be explained by a loading on a unitary factor. Such a factor analysis also enables the establishment of convergent and divergent validity in that theoretically similar items should converge (i.e. correlate) and theoretically dissimilar items should diverge (i.e. not correlate). Moreover, those items that converge should match self-evidently with the theoretical concepts from which they were originally derived or used in their formulation (Henerson et al. 1987).

Evidence that the field has had problems in developing instruments which meet these criteria comes from a recent comprehensive review conducted of 66 instruments for measuring attitudes by Cheryl Blalock et al. (2008). Twenty 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 Paul Germann (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, p. 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, for example, Richard Moore and Frank Sutman's Scientific Attitude inventory (Moore and Sutman 1970) have been used in 13 additional studies. What Blalock et al. points 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. The practice of reusing non-validated instruments has clearly hindered the development of methods and expertise in this field.

Some recognition of these criticisms can be found in more recent work. For instance, the instrument developed by Per 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, Steven Owen et al. (2008) have re-evaluated one commonly used instrument – the Simpson-Troost Attitude Questionnaire (Simpson and Troost 1982) which consisted of 59 items. Using a sample of 1,812 participants split into two groups – half of which were used for exploratory factor analysis and half for confirmatory factor analysis – using only 22 items, they were able to reduce the instrument to a 5-factor model which they identified as: the extent to which the science class was motivating; the level of effort that 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 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, in order to 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 alpha) 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 includes 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 would weaken the validity and value of the findings.

In the more advanced studies, such factor analysis is used as a basis for structural equation modelling to identify the latent variables and how the factors interrelate. Well-known models are:

- The Eccles Expectancy-Value Model (Eccles et al. 1983), which focuses on students' engagement in terms of how a task is valued (or not) and their expectancy of success.
- Albert Bandura's (1997) model that emphasises perceptions of self-efficacy, which are beliefs in whether individuals can perform the behaviours necessary to achieve a required outcome. Bandura argued that such beliefs are a major determinant of an individual's activity choice and their willingness to expend effort and motivation. This work has proven powerful in explaining individual's motivation and engagement and has been used in major studies exploring, for instance, career choice (Bandura et al. 2001a, b).

However, of themselves, attitudes might not necessarily be related to the behaviours that a person actually exhibits (Potter and Wetherell 1987). For example, a pupil might express interest in science, but avoid publicly demonstrating it amongst his or her peers who regard such an expression of intellectual interest as not being the 'done thing'. In such a case, motivation to behave in a particular way might be stronger than the motivation associated with the expressed attitude or, alternatively, anticipated consequences of behaviour could modify that behaviour so that it is inconsistent with the attitude held.

Consequently, it is behaviour rather than attitude that has become a focus of interest and which has led researchers to explore models developed from studies in social psychology. Icek Ajzen and Martin Fishbein's (1980) theory of reasoned action – which is concerned fundamentally with predicting behaviour – is one such model. This model focuses on the distinction between attitudes towards some 'object' and attitudes towards some specific action to be performed towards that 'object' (e.g. between attitudes *towards* science and attitudes towards *doing* school science). Ajzen and Fishbein argue that it is the latter kind of attitude that best predicts behaviour. Their theory represents a relationship between attitude, intention and behaviour. Behaviour is seen as determined by intention, and intention is a joint product of attitude towards the behaviour and the subjective norm (i.e. beliefs about how other people would regard one's performance of the behaviour). The theory of reasoned action has been applied to some attitude and behaviour studies in science education. For instance, Frank Crawley and Annette Coe (1990), Tom Koballa (1988) and Steve Oliver and Ronald Simpson (1988) have all found that social support from peers and attitude towards enrolling for a course are strong determinants of student choice to pursue science courses voluntarily, which suggests that the theory has at least some partial validity. The effect of attitudes on behaviour has been a particular focus of interest in the field of research on environmental education, with Joe Heimlich and Nicole Ardoin (2008) providing a useful review of the main theoretical ideas and empirical studies.

There are numerous other methods of measuring attitudes. *Interest inventories* provide a common technique in which respondents are presented with a list of items and then asked to identify the ones in which they are interested. The Relevance of Science Education (ROSE) study (Sjøberg and Schreiner 2005) used such an approach in trying to identify which topics in science about which children were interested learning. However, such inventories are generally restricted to their specific focus, yielding only a limited view of what might or might not be formative influences on attitudes to science.

Enrolments in science subjects are another major source of data of increasing concern. However, any attribution of significance to such data as a sole measure of interest in science is questionable, as subject choice can be highly affected by changes in society that affect the structure of economic opportunities, the desire not to foreclose opportunities, the perceived difficulty of the subject and, particularly in the case of boys, the association of subject with gender identity – all of which might well be independent on attitudes towards school science.

Subject preference studies typically list school subjects and ask students to rank them in order of importance (Jovanovic and King 1998; Lightbody and Durndell 1996b; Whitfield 1980). The main criticism of such studies is that a student might still have a positive attitude towards science yet rank science lowly as they are more positive about other subjects. Such scales only establish a relative ranking rather than an absolute measure.

A common criticism of all attitude scales derived from questionnaire surveys is that, while they are useful in identifying the nature of student attitudes, they have been of little help in understanding the generative mechanisms. This has led, more recently, to the growth of *qualitative methodological approaches*, three recent examples of which are studies undertaken by Britt Lindahl (2007), Terry Lyons (2006) and Jonathan Osborne and Sue Collins (2001). While such studies are subject to limited generalisability and, of necessity, have smaller samples and lack the ability to identify significant variables in a clearly defined manner, they can provide more insight into the origins of attitudes to school science than quantitative methods. For instance, it is difficult to envisage how the following student perceptions of the nature of school science and the disjuncture that exists with contemporary science could be elicited through survey methods:

> Roshni: The blast furnace, so when are you going to use a blast furnace? I mean, why do you need to know about it? You're not going to come across it ever. I mean look at the technology today, we've gone onto cloning. I mean it's a bit away off from the blast furnace now, so why do you need to know it? (Osborne and Collins 2001, p. 449)

What Is Known About Student Attitudes to Science?

Emerging from this body of work on attitudes towards science are some clearly defined features. First, students' attitudes towards school science typically decline from the first year of elementary school onwards (Murphy and Beggs 2003; Pell and Jarvis 2001). Studies conducted in secondary schools have identified a similar trend (Breakwell and Beardsell 1992; Simpson and Oliver 1985; Yager and Penick 1986).

In one sense, this is not surprising as attitudes towards school decline throughout adolescence (Eccles and Wigfield 1992; Epstein and McPartland 1976). The more fundamental question is how such attitudes to science decline relative to attitudes to other subjects. Richard Whitfield's (1980) analysis of 1971 Institute for Educational Assessment data showed that physics and chemistry were two of the least popular subjects once children reach the age of 14 years, and that these were distanced in pupils' minds from biology, a finding confirmed as still existing in a small study conducted by Neil Havard (1996). A similar picture of differential ranking between the sciences emerges from Osborne and Collins' (2001) study. Given the relative simplicity of Whitfield's instrument and its use of preference ranking, it is perhaps surprising that this kind of study has not been repeated on a larger scale. What such studies do, however, is to call into question whether the construct of 'attitude towards school science' is really a valid construct as students clearly have different attitudes towards the different sciences – though such a point is only true for high school students who have been taught courses that have more explicitly distinguished the sciences.

A study which has attracted considerable attention recently is the Norwegian-based ROSE study (Sjøberg and Schreiner 2005). Students were asked to respond on a 4-point Likert scale about whether they agree or disagree to statements of the kind 'I like school science better than other subjects'. Two major features emerged from these data and other responses: the decreasing interest in school science in more advanced, industrialised countries; and the more negative attitudes of girls. Whereas all of the samples were opportunistic and not randomly selected, such data have been greeted with some alarm in the developed world where there is a significant body of concern about the future supply of scientists (European Commission 2004; Lord Sainsbury of Turville 2007; National Academy of Sciences: Committee on Science Engineering and Public Policy 2005). However, another interpretation of these data is that, even in the worst-case scenario (Norway), 40% of boys and 22% of girls answered this question positively. On that basis, a question must be asked whether the concern has been exaggerated.

Similar findings emerge from an analysis of the 1999 data for the Third International Mathematics and Science Study (TIMSS) by Yasushi Ogura (2006). Ogura plotted students' achievement scores, measured by their knowledge of science concepts, against the mean of their responses to various items measuring their attitudes towards science. Again what stands out is that those countries whose students were the most successful, and which many other countries seek to emulate and which offer a very traditional science education with an emphasis on learning scientific knowledge, have students with the most negative attitudes. Such alienation is undoubtedly of concern to teachers, as their job satisfaction is likely to be strongly influenced by their pupils' affective responses to what is offered in science lessons. Moreover, recent evidence comparing the performance of Chinese and American students on tests of conceptual knowledge and scientific reasoning shows that, whereas those educated in China perform significantly better on tests of conceptual knowledge, they perform no better on tests of scientific reasoning (Bao et al. 2009). Thus, if the goal is to develop students' ability to think critically, an emphasis on content might have little effect.

Insights into student dissatisfaction with school science come from qualitative studies that have articulated the student voice (Lindahl 2007; Lyons 2006; Osborne and Collins 2001). Students complain that: school science lacks relevance; consists of too much repetition in that similar concepts appear in both the elementary, middle and high school curriculum; there is a lack of opportunity to discuss the science or it implications; and there is an overemphasis on copying as the standard form of writing. In addition, the curriculum appears to be dominated by a large body of content which must be learnt and reproduced for examinations – which is reinforced by the use of 'high stakes testing' as an accountability mechanism (Au 2007). Wayne Au's work – an extensive meta-analysis of all relevant studies undertaken in the field of assessment – led him to the conclusion that the consequence of such testing is a more fragmented curriculum and a pedagogy dominated by transmission – an approach which tends to lead to performance learning by students who are motivated by extrinsic rewards rather than by an inherent interest in the subject itself.

Detailed insights into why such an approach singularly fails to engage students comes from a study led by Mihaly Csikszenmihalyi and Barbara Schneider (2000) using the theoretical concept of 'flow' – the feeling generated by total engagement with an activity. They collected data at random from students eight times a day using a one-page, self-report form to identify the kinds of experience that are generative of 'flow'. Developing a composite measure of optimal learning experiences from data that included measures of challenge and skill, as well as concentration and enjoyment, they found that tests and quizzes, group work and individual work all produced above-average levels of 'flow', whereas listening to lectures and watching television or videos produced little 'flow'. Their conclusion was that classroom activities that facilitate flow experiences are those that are well structured and for which students are given adequate opportunities to demonstrate their skills and knowledge as autonomous individuals. One of the experiences that clearly generates the experience of 'flow' for most pupils is laboratory work (Csikszentmihalyi and Schneider 2000; Solomon 1980; Woolnough 1994), but the failure of school science to generate sufficient experiences of this nature remains a matter of concern.

Such findings support the view that school science education is unappealing when it is dominated by short-term goals, presented through lectures with an emphasis on transmission, and lacks challenge. Other research suggests that what school science lacks for students is a sense of purpose – why does it matter, what are its major ideas, how do they relate to each other and why should these matter to students (Claxton 1991; Millar and Osborne 1998; Osborne 2008)?

Nevertheless, most studies report that students' attitudes towards the overall experience of their science course are predominantly positive. For instance, for a sample of 1,227 English students, 61% agreed or strongly agreed with the statement 'school science is interesting'. Such data are similar to those found in previous studies (Assessment of Performance Unit 1988; The Research Business 1994). Moreover, a recent study of public attitudes to science by the Research Councils UK (2008), based on a random sample of 2,137 individuals, found that a third of young people (aged 16–24 years) felt that their school science education had been better than other subjects and that 43% felt it had been about the same. Comparable figures for adults (aged 25 years or over) were, respectively, 17% and 48%. Likewise, the recent PISA studies of 8th grade students present a similar positive picture of US students, with 45% indicating that they would like to study science after high school (OECD 2007).

What Are the Major Factors Determining Student Engagement with Science?

Research has identified a number of variables which contribute towards student engagement in science. Three factors stand out as the major determinants of student interest in school science – gender, the quality of teaching and pre-adolescent experiences. Space only permits detailed consideration of these three but more information can be found in previously published reviews (Osborne et al. 2003; Schibeci 1984).

Paul Gardner comments that sex is probably the most significant variable related to pupils' attitude to science (Gardner 1975). This view is supported by Renato Schibeci's (1984) extensive review of the literature, and more recent meta-analyses of a range of research studies (Brotman and Moore 2008; Murphy and Whitelegg 2006; Weinburgh 1995) covering the literature between 1970 and 2005. All four publications summarise 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 and Schreiner 2005) and more recent work (Haste 2004; Jones et al. 2000). However, it would be better to say that the real difference is in attitudes to the physical sciences and engineering (OECD 2006) and, despite a large number of interventions undertaken in the 1980s and 1990s to engage more young women with the study of science, Gail Jones et al. (2000) concluded 'that the future pipeline of scientists and engineers is likely to remain unchanged' (p. 190). Thus, this problem is both chronic and a matter of concern (Adamuti-Trache and Andres 2008). Despite 25 years of effort, little, if any, change has been achieved. This 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 program options at the post-secondary level' (Adamuti-Trache and Andres 2008, p. 1577).

A useful review of nine explanatory hypotheses for women's lack of engagement with science is offered by Jacob Blickenstaff (2005) who argues strongly against the suggestion that there are innate genetic differences. Rather, examining the other hypotheses, he suggests that the problem is complex and not amenable to simplistic solutions. Currently, the most useful insights come from work that focuses on the context in which physics is presented. For instance, the ROSE questionnaire presents 108 topics about which students might like to learn and asks respondents to rate them from 'not at all interested' to 'very interested'. Between English boys and girls there were 80 statistically significant differences. The top five items for boys and girls are shown in Table 41.1.

Table 41.1 The five top-ranked items that boys would like to learn about in science and the top five for girls (Jenkins and Nelson 2005)

Boys	Girls
Explosive chemicals	Why we dream when we are sleeping and what the dreams might mean
How it feels to be weightless in space	Cancer – what we know and how we can treat it
How the atom bomb functions	How to perform first aid and use basic medical equipment
Biological and chemical weapons and what they do to the human body	How to exercise the body to keep fit and strong
Black holes, supernovae and other spectacular objects in outer space	Sexually transmitted diseases and how to be protected against them

Based on the stark contrasts in lists such as these, it has been argued that the content of interest to girls is significantly under-represented in the curriculum (Haussler and Hoffmann 2002). These data are also supported by other research which would suggest that girls would be interested in a physics curriculum which had more human-related content (Krogh and Thomsen 2005). Indeed, a recent survey by Helen Haste and colleagues (2008) of student attitudes based on a sample of 327 14–15-year-old boys and 256 girls looked at how their perceptions of science were related to their personal, social and ethical values. 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 factors which discriminated between boys and girls: 'trust in the benefits of science', 'science in my life', 'ethical scepticism' 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 while it was a negative factor for boys. Likewise, the perceptions of how science was relevant to their lives were 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 is likely to reduce their engagement. Such data also strongly suggest that offering a homogeneous curriculum to all is a mistake – what interests girls is unlikely to interest boys and vice versa.

Quality of Teaching

Quality of teaching is a difficult construct to operationalise, let alone measure. Nevertheless, a considerable body of evidence now exists that identifies the quality of teaching as a major determinant of student engagement with and success in a school subject (e.g. Osborne et al. 2003; Rivkin et al. 2005; Wayne and Youngs 2003). The most recent systematic study was undertaken in two states in the USA by Linda Darling-Hammond (2007), who showed that the major factor correlating with the percentage of students scoring 'below basic' on the South Carolina state tests were the percentage of teachers with substandard teaching certificates and the percentage of teaching vacancies open for more than 9 weeks. In contrast, teachers having advanced degrees correlated negatively with the percentage of 'below basic' scores. Likewise, in the state of Massachusetts, the two factors correlating most highly with the number of students failing the State English language test were the percentage of teachers unlicensed in the field and the percentage of paraprofessionals not highly qualified. A major OECD commissioned international review of school systems (Barber and Mourshed 2007) found:

> The experience of these top school systems suggests that three things matter most: 1) getting the right people to become teachers, 2) developing them into effective instructors and, 3) ensuring that the system is able to deliver the best possible instructions for each child (p. 5)

On the basis of comparative data across educational systems on student outcomes, Barber and Mourshed argued that reform efforts are often ineffective in delivering student learning and engagement if they do not reach down into classroom instruction, where the real effects on learning take place.

Identifying the constitutive elements of what makes a good teacher of science has been the focus of several strands of research including a series of projects at the secondary level by Ken Tobin and Barry Fraser (Garnett and Tobin 1989; Tobin and Fraser 1990; Tobin et al. 1994) and at primary level by Russell Tytler and colleagues (Tytler 2003; Tytler et al. 2004). Clearly a necessary condition is good subject knowledge which provides a base level of confidence essential for providing high-quality feedback and scaffolding (Hattie and Timperley 2007). Robin Alexander (2005) argues powerfully for a pedagogy based more in a dialogic approach suggesting that, whereas 'rote, recitation and expository teaching' might provide teachers with a sense of security as they enable the teacher to remain firmly in control, they make it less likely that the classroom will become a theatre for dealing with awkward, contingent questions which deal with issues of evidence and reasons for belief – exactly the kind of interaction, which Leo Van Lier (1996) argues, is engaging. Robert Sparkes (1995) makes the salient point that there is no problem with the supply of teachers of physics in Scotland as good teachers generate engaged students who in turn become teachers. Hence a problem never arises.

Pre-adolescent Engagement with Science

Student interest in science at the age of 10 years has been shown to be high and with little gender differences in either interest (Murphy and Beggs 2005; Pell and Jarvis 2001) or aptitude (Haworth et al. 2008). However, recent research suggests that, by the age of 14 years, interest in pursuing further study of science has largely been formed for the majority of students. In a recent analysis of data collected for the US National Educational Longitudinal Study, Robert Tai et al. (2006) showed that, by the age of 14 years, 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 years 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 the age of 14 years are the major determinant of any decision to pursue the study of science comes from a survey by the Royal Society (2006) of 1,141 SET practitioners' reasons for pursuing scientific careers. Just over a quarter of respondents (28%) first started thinking about a career in STEM before the age of 11 years and a further third (35%) between the ages of 12 and 14 years. Similar evidence came from a study by Adam Maltese and Robert Tai (2008) based on analysis of interviews with 116 scientists and graduate students. They found that 65% of respondents 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 interest related to school or family compared with males who tended to claim intrinsic or self-related interest in science. Likewise, a small-scale longitudinal study conducted by Britt Lindahl (2007) followed 70 Swedish students from grade 5 (age 12 years) to grade 9 (age 16 years) and revealed that their career aspirations and interest in science were largely formed by age 13 years. 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. (2001) on children's aspirations and career choices.

Such data demonstrate the importance of the formation of career aspirations of young adolescents long before the point at which many make the choice about subjects in which to specialise. These findings suggest that efforts to engage school students with science would be more productively expended by: understanding the formative influences on student career aspirations between the ages of 10 and 14 years; and attempting to foster and maximise the interest of this cohort of adolescents, particularly girls, in STEM-related careers.

Other Variables

The determinants of student choice of science as a subject, or Science, Technology, Engineering and Mathematics (STEM) subjects generally, are multiple and interacting. Nadya Fouad and colleagues (2007) used a questionnaire with 1,151 students at different stages of schooling to identify key supports and barriers. The instrument was based on social cognitive career theory that considers student interest and aspirations in terms of interactions between personal factors and learning experiences on self-efficacy and outcome expectations. Key barriers identified were perceptions of subject difficulty (related to self-efficacy) and the presence of test anxiety. The list of variables that were significant predictors of choice to take ongoing science subjects were *science interest* (which, as we have shown above, itself might represent a number of factors), self-evaluation of science ability, parental expectation and guidance, exposure to career guidance and having goals, and exposure to inspirational teachers. For middle and high school students, teacher support and teacher expectations of success were significant supports.

The question of the difficulty of subject seems to be more important for mathematics than science, and for physical sciences than biological sciences. Lyons (2006) studied attitudes to science and backgrounds to subject choice for high-performing year 10 students in Australia. He used a combination of questionnaire and interview data. From the interview data, he identified that students choosing physical science were those who had supportive family relationships, parents who recognised the value of formal education, and family members advocating or supporting an interest in science. These students had higher levels of self-efficacy, which he argued was important in their decision to take these subjects with a reputation for difficulty. Lyons explained these findings in terms of 'cultural and social capital' needed by students to select into STEM pathways.

Maria Adamuti-Trache and Lesley Andres (2008) drew upon Pierre Bourdieu's work in examining the level of influence that parents have in transmitting cultural values and practices to their children, and thus disposing them towards STEM fields of study. Students with university-educated parents were shown in this study to decide earlier about their career directions, and they were more likely to choose science subjects. Thus, it is reasonable to infer that the transmission of cultural capital restricts prematurely the pathways of students whose parents and family contexts do not facilitate, encourage, assist and fund academic pursuits in STEM. There is also evidence from this study that the job satisfaction of parents in STEM careers, particularly the mother, can have significant influence on children's career aspirations.

The influence of parents is not necessarily straightforward. The Australian Department of Education Science and Training's (DEST 2006) Youth Attitudes Survey found that students who chose science and technology subjects reported overall higher levels of parental influence upon their decision-making. Haeusler and Kay (1997) found that parental and teacher advice played a more prominent role in the selection of science subjects than for other school subjects, and there is some evidence (Watt 2005) that this influence is greater in the earlier years of schooling, compared to the later years when perceived natural talent and interest drives choice.

A recent UK study conducted by the National Foundation for Educational Research for the UK government (Blenkinsop et al. 2006) points to the work of Bandura and colleagues (2001) who perceive self-efficacy (the belief that one has the power to produce effects by one's actions) as having greater predictive power in occupational choice than other theories. Following an analysis of socio-cognitive data from 272 children, they concluded that self-efficacy emerged from the interaction between 'socioeconomic, familial, academic and self-referent influences [operating] in concert to shape young people's career trajectories' (Bandura in Blenkinsop et al. 2006, p. 4). Family socio-economic status, they argued, had only an indirect effect on young people's perceptions of their capabilities. Higher status parents had raised parental aspirations which, in turn, were passed on to their children both as expectations and belief in their own capabilities and academic aspirations.

Many studies have shown that students who persist in STEM are more likely to have higher socio-economic status (see Committee for the Review of Teaching and Teacher Education 2003; Helme and Lamb 2007; Lamb and Ball 1999; Thomson and De Bortoli 2008). However, there continue to be questions raised about the nature of the causal link operating and the usefulness of SES as an indicator of student participation in STEM subjects. We have seen in the studies above how social capital and child–parent relations are important, and these can link to SES. Robert Putnam (2001, 2004) found that community-based social capital was a better indicator of improved educational outcomes than socio-economic status. David Grissmer et al. (2000) argue that this occurs through 'peer effects, quality of communication and trust among families in communities, the safety of neighbourhoods, and the presence of community institutions that support achievement' (pp. 17–18). Further research into this issue is required.

A few studies have shown the interactions between these various factors – self-efficacy, perceived difficulty and usefulness, parental and teacher encouragement – at different stages in schooling. For instance, Maltese (2008) undertook a complex data analysis of a large US longitudinal data set involving information over the school and college years about family demographics and background, academic support and achievement test results in a variety of subjects. He found a complex flow into and out of STEM subjects governed by a variety of factors, namely, the importance of early perceived usefulness of STEM (as an indicator of future degrees in STEM), academic score as an important indicator of choice of subject, the perception of usefulness of science and mathematics (a positive indicator of persistence in these subjects). However, a teaching emphasis on lecturing and textbooks was a negative indicator of persistence in science.

Anna Cleaves (2005) conducted interviews with 72 high-achieving secondary students to explore the factors influencing their subject choices across time from year 9 to year 11. She used a grounded theory approach to separate student trajectories into five categories that represented different patterns of choice regarding persistence, or not, in STEM. In the study, she identified many of the negative attributions to school science that have been described in the literature, such as irrelevance and boredom and stereotypical views of scientists and their work. However, for some students, these negative experiences were not enough to deter them from a commitment to pursue further studies. Cleaves paints a picture of interested students choosing to continue in STEM study, despite negative experiences of school science, and gaining a deeper appreciation of what a science career might be like outside of the classroom. She argues that raising the profile of science and understanding of science-related work are important in encouraging students into science. She adopts an identity framework to interpret the self-perceptions of students, showing that students' perceptions of their ability, in conjunction with their life aspirations, drive the decision to opt into, or out of, STEM (see also Leonardi et al. 1998).

A particular question of interest has been how much students know about careers in science. For instance, Lindahl's (2007) longitudinal study of students and their aspirations revealed that, at the early ages when their career aspirations were being broadly set, students had very little idea about the variety of work to which a focus on science subjects might lead. This has been the broad finding of a number of studies (e.g. Blenkinsop et al. 2006; Stagg 2007). A survey conducted in the UK for the Engineering Council by the National Foundation for Educational Research using a questionnaire survey of a random sample of 1,011 students at age 14 (Engineering and Technology Board 2005) found very limited and stereotypical views of what engineers, technologists and scientists might do. Technology was seen as the province of 'designing things' and 'having new ideas', and was correspondingly popular as a potential career. In terms of information about careers, Sarah Blenkinsop et al. (2006) reported that 14–16 year olds believed that media portrayal of jobs and careers influenced their choices, but that direct information from someone who works in the job, or a school careers teacher, is more likely to have been influential. Contact with people working in the field has been found to be highly valued:

> People, their lives, and the work they do are the richest and most respected resource for learning about careers. Whilst a proportion of young people are attracted to science and technology for itself, many are interested first in the people (role models, etc.). (Stagg 2007, p. 4)

This was a finding echoed, particularly for girls, by Gayle Buck et al. (2008) who found that role models were people with whom they held a 'deep personal connection' and that it was essential to establish a personal connection with girls if they were to engage them with the work that scientists undertake.

Students identified subject teachers as the most useful source of career information, but UK research has revealed that teachers of science did not perceive themselves as a source of career information, regarding it as the responsibility of the careers teacher (Munro and Elsom 2000). Further, Peter Stagg (2007) found that teachers were not well informed about careers in science let alone careers outside science which permitted the study of science. This situation is not aided by the fact that most careers teachers come predominantly from non-science backgrounds. These findings suggest that there is a need to develop an effective policy approach to enable students to be more aware of career possibilities associated with science.

The final point that should be made here is that the basic premise of this concern – that not enough children are choosing to study science – is open to question. There is a growing body of evidence that the production of scientists is in fact healthy (e.g. Butz et al. 2003; Lynn and Salzman 2006; Teitelbaum 2007). Further, Christopher Hill (2007) has made a cogent argument that advanced societies will become 'post-scientific' over those that are less dependent on basic scientific research and more dependent on their ability to create new artefacts by drawing on a range of disciplinary knowledge.

Identity: Making Sense of Student Engagement with Science

To understand student responses to science, there has been recent and increasing interest in exploring the construct of identity. This has been fruitful both for exploring 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.

Glen Aikenhead (2005) argues that, for many students, especially indigenous students, coming to appreciate science requires an identity shift in which students come to consider themselves as science-friendly – that 'to learn science meaningfully is identity work' (p. 117). Similarly, he argues that the persistence of status quo versions of school science in the face of considerable critique relates to the strong discursive traditions subscribed to by teachers of science resulting from their enculturation during their own schooling and undergraduate studies. There is widespread concern in many countries about gaps in performance in science and other subjects between indigenous and non-indigenous students (e.g. Thomson and De Bortoli 2008). Aikenhead and Masakata 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 marginalise some students on the basis of their 'cultural self-identities' (Aikenhead and Ogawa 2007, p. 540). Aikenhead (2001, p. 338) argues elsewhere that only a small minority of students' '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 identity futures consonant with science work. Elizabeth McKinley (2005) identifies the difficulty experienced by Maori women scientists in managing inconsistent images of themselves – as women, as Maori and as scientists – and argues that competing legacies of science, knowledge and culture have built strong cultural stereotypes of Maori women, who in interviews describe being discriminated against, prejudged and overlooked in their scientific roles.

In a similar vein, Angela Johnson (2007) in the USA 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 such as asking students questions in lectures can advantage White male students who are more competitive and confident, and cause women to feel a loss of status and rob them of the 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)

As we have shown, the evidence demonstrates that contemporary youth is not a homogeneous population. Young people in today's society see themselves as free to choose their address, religion, social group, politics, education, profession, sexuality, lifestyle and values (Beck and 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. The decision-making landscape is complex as young people negotiate as they select their school subjects, decide who they want to be, and address their aspirations for a fulfilling future. Furthermore, analysis is complicated by that fact that the barriers that hinder young people's decision-making are not always immediately apparent and will change over time, and in degree, as students grow and develop (Engineering and Technology Board 2005; Fouad et al. 2007; Walker 2007; Walker et al. 2006).

There is a significant body of research on the impact of identity on the education-related choices of young people (e.g. Archer et al. 2007; Boaler 1997; Francis 2000). Many of these choices – whether or not to continue, which subjects to continue with, who they will aspire to become – impact upon students' success or failure in fulfilling their aspirations. Nadya Fouad et al. (2005) found in the USA that while race does not have an impact on students' initial career aspirations, it does affect the barriers that students encounter as they take action to fulfil those aspirations. Such barriers might include expectations of teachers, peers or family, or lack of role models. From this, it is clear that 'choice' is a highly constrained concept in the context of education, and experienced as limited or expansive depending upon factors such as prior academic performance, student cultural capital or school location. In this respect, the work of Geoffrey Cohen et al. (2006), which has attempted to address such barriers, is extremely interesting. Cohen and his co-workers take a psychological approach and argue that what inhibits students' performance is what they term 'stereotypical threat' – the notion that individuals are members of a group of students who commonly are perceived to fail at science (e.g. African American or woman). By conducting a small intervention at the beginning of the year to address and challenge such notions, this group has been able to show significant improvements in the performance of underperforming minorities and women.

Identity is a construct that goes beyond concerns such as curricula, intrinsic interest or career intentions, and it frames aspirations and perceptions in terms of social relationships and self-processes instead (Lee 2002). In identity theory, the self (or selves) is bounded by social structures, and interactions shape the organisation 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 et al. 2007).

Two recent studies have contributed to our understanding of how youth respond to science, school science and environmental issues. Helen Haste (2004) conducted a survey of the values and beliefs that 704 11–21-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, were sceptical about interfering with nature and were predominantly girls under 16 years;

the ‘techno-investors’ 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, 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 sceptical of its potential and who were predominantly female. Haste found that girls were not less interested in science or science careers than boys, but they focused on different things. Girls 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 argued that the science curriculum needs to represent both these dimensions of science, as well as acknowledging the value aspects and ethical concerns surrounding science and its applications.

Camilla Schreiner (2006) administered a questionnaire which had been extensively validated to a sample of 1,204 Norwegian students drawn from 53 randomly selected schools consisting of equal numbers of boys and girls. From a cluster analysis of her sample, she identified five distinct student types, each of which had a different response to science and to their own aspirations with respect to science. As with the Haste study, the categories were highly gender specific and showed different patterns of response to a range of items relating to the perceived value of school science and science, as well as their future aspirations.

Schreiner interprets the low recruitment into STEM subjects in wealthy, modern societies in terms of changing values of youth in late modern societies. This analysis has a significant identity component. Schreiner and Svein Sjoberg (2007, p. 242), draw on three perspectives to make sense of the data:

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 et al. 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.

Examined from the first perspective, in early and late industrial countries where the major national project goals are progress, growth and building the country, scientists and engineers were 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. In advanced societies with a diminishing industrial base, and where material needs are satiated compared to previous generations, 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 and Durndell 1996a; 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 suggest 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-realisation, creativity and innovation, working with people and 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 making us aware of the complexity of the issue of response to school science, and that, if we are to engage students with science in school, thought needs to be given both to the complex and varied histories of students who attend our classes, as well as to the nature of the science curriculum. Because we cannot hope for a simple match, 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 vision of science and its value in school.

Enrichment Experiences in School Science

This work on identity highlights a direction that is being increasingly embraced by government reports into the status of school science: greater attention needs to be given to representing the practices of science and their social implications than traditionally has been the case. In a number of countries, this has led to projects designed to encourage more links between practising scientists and school science classrooms. Academies of science and engineering that are concerned with the decreasing number of students in these areas have supported initiatives that bring exemplars of contemporary practice into classrooms. From the perspective of the identity-based research described above, two measures are of value: the need to increase awareness of career options in the sciences; and the provision of a diversity of role models with which students can identify, in terms of the personal, human possibilities opened up by an education in the sciences.

Such schemes are often reported as very successful but, because the evidence is largely anecdotal and the schemes vary widely, there is limited scope to generalise about outcomes in these areas. In the USA, service learning, in which students spend time working in organisations on a voluntary basis as part of their studies, is well established and surveys of participants have been encouraging (Gutstein et al. 2006). The Australian School Innovation in Science, Technology and Mathematics (ASISTM) project, which involves partnerships between clusters of schools, scientific and industrial organisations, universities and government organisations, has facilitated the development of innovative curriculum experiences for students. A study of ASISTM exemplar projects (Tytler, Symington et al. 2008;

Table 41.2 Index of science-related activities for selected countries (OECD 2007)

Country	Mean		
	Whole sample	Boys	Girls
UK	−0.35	−0.25	−0.45
Germany	0.11	0.16	0.06
Finland	−0.16	−0.18	−0.15
USA	−0.09	0.04	−0.21

Tytler, Symington and Smith 2011) involved developing an innovation framework for interpreting these projects, pointing out that the practices and ideas developed were in alignment with the open pedagogies and focus on contemporary practice advocated in writing about schooling for students in their adolescent years. The Australian Scientists in Schools programme (www.scientistsinschools.edu.au) has over 500 scientists working as partners with teachers across the country and on a variety of projects. The model is one of equal partnership, aimed at motivating students and providing teachers with professional learning opportunities about the contemporary practice of science.

Some evidence for the value of such interventions comes from the recent PISA study of 8th grade students (OECD 2007), which asked them about the frequency with which they watched TV programs about science, read science magazines or newspapers, visited science websites, borrowed books on science topics, listened to radio programmes about advances in science, or attended a science club. From this they developed an index of science-related activities (−2.5 to +2.5). A sample of figures from the index is shown in Table 41.2. For nearly all the countries in the study, a positive unit of the index resulted in an enhanced science performance of around 20 points on the mean score of 500. Once again, girls had a lower level of engagement with such activities than boys. The question of interest is whether the weaker engagement of, for instance, UK students, is because of a lack of opportunity or lack of interest.

Enrichment activities for science are often designed at a local level at the instigation of enthusiasts or interested associations, and there is a lack of understanding about the variety of such initiatives or their relative effectiveness. There is considerable anecdotal and weak evidence that student learning and engagement in science are enhanced by participation in enrichment activities such as excursions, visits by science practitioners, travelling shows, competitions such as mathematics and science Olympiads or engineering design challenges, science clubs and extension activities. This is mainly because any one-off event is unlikely to lead to significant learning in and of itself. Secondly, the methodology for capturing such experiences and its outcomes still remains problematic (Osborne and Dillon 2007). Moreover, as John Cripps Clark (2006) found in a study of science-enthusiastic primary school teachers, elementary schools offer a considerable range of such activities in their curriculum, but these required dedicated efforts in the face of systemic factors operating against their inclusion. Mary Munro and David Elsoms' (2000) study of the choices made by UK students after the age of 16 years revealed that teachers regularly complained that the curriculum was so scripted and crowded that it discourages engagement in such activities, despite their perceived importance in providing a stimulating environment for engaging students in learning mathematics, science and technology.

The report from the Science Education in Europe: Critical Reflections forum (Osborne and Dillon 2008) makes the point that most of students' waking lives are spent out of school and that much of their science (a similar point could be made about mathematics) learning occurs largely in informal settings. There is a wealth of literature on learners' experience of informal settings and museums (see Falk et al. 2000; Leonie Rennie 2006), but there is a need for further research into the impact of these public science resources on student attitudes to and engagement with science.

Conclusion

In this chapter, we have attempted not only to present a body of evidence about what is known about the methods and outcomes of this field of attitudes and aspirations towards science, but also to develop an argument as to why the domain is significant and of enduring interest in the field of science education. In addition, our analysis has offered some insights into what issues remain to be studied. In its methodology, the field is at last learning from the errors of the past and looking increasingly to use instruments which have been tested and analysed for their validity and reliability. This has been supplemented by analyses of existing longitudinal data and some growth in studies of a qualitative nature. The challenge for the field is to develop better insights and, as a corollary, better theoretical models which account for student engagement (or the lack of it) with science. This is particularly pressing in the case of girls and certain ethnic and minority communities. Here, the research focus needs to be on identifying student aspirations, their formation and their diversity. The question to be explored, then, is what kind of formal educational experience in science might engage young people and assist a process of self-realisation – either by developing a better knowledge and understanding of the diversity of future careers offered by science or by developing an enhanced sense of self-esteem acquired through satisfactory learning experiences in science. Some of this could be achieved by paying more attention to educating students about the career opportunities offered by science. After all, students cannot aspire to that which they have never seen. A recent analysis of research in science education (Lee et al. 2009) of the three leading journals in the field would suggest that the topic still remains of interest, because the findings are of significant interest to policy makers and because, we contend, the answers to the questions raised by the study of attitudes and aspirations towards science are of central concern to improving any education in or about science.

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