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**Attitudes, interest and factors influencing STEM enrolment behaviour - an overview of relevant literature**

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# Abstract

Post-compulsory participation in science, technology, engineering and mathematics (STEM) education is an ongoing international concern and forms a key motivation underpinning the Interests and Recruitment in Science (IRIS) research project. In this chapter, we draw upon the extensive research base connected to this issue in order to draw out and reflect upon some of the factors influencing STEM enrolment behaviour, paying particular attention to issues of gender imbalance in STEM study. In the first half of the chapter, we focus on theoretic models of choice, calling attention to research on attitudes to science, which is considered closely related to post-compulsory subject choice. We also acknowledge work that draws upon psychological constructs related to identity and interest, which also may inform understanding of STEM participation. In addition, the complexity of the issues surrounding and underpinning STEM enrolment is, we believe, highlighted by the relatively limited number of models of enrolment behaviour that integrate results from a range of research. Following this reflection, the remainder of the chapter is devoted to outlining a number of factors which have been identified by multiple research studies as influencing STEM choice, namely: age, attainment, teaching and learning, school type, influential individuals (parents and teachers), and images of science and scientists. We finish by reflecting on the influence of gender on subject choice, given the IRIS study’s particular concern with this issue.

# Introduction

There have been many calls internationally for more people studying science, technology, engineering and mathematics (STEM), although the real need for more STEM students has been challenged at least in the UK (Smith, 2010a, 2010b; Smith & Gorard, 2011). Since the 1970s, researchers have discussed enrolments in the sciences in terms such as the ‘flight from science’ (Reitz, 1973). Concerns about the trend away from studying the sciences have continued since that time (Cleaves, 2005; George, 2006; Ormerod & Duckworth, 1975; Solomon, 1997). Several explanations for the ‘swing from science’ in Britain have been suggested, including a decrease in interest in science and disaffection with science and technology among students. In particular, concerns about declining enrolments have focused on interests and attitudes, noting that pupils’ attitudes likely play a role in their choice of subjects (e.g. Atherton, Cymbir, Roberts, Page, & Remedios, 2009; Ormerod & Duckworth, 1975; Vidal Rodiero, 2007). An additional, related, focus has also been on the quality of science education in schools (Bull, Gilbert, Barwick, Hipkins, & Baker, 2010; Fensham, 2008; Goodrum, Hackling, & Rennie, 2001; HM Treasury, 2006; Millar & Osborne, 2001; National Academy of Science: Committee on Science Engineering and Public Policy, 2005).

There are many similarities in enrolment patterns among European Union countries and worldwide, where recruitment to STEM subjects is falling (Ainley, Kos, & Nicholas, 2008; European Commission, 2010; OECD, 1997; Eurydice, 2012; Sjoberg, 2002). Several cross-cultural international comparative studies have been conducted which address issues of enrolment in the sciences by exploring influencing factors such as achievement, attitudes and relevance with differences most pronounced when comparing developed and developing countries (Barmby, Kind, & Jones, 2008; Jenkins 2006). Examples include Science and Scientists (SAS) which evolved into the Relevance of Science Education (ROSE) project (Jenkins & Nelson, 2005); Trends in Mathematics and Science Education (TIMSS) (Kaya & Rice, 2010) and the Programme for International Student Assessment (PISA) (Olsen & Lie, 2011; Olsen, Prenzel, & Martin, 2011).

The IRIS project aims to understand young people’s choices with regard to participation in STEM education, particularly in the transition from upper secondary school to higher education. This chapter provides an overview of some of the extensive range of literature in the area of STEM subject choice, exploring the question: what factors influence STEM enrolments? In this chapter, as in much of the literature, we describe the concern with enrolments (the result of the actual act of choice) using terms such as subject choice, subject uptake, participation in STEM, enrolment patterns/behaviour and recruitment. Although in many publications, the act of choice is described by the term ‘interest’, we categorise interest, attitude and identity as factors which explain or help us to understand this behaviour.

The issues relating to STEM participation in higher education are best understood when we consider both school and childhood experiences. In this chapter, we explore the factors affecting STEM subject choice and enrolments, interest, and attitudes towards science, as distinct from a treatment on the research on drop out/opt out from STEM programmes (Ulriksen, Madsen, & Holmegaard, 2010; see also Part III in this book). We begin with a brief overview of the methodological and theoretical approaches that have been taken by many researchers in the field to describe, understand and explain patterns in STEM enrolments, highlighting the common issue across the constructs – inconsistent and varied conceptualisations of theory. This provides a brief follow-on from the chapters in Part I of this book, which focused on the expectancy-value model and narrative and gender perspectives which dominate the work in the IRIS project. Here we briefly explore models of enrolment and some key constructs for understanding choice of STEM. The remainder of the chapter then explores key factors affecting STEM choices for young people derived from empirical studies.

# Exploring subject choice and enrolments

Subject choice for A-levels (or upper secondary school) is of critical importance since it has consequences in terms of career paths (Lamb & Ball, 1999; Warton, 1997; Warton and Cooney, 1997).

‘Students who study Physics and Chemistry, for example, have a wide range of further education courses available to them, from engineering to the arts. Those who do not do any science or mathematics courses may have more limited choices both in further education and in the types of jobs they want to pursue’ (Lamb & Ball, 1999, p.10).

Studies on subject take-up have mostly centred around the idea of individual choice with emphasis on the influence of career value, interest value, performance expectations and perceptions of the subject (Greenfield, 1997; Kelly, 1988b; Malone & Cavanagh, 1997; McEwen *et al.*, 1997; Solomon, 1997; Stokking, 2000; Ventura, 1992; Whitehead, 1996; Wikeley & Stables, 1999; Woolnough, 1994). A vast array of factors has been considered to be influential in enrolments and subject choice (Barnes, McInerney, & Marsh, 2005; Lyons, 2006), particulalry gender and achievement (Colley & Comber, 2003; Davies, Telhaj, Hutton, Adnett, & Coe, 2008; Francis, 2000; Francis, Hutchings, Archer, & Melling, 2003; Lamb and Ball, 1999; [Skelton, 2010](#_ENREF_65); [Skelton, Francis, & Read, 2010](#_ENREF_66); [Smyth & Darmody, 2009](#_ENREF_69)). This section presents an overview of some of the key theoretical and methodological approaches to the study of STEM choices, notably, attitudes towards science, modelling the choice process and explanatory constructs derived from psychology such as identity and interest.

## Attitudes towards science

Within the field of science education concern for falling enrolments and attitudes of secondary school pupils in England led to a research focus on attitudes towards science (Reid, 2006). The term ‘attitude’ has become part of our ‘common-sense’ language and has arisen out of the need to explain and predict behaviour. It can be defined as feelings towards an object or an evaluative judgement formed by a person (Ajzen, 2001; Crano & Prislin, 2006; Kind, Jones, & Barmby, 2007), and is seen as a construct which precedes behaviour and guides our decisions and choice, even though it is not directly observable. Attitude has cognitive, affective and behavioural components and there is a strong relationship between all three since the manner in which a person perceives an object should influence the strength of their feeling about it and thus in turn, influence his or her overt behaviour (Lemon, 1973). Attitudes can be defined by their content (for example, attitude towards science), their direction (positive, negative, neutral feelings about science, for instance) and their intensity (such as strongly disagree/agree). Within science education, it can be divided into ‘attitudes towards science’ (for example towards school science or ‘real’ science) and ‘scientific attitudes’ (such as mind-sets about thinking in a scientific way) (Gardner, 1975). ‘Attitudes towards science’ are what is frequently studied when exploring subject choice.

Due to the abstract nature of attitude (Ramsden, 1998) the task of measurement becomes complex, since attitude cannot be observed directly but must always be inferred from behaviour. Research on attitudes towards science has received much criticism around the validity of the attitude constructs (Fishbein & Ajzen, 1975; Gardner, 1975; Munby, 1982) and lack of standardised definitions and measurement instruments, which can often lead to contradictory results (Barmby, Kind, & Jones, 2008).

Despite these challenges, much research highlights that attitudes towards science form a key factor influencing enrolments and subject choice (e.g. Tytler & Osborne, 2012), and a number of seminal review papers have been conducted in the area (Gardner, 1975; Osborne, Simon, & Collins, 2003; Schibeci, 1984; Tytler & Osborne, 2012). Gardner (1975) declared in his review of attitudes to science (reiterated later by Schibeci (1984, p.26)) that ‘*the volume of research on attitudes in the field of science education has grown so large that it is no longer possible to produce a comprehensive review of the literature within the confines of a journal article*’ (p.2). More recently, Osborne et al. (2003) highlighted a more pressing issue: that while there is a large volume of work exploring student attitudes towards science ‘*it has little to say definitively about how the problem could be remedied*’ (p.1073). In the same way as the factors affecting student subject choice are complex and multifaceted, so too are the influences on student attitudes. Consequently many of the research studies on attitude measurement concentrate on the influence of a single variable, which may further contribute to the problem of practical implications. (Due to the enormous volume of studies in this area, we do not attempt to summarise them here.)

## Models of enrolment behaviour

The process leading to enrolment in STEM study is complex, with various individual, psychological, contextual and social influences (Wang, 2013). Owing to the complexity of the subject choice process, there have been limited attempts to explore the relationships between these factors in a manner which could productively integrate empirical results into models of enrolment behaviour. Some recent examples of those that have include: Bøe, Henriksen, Lyons, and Schreiner, 2011; Bøe and Henriksen, 2013; Cerinsek, Hribar, Glodez, and Dolinsek, 2013; Jensen and Sjaastad, 2013; Skryabina, 2000; Smyth and Hannan, 2002; Wang, 2013 and several chapters in the present volume. The majority of frameworks used in these models originate in the field of motivational psychology. These include:

* Eccles et al.’s expectancy-value model presented in Chapter 2, which describes how young people base their educational choice on their expectation of success and the interest and enjoyment, attainment value, utility value and cost they ascribe to various educational options.
* Fishbein and Ajzen’s Theory of Reasoned Action, which explains that a person's voluntary behaviour is predicted by their attitude toward that behaviour and how they think other people would view them if they performed the behaviour.
* Theory of Planned Behaviour, which is an extension of Fishbein and Ajzen’s Theory of Reasoned Action and argues that attitude toward behaviour, subjective norms, and perceived behavioural control, together shape an individual's behavioural intentions and behaviours (Dalgety, Coll & Jones, 2003; Khoo & Ainley, 2005).
* Social Cognitive Career Theory (SCCT), whcih is based on Bandura’s (1986) general social cognitive theory and posits that the determination to produce a particular choice can be explained as a result of interests and self-reference beliefs. Key factors in SCCT include self-efficacy beliefs, outcome expectations, interests, environmental support and barriers, as well as choice actions (Lent, Sheu, Gloster, & Wilkins, 2010).

In a study drawing on the Eccles et al. expectancy-value theory to explore the choice of Physics in Dutch secondary education, the main predictors of choice were found to be: future relevance, interest, appreciation, physics achievement, self-confidence, difficulty, and clarity (Stokking, 2000). Some of these predictors were also found in an analysis of patterns for career choice among university students in Finland (Salmi, 2002). These patterns included: interest in the context of study and future work; interest in future work career, salary, and new positions; social pressure from parents, relatives and peer groups; the effect of career campaigns, school career advice, and work experiences; a special course at school and an exceptionally skilful teacher; own hobby, media, and other informal sources.

Social Cognitive Career Theory (SCCT), has been used in a small number of studies on STEM-related academic choice intentions (e.g. Gainor & Lent, 1998; Lent, Lopez, & Bieschke, 1993; Lent, Lopez, Lopez, & Sheu, 2008). Wang (2013) found that intent to pursue STEM was significantly and positively influenced by maths self-efficacy, exposure to maths and science and maths achievement (in the latter case, with the exception of Asian students). Self-efficacy in STEM while at university has also been shown to be a predictor of college majors (Heilbronner, 2011).

## Psychological constructs: the act of choosing

Solomon (1997) asserts that little effort has been made to explain psychological effects involved in the act of choosing. She feels that there is a need to focus on the construction of personal choosing, and cultural persuasion rather than simple explanations such as ‘liking’ or finding ‘interesting’ aspects of the subject (Solomon, 1997). Historically, work in this vein has included analysis of the personal process of subject choice which led to Kelly’s (1988) extensive work on girls in science and Head’s ‘personality in the pursuit of science’ (Roe, McClelland & Head, cited in Collings & Smithers, 1983). More recently work focusing on subject choice process has moved from cognitive preferences (Malone & Cavanagh, 1997) to the formation of science choices (Cleaves, 2005; see also Chapter 7 in the current volume) and constructing desirable identities (Holmegaard, Ulriksen, & Madsen, 2014; see also Chapter 3 in the present book). In the next section, we articulate what is meant by identity within the context of STEM enrolments.

#### Identity

It has been claimed that ‘*post-16 choices are bound up with the expression and suppression of identities. These choices are one aspect, of varying importance, of the sort of person you may become*’ (Ball, Maguire, & Macrae, 2000). Identity in science education has been used to address questions such as ‘*what does it mean to do science*?’ (Carlone, 2003, p.21) or who do ‘*we think we must be to engage in science?*’ (Calabrese Barton, 1998, p.379). The construct is also explored in Shanahan (2009) and in chapter 3 of this volume with regard to narrative explorations. Similarly to the concept of attitude, researchers have employed a multitude of definitions of ‘identity’ both in sociology (Lawler, 2008) and psychology (Cȏté & Levine, 2002). The nature of the problem stems from the fact that there are at least two aspects to identity, core identity and a concept of the self that is frail, brittle and fragmented (Roth & Tobin, 2007). A generally accepted definition of identity is encapsulated by Ehle (1989) who sees identity as: ‘*how one sees oneself (self-concept), how one evaluates himself (sic) (self-esteem), how one desires to be (self-ideal), and how assured one is at meeting life (self-confidence)*’ (p. 46). Studies of identity have recognised that identities are not isolated constructs but co-constructions between the individual, their surroundings and their relationships, consequently, focused on individuals, their actions and their agency (Shanahan, 2009). Schreiner and Sjoberg (2007) focused on student ‘identity construction’, a ‘*who do you want to be*’ rather than ‘*what do you want to be’* approach also thought to play a stronger role in the way young people in western societies relate to science.

In an exploration of 10-11 year olds’ attitudes toward and interest in science, identity has been described as an embodied and a performed construction (Archer et al., 2010). Similar to other work (Jenkins & Nelson, 2005), this research found that although children can report enjoying science they may still not choose it as they see it as ‘not for me’. Analysing decisions regarding participation in STEM using an identity framework involves exploring relationships with family, teachers, peers and others to determine the degree of synergy or disjuncture experienced by young people between their everyday lives and the pursuit of STEM (Archer, Hollingworth, & Halsall, 2007). Pike and Dunne (2011) report that pedagogies of secondary school science have a major influence on students’ learner identities, their identification with science, and their decision about whether to continue to pursue the study of science as part of their future. Wong (2012) also applies an identity lens, using Bourdieu’s notion of habitus, to explore the ways in which ‘two high achieving working-class’ British Asian girls engage with science, while Archer et al. (2012; see also chapter 6 in this volume) explore how family habitus contributes to the formation of children’s aspirations in science. Taconis and Kessels (2009) argue that the unpopularity of science, at least in industrialised countries, is due to the gap between the subculture of science and students’ self-image. They found that Dutch students perceived themselves as less similar to science prototypes than to humanities prototypes, viewing peers who favoured science subjects as less attractive, less popular and socially competent, less creative and emotional and more intelligent and motivated than peers who favour humanities. An additional study examined the nature and extent of participation in science-based courses in Canada through cultural reproduction and gender lenses, showing how the intersection of organisational structures and cultural capital shapes STEM opportunities for students (Adamuti‐Trache & Andres, 2008). Other researchers have discussed the ‘process of enculturation’ of individuals to a culture, or a science sub-culture, as the acquisition of values, beliefs, expectations, communicative codes, conventional actions and attitudes of the science culture, in addition to the acquisition of knowledge (Aikenhead, 2001; Krogh & Thomsen, 2005; Lyons, 2006).

Holmegaard, Madsen, and Ulriksen (2014) report that that the students who did not choose STEM, perceived STEM as stable, rigid and fixed, and, hence, too narrow a platform for developing and constructing desirable identities. Furthermore, the process itself of choosing was a complex ongoing and social process, rather than an isolated individual event (also see Chapter 3). Hernandez-Martinez et al. (2008) identified four identity repertoires of aspiration and choice in higher education mathematics in the UK: ‘becoming successful’, ‘personal satisfaction’, ‘vocational’ and ‘idealist’, which were strongly related to background factors such as class, gender and ethnicity. Overall, studies reflect that continuities and discontinuities between students’ identities and science are likely to play an important role in the choice process, leading to the use of identity as an important theoretical construct in the study of choice. Interest is another key construct in the study of choice and the next section explores the concept of interest in science education.

#### Interest

In general, the term *interest* describes the mind-set characterised by a need to give selective attention to something that is significant to a person such as an activity, goal or subject. With regard to science it can be used to describe ‘*tendencies to engage in science-related activities inside and outside of schools*’ (Olsen, Prenzel, & Martin, 2011 p.2). The notion of interest in science can be interpreted in a number of ways, particularly in relation to students’ motivation in science, and similarly in relation to attitude and identity. The lack of a consistent theory of interest has persisted since the 1940s (Allport, 1946; Renninger & Hidi, 2011) and researchers often fail to articulate their conceptualisation of interest and the connections to their measurements. Despite this, research conducted over the years has articulated five characteristics of interest as a motivational variable: interest is content or object specific; it involves a particular relation between a person and the environment, sustained through interaction; it has both a cognitive and an affective component; a person may not be aware of when their interest was triggered or their interest during engagement; and it has a neurological/physiological basis (see Hidi & Renniger, 2006 and Renninger & Hidi, 2011 for a full explanation of each characteristic).

A number of studies (Ainley, 2007; Hidi & Renninger, 2006; Krapp, 2002) discuss interest as a psychological state, while others (Ainley, 2007; Silvia, 2006) focus on interest as an emotion. The most commonly referred to form of interest is individual interest: a personal orientation, predisposition or tendency to engage with something, which would seem also to be applicable to individual differences in students’ general orientation to science (Ainley & Ainley, 2011a). Situational interest however, is a temporary concentration of attention and feeling in response to a specific situation (Hidi, 1990) that can be ‘triggered’ and ‘maintained’ (Hidi & Renninger, 2006) or ‘stabilised’ (Krapp, 2003). Renninger, Hidi, and Krapp (1992) view interest from a person-object theory perspective, as a relationship between a person and an object. Two models of interest development which have been frequently used in research include: Krapp’s (2003) stage model of interest development, an extension of the person-object conceptualisation, and that of Hidi and Renninger (2006). Both distinguish between stages of interest development, from an ‘emerging’ to a more well developed, individual interest. Knowledge, affect and value are key components of a strong individual interest. A full account of the conceptualisations of interest can be found in Renninger and Hidi (2011) and Krapp and Prenzel (2011). The latter is also consistent with sociological theories of interest development as an integral part of identify formation (Olsen & Lie, 2011; Osborne, Simon, & Collins, 2003; Schreiner & Sjoberg, 2007).

Research has shown that individual interest in science is very important for choosing science and often forms at an early age (Ainley & Ainley, 2011b; Maltese & Tai, 2010; Tai, Liu, Maltese, & Fan, 2006). Interest was identified as the dominant influence on enrolment behaviour in many studies examining both the direct and indirect effects of interest (Kelly, 1988) and strong predictive relations have been found between personal value of science, enjoyment of science, and interest in learning science (Ainley & Ainley, 2011b). Consequently, interest is one of the strongest predictors of decisions in relation to choice of subjects and courses (Olsen, Prenzel & Martin, 2011, Chapter 9 in the present volume). Regan and Childs (2003) found that students’ choice of science at the junior level was determined by their expressed interest in the subject and by their future/career plans. Taking career expectations as an indicator of interest, a large-scale study of 3,300 university-level students found that those who had expected to be working in a science career by age 14 were 3.4 times more likely to earn a physical science and engineering degree than those who had not (Tai et al., 2006). Maltese and Tai (2010) also found that the majority of scientists reported that their interest in science began before their middle school years. Another recent study used PISA 2006 data to explore student interest in science across different countries. This research found that having a general interest in learning science predicts both current and intended future participation in science related activities and concluded that where science education is perceived as personally important to students, and where they are doing well, a stronger interest in learning science will result (Ainley & Ainley, 2011a).

In the next section, we explore in more detail empirical studies of some of the key factors influencing STEM choice and enrolment patterns, based on research drawn from the range of perspectives discussed in this section, both as single variable perspectives and models of decision-making processes.

# Factors influencing STEM choice

The remainder of this chapter concentrates on the identification of various influences on enrolment behaviour and consideration of their importance. The findings from the studies reviewed here tend to produce fairly consistent results in so far as they have identified the same variables, but differences occur in the relative importance attributed to each variable. This seems most likely to be a consequence of the varying contexts of the research, different school systems and techniques of analysis, which provide a range of additional factors which could be influential on findings. Moreover, the same factors cannot be assumed to exert influence in the same way on take-up of the three main science subjects (Smyth & Hannan, 2002). Complicating the picture further, a recent review of STEM choices in the UK highlighted that much of the research in the area relied on small sample sizes, short-term ‘snapshot’ approaches, inconsistent analysis, imprecise terminology and over-reliance on historical (pre-2000) data (Tripney et al., 2010).

In a study investigating information sources utilised by students selecting subjects, Warton (1997) reports that adolescents indicate a lack of knowledge about their options. Similarly, Wikeley and Stables (1999) cite studies that found that students make naïve links between subjects and careers, that the choices are volatile, that parents act as the ‘*chief advisers*’, that boys and girls can receive differing advice and that schools implement implicit policies of selection. Warton (1997) concurs, stating that she found little evidence that students treat subject choice as a deliberate planned activity where information should be sought. Thus when students are making subject or career decisions they generally attempt to match personal needs with the experiences which are likely to result from the choice (Malone & Cavanagh, 1997). Students are more likely to choose a subject that they believe to be useful for a job or career or a requirement for a college course, a subject they find interesting, or a subject that they can achieve a good grade in (Regan & Childs, 2003). Similar reasons were also found to underpin students’ subject choices at ages 14 and 16 in Britain (Blenkinsop, McCrone, Wade, & Morris, 2006), as well as A-level subject choices (Vidal Rodiero, 2007). The latter two studies also highlighted that students’ choices (or anticipated choices) vary over time, as well as reflecting the role played by families and school experiences on choices.

While the above studies focus on subject choice more broadly, the sections below focus on factors identified by a number of studies as being key influences on choice of and, consequently, enrolments in science. Some of these factors could be considered individual background characteristics such as age, ability and gender, while others involve the way in which students experience science in school (teaching and learning, other school-related factors) and key individuals of influence (teachers and parents). We also discuss possible influences of the images students have of science and scientists.

## Age

Research has suggested that attitudes towards science decline with age, particularly in secondary school (Barmby et al., 2008) with positive attitudes towards school science declining significantly from the age of 10 (Bennett & Hogarth, 2009; Murphy & Begg (2005). George (2006) explored attitudinal dimensions in American middle and high school students and found that overall students’ attitudes about the utility of science were positive but their attitudes towards school science declined over the middle and high school years. However, other research has challenged this perspective, reflecting that attitudes to school science do not necessarily decline as students move into secondary school (DeWitt, Archer, & Osborne, 2014; Lyons & Quinn, 2010; NFER, 2011). Despite mixed findings with regard to potential declines in attitudes to science, research more clearly suggests that positive attitudes to science at a young age are related to later participation in science. For instance, attitudes to subjects at the age of 14 were found to be highly predictive of Biology, Physics and Chemistry take-up (Lamb & Ball, 1999). Similarly, Lindahl (2007) found that Swedish students had formed their career aspirations and interest in science by the age of 13 years, highlighting the importance of engaging with students long before they make their choices about what subjects to select in school (Tytler & Osborne, 2011).

## Attainment

Previous science performance is highly predictive of science take-up: young people with higher levels of prior attainment are more likely than those with lower levels of prior attainment to continue their studies in STEM subjects (Smith & Gorard, 2011). For instance, Gill and Bell (2013) found that attainment in physics and maths at age 16 (and attending a grammar school) was associated with a greater probability of uptake of A-level physics. However, other work has suggested that interest and enjoyment may be more predictive of a degree in STEM than achievement alone (Maltese & Tai, 2011). Moreover, the link between attainment and participation or take-up may also vary by subject within STEM. For instance, in an Australian study, mathematics and the physical sciences were claimed to be the domain of high achievers and ability grouping at junior level was found to have a significant relationship with take-up of Physics and Biology (Lamb & Ball, 1999). All students from ability grouped classes were more likely to take Physics than pupils from mixed ability classes. Students in the top and bottom streams were less likely to choose Biology than students in mixed ability or middle stream classes.

## Teaching and learning

The quality of teaching is a major determinant of student engagement with and success in a school subject (Tytler & Osborne, 2011) and a number of studies reflect the critical role that school science experiences may play in influencing STEM choice. Chapter 7 in the current volume also discusses how school science curriculum may impact on STEM uptake. A huge variation in quality of teaching and resources for science in Australian schools has been found, with some schools having outstanding programs supported by well qualified and enthusiastic teachers, while others have no programs in place at all (Sadler, 2002). A telephone survey indicated some additional causes of students’ retreat from the sciences, including poor transition from primary to secondary school, low levels of experimental work in science classes, an increase in available choice of non-science subjects, advice from career guidance teachers and lack of role models in science (Sadler, 2002). Tytler and Osborne (2011) have also suggested that school science lacks purpose for students, making it unappealing, which would in turn dissuade students from continuing with post-compulsory science. Relatedly, a study of students in England found key influences on post-16 choice of science to include school pedagogical experiences, the different ways subjects were perceived (e.g. as ‘higher status’ or not) and students’ future aspirations (Pike & Dunne, 2010). Similar factors – such as the ability to imagine themselves in science and experience of school science – have also been identified as possible reasons for the decline in science enrolments in Australia (Lyons & Quinn, 2010). Moreover, such factors (e.g. achievement in science, science classes and teachers, as well as interest in science) were identified by practicing scientists as contributing to their decision to pursue science (Venville, Rennie, Hanbury, & Longnecker, 2013). A retrospective study conducted in the US with 8,178 university students focusing on science attainment at university (which would be connected to retention) found that one of the significant predictors (in addition to achievement) of success in university science courses was the type of instruction students received in high school (Tai, Sadler, & Mintzes, 2006).

The experience of a school/education activity (such as a science competition, camp, teacher demonstrations, project work, or enrichment activity) was the second most common factor attributed as the initial source of interest and was a greater influence on females than males (Maltese & Tai, 2010). The influence of the teacher was also prominent for both male and female students who became interested in science after middle school. In addition, PISA 2006 data indicate an association between students’ motivation towards science, enjoyment of science and future orientation towards science, and the frequency of various teaching and learning activities in the classroom (Hampden-Thompson & Bennett, 2013).

## School type

Type of school seems to be another factor influencing choice, where girls from single-sex schools are more likely to choose physics than those from mixed schools (Bryne, 1993; Solomon, 1997). A task force in Ireland examined schools that exhibited a high take-up of the physical sciences in order to identify strategies for increasing take-up. Four approaches were illuminated in these schools, which also had a higher level of laboratory resources than the norm (The Task Force on the Physical Sciences, 2002): high priority attached to science at management level; good subject level coordination and planning; emphasis on building positive student experiences at the junior level; and emphasis on practical work. Other work comparing high- and low-uptake schools found that students in high-uptake schools appear to make a proactive choice in relation to career aspirations, rather than a reactive choice on the basis of past experience (Bennett, Lubben, & Hampden-Thompson, 2013).

## Persons of influence

The influence of parents and teachers on choices, particularly during the earlier years of schooling, has been well-documented (Maltese & Tai, 2010; Mujtaba & Reiss, 2012; Olszewski-Kubilius & Yasumoto, 1994; Raved & Assaraf, 2011; Salmi, 2002; Solomon, 1997). Perceived support from both parents and teachers was identified as the strongest predictor of continuing with a subject (Kelly, 1988; Maltese & Tai, 2010). Research has also shown that the early years of secondary education are crucial in terms of the impact a teacher can have on students’ views of science and careers involving science (Cerini, Murray, & Reiss, 2004; Munro & Elsom, 2000; Osborne & Collins, 2001; Watt, 2005). Students who report negative interaction with teachers are less likely to choose Physics (Smyth & Hannan, 2002).

More recent work has highlighted the important role that teachers play in promoting student interest in science through scaffolding and guidance (Xu, Coates, & Davidson, 2011). Similarly, Sjaastad (2011), in his exploration of people influencing STEM choice, distinguished between persons acting as *models* (e.g. parents, teachers or others displaying a STEM professional identity) and those acting as *definers* (parents or others helping the young person in the process of setting goals, defining values and identifying personal strengths in the educational choice process). For instance, teachers are models by displaying how STEM might bring fulfilment and by giving pupils a positive experience with the subject, and they are definers who help young people discover their STEM abilities. Teachers, however, are generally not well informed about careers in or outside science (Stagg, 2007) and often do not perceive themselves to be sources of careers information for their students (Munro & Elsom, 2000).

Other factors, such as the education level of parents or social class background, have also been demonstrated as influencing choice (Ayalon, 1995; Solomon, 1997; Uerzet al., 1999), however, socio-economic status has been shown to have only an indirect effect on young people’s perceptions of their capabilities (Blenkinsop et al., 2006). All the same, students who continue within STEM are more likely to have higher socio-economic status (Thomson & De Bortoli, 2008). The degree and extent of relatively low attainment amongst students from lower socio-economic groups across all subjects in school has recently been explored in light of recent curricular reforms in England (Homer, Ryder, & Donnelly, 2013). This work explored the impact of curricular reform on the overall pattern of participation and whether the existing stratification persisted following the reform. Using data from the National Pupil Database this study shows that curricular reform ‘and the offer of entitlements for particular course can and do impact on stratification’ (p. 261), at least for some sub-groups. Relatedly, Lyons (2006) found higher levels of cultural and social capital in students choosing physical sciences relative to those who did not. They had supportive family relationships, parents who recognised the value of education and family members supporting an interest in science. Similarly, other work highlights that the transmission of cultural capital can restrict STEM pathways when parents do not encourage academic pursuits in STEM (Adamuti-Trache & Andres, 2008). Focusing on children’s aspirations and attitudes towards science Archer and colleagues (Archer et al., 2010; Archer et al., 2012; Archer, DeWitt, & Wong, 2014; see also Chapter 6 in the present volume) explore similar themes.

## Conceptions of science and scientists

Conceptions of science and scientists held by students have also been postulated as forming an integral part of the framework of the subject choice patterns. That is, the ability of students to imagine themselves in a science profession (which, in turn, impacts on subject choice) is influenced by the images they hold of science and scientists. One recent study found that US students considered scientific professions to be less creative and less people-oriented than other career choices, holding misperceptions that ‘science is difficult, uncreative and a socially isolating pursuit’ (Masnick, Valenti, Cox, & Osman, 2010, p. 693). Another study (Dalgety & Coll, 2004) found that students saw chemistry and media portrayals of the subject in terms of images of laboratory work, experiments and wearing white coats, consistent with early research on conceptions of science (Mead & Metraux, 1957; Schibeci 1986). Within the ASPIRES project, Archer et al (2010) found that science was viewed as a difficult subject that requires a natural interest, which sometimes students associated with natural ability. Although students were found to be mostly enthusiastic about science, aspects of a science identity were rejected by many students along gender, ethnic, and class lines. Steinke et al. (2012) explored traits found in media portrayals of scientists with 370 students from three middle schools in the U.S. The results clearly indicate that when identifying with female scientists, students identified most strongly with characters showing *respect, caring,* and *dominance.* When identifying with male scientists, however, students selected those with the traits *intelligence, dominance*, and *respectedness*. This suggests that students do identify with scientists on television; it also reflects that these identifications are nuanced and depend on the TV scientists’ behaviours, gender, and context. Although few students held ‘negative’ representations of science/scientists, other recent work reports that students are influenced by popular constructions of science, such as ‘specialist’ and ‘clever’, which in turn feed into their feelings that science is not for them (DeWitt, Archer, & Osborne, 2013).

Another key influence on STEM subject choice and retention is that of gender, which was also a focus of the IRIS project discussed in this volume. The next section focuses specifically on what the research has to say about gender as an influencing factor on subject enrolment.

## Gender as an influencing factor

One of the major factors connected with student interest in school science is gender, with boys consistently showing more positive attitudes to school science than girls (e.g. Brotman & Moore, 2008; Haste, 2004; Jenkins & Nelson, 2005; Jones, Howe, & Rua, 2000; Murphy & Whitelegg, 2006; Scantlebury & Baker, 2007; Sjoberg & Schreiner, 2005). Given the relationships between interest in science and decisions to pursue post-compulsory science, this gendered difference in interest is likely to contribute to gendered subject choice. Allegrini explores the construct in more depth in chapter 4 but an up to date review of the literature on gendered study choice can be found in Yazilitas, Svensson, de Vries, and Saharsp (2013).

The major concern with regard to the low representation of women studying science is the polarization of choices of boys and girls (Bell, 2001; Smyth & Hannan, 2002), which leads to potentially large numbers of qualified people missing from the work force (Fouad, 1995; Malone and Cavanagh, 1997). Moreover, gendered choice of science is also an equity concern, given the opportunities that can be open to individuals who pursue post-compulsory science. The metaphor of a ‘leaky pipeline’ is often used to describe the manner in which individuals, particularly females, drop out of science at various choice points (Blickenstaff, 2005). Gender differences in subject choice have been well documented and persist despite minimal – if any – attainment-related differences between genders (e.g. Hyde & Lynn, 2006) and many interventions targeting girls and science (Brotman & Moore, 2008; Colley & Comber, 2003; Davies et al., 2008; Francis, 2000; Francis et al., 2003; Malone & Cavanagh, 1997; Murphy & Whitelegg, 2006; Sadler, Sonnert, Hazari, & Tai, 2012; Skelton, 2010; Skelton, Francis, & Read, 2010; Smyth & Darmody, 2009; Whitehead, 1996). Indeed, despite these efforts, undergraduates in physical sciences in the UK remain largely high-achieving, White, middle-class young men (Smith, 2010a).

Blickenstaff (2005) summarises the explanations put forward in the research for the underrepresentation of women in STEM careers and post-compulsory study as being: biological differences between men and women; girls’ lack of academic preparation for a science major/career; girls’ poor attitude toward science and the lack of positive experiences with science in childhood; the absence of female scientists/engineers as role models; science curricula being irrelevant to many girls; the pedagogy of science classes favouring male students/a ‘chilly climate’ for girls in science classes; cultural pressure on girls to conform to traditional gender roles and an inherent masculine worldview in scientific epistemology. Blickenstaff argues that these explanations ‘hold very little water’ in explaining the underrepresentation of women in science and concludes with seven suggestions to tackle the under-representation. In the UK, the schools inspection agency has reported that although many girls do not consider gender to be a barrier to participation, their actual choices of subjects and careers remain gender-traditional (Ofsted, 2011).

A 2008 special issue in Studies in Educational Evaluation entitled *Narrowing the Gap* explores trends in gender and achievement in the TIMSS study (Neuschmidt, Barth, & Hastedt, 2008; Thomson, 2008). In addition, studies in the UK, Ireland and United States reflect that girls are now out-performing boys in most school subjects (McEwenet al., 1997; Smyth & Hannan, 2002; Solomon, 1997). Nevertheless, gender remains a strong predictor of A-level physics uptake in the UK, even controlling for prior attainment (Gill & Bell, 2013). Skelton (2010) claims that despite girls being heralded as educational ‘success stories’, classroom research continues to find they are less confident than boys. The discussions about girls and science suggest that there is a disparity between the ‘masculine’ image of the physical sciences and girls’ identification with the ‘feminine’ role in adolescence (Archer et al., 2013; Brotman & Moore, 2008; McEwenet al*.*, 1997) and feminist theorists have a long established concern about this association between STEM and ‘masculinity’ (Burton, 1990; Haraway, 1988; Harding, 1998). For instance, Archer et al. (2013) found that the highly gendered nature of girls’ aspirations were indicative of underlying masculine constructions of science careers and how imagined science careers were incompatible with girls’ performances of popular femininity; see also Part IV of the present volume for discussions of this.

A consistent picture from early research on choosers of science depicts them as male (Baker & Leary, 1995; Buck, Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008). Many students consider STEM subjects to be ‘for boys’ (Adamuti‐Trache & Andres, 2008; Calabrese Barton & Tan, 2009; Mendick, 2005) – or at least science careers as being done primarily by men – a perception that could contribute to girls not seeing themselves as ‘science people’ (Carlone, 2003). A recent cross-national analysis of young people’s preferences, expectations, and perceptions of ability regarding STEM subjects using PISA data from four countries (Switzerland, Finland, Australia and Korea) found that gender plays a crucial role in students’ choices regarding STEM study and careers (Buccheri, Gürber, & Brühwiler, 2011). Moreover, even within STEM, career choices tend to follow a gendered pattern with females choosing medical/health and biology careers and males choosing engineering and computer sciences (Sikora & Pokropek, 2012). One potential reason underpinning such discrepancies, beyond associations between science careers and masculinity, concerns the kinds of values that students seek to fulfil in their subject – and career – choices. For instance, students’ physics identity, which strongly predicted career intentions in physics, was closely linked to a desire to pursue a career that involved working with knowledge, skills or products and negatively related to more people-related career motivations (Hazari, Sonnert, Sadler, & Shanahan, 2010). Similarly, a study of Slovenian university students found that they wanted to do something interesting and fulfilling using their talents and abilities, with female STEM students favouring inter-personal career priorities (i.e. helping other people, contributing to society and protecting the environment) more than males (Cerinsek et al., 2013). Put differently, it is possible that the differential values that male and female students seek in a future occupation at least partly underpin the gender discrepancy in subject choice, given the link between subject choice and career aspirations (Jones, Howe, & Rua, 2000).

Other factors that have been explored as related to gendered choice of science concern the curriculum and students’ self-concept or self-efficacy in science. It has also been argued that curricular content in science is unbalanced, favouring boys’ interests (Brotman & Moore, 2008; Haussler & Hoffmann, 2002) and would benefit from a more human-related focus (Krogh & Thomsen, 2005) that considered ethical factors and how science was relevant to students’ lives (Haste 2004). This situation is also likely to be exacerbated by the way in which the nature and culture of science are portrayed in the classroom (Brotman & Moore, 2008). At the same time, attempts to reform the curriculum to better align with girls’ interests have met with mixed success. While some studies have found that curricular interventions have improved girls’ interest and achievement in science (e.g. Haussler & Hoffmann, 2002), Carlone’s (2004) ethnographic study of girls’ cultural production of science in a reform-based physics class found that the girls were most concerned about maintaining their ‘good student’ identities and resisted promoted science learner identities.

In addition to classroom experiences in science which are more aligned with boys’ interests and portray a masculine view of science, gendered subject choice is also likely to be impacted by students’ self-concept in science. Students with strong self-concepts of their abilities in science are more likely to pursue science once it is no longer compulsory and to aspire to science-related careers (Halpern et al., 2007). However, girls often have less positive self-concepts in science than boys (DeWitt et al., 2013), although this can vary within areas of science (Britner, 2008). Moreover, girls’ self-concepts in science may also be affected by the extent to which they receive recognition of their science achievements or encouragement to pursue science from teachers, family and friends, with research finding that females often receive less recognition and encouragement than males (Carlone & Johnson, 2007; Hazari et al., 2010; Mujtaba & Reiss, 2012).

In addition to work on self-concept in science, other studies have focused on more psychological factors as potentially underpinning gender discrepancies in subject choice. For instance, a study exploring girls’ decisions about whether or not to pursue science via the lens of cognitive preferences found that a large proportion of the girls who chose not to enrol in science, but who were capable – as identified by their teachers – held cognitive preferences for ‘feeling’ and ‘judging’ and negative preferences for ‘intuition’ and ‘thinking’. The cognitive preference differences between the girls who accepted teacher recommendations and those who did not is indicative of a perceived mismatch between the curricula of these subjects and the needs of these students, which may lead them to avoid post-compulsory science (Malone & Cavanagh, 1997).

A more recent study (Zeyer & Wolf, 2010) is based upon a body of work that characterises individuals as being either primarily empathizers, systemizers, or an equal balance of both. *Systemizing* describes the ability to understand the world in terms of a system, whereas *empathizing* is the ability to identify and perceive the mental states of others. In this study, the authors examined whether gender played a role in determining motivation for science learning or whether the personality attributes of either systemizer or empathizer were more significant. Analyses reflected no statistically significant difference in the motivational levels between male and female students to learn science. However, there were highly significant differences between personality attributes, with female students being more likely to be empathizers. This discrepancy between genders has interesting implications, the authors assert, for student engagement with system-rich disciplines such as the physical sciences, with systematizers possibly having a greater *motivation* to learn science than empathizers. Thus, although gender alone was not found to be significant in determining motivation level for science learning, the authors argue that the secondary correlation – that male students are more likely to be systematizers – may help to explain the observed gender differences in the choices of male and female students regarding STEM study and careers.

# Conclusions

The goal of this chapter was to provide an overview of what the research literature has to say about attitudes, interest and factors influencing subject choice in STEM. The message from the literature is “that we are not going to find one single factor which is universally influential; different students are persuaded by quite different factors” (Woolnough, 1994, p.672) and “many different factors contribute to children’s decisions, and these factors are inter-related among themselves” making it “difficult to disentangle the effect of any one variable” (Kelly, 1988, p.18). Twenty years after the Woolnough article, and even longer since Kelly, the research reviewed in this chapter highlights that this is indeed still very much the case.

In this chapter we have explored a myriad of factors that have been proposed as impacting on STEM subject choice and ensuing enrolment behaviour. STEM choice and enrolment have been examined in a number of ways, drawing on both qualitative and quantitative methods in an attempt to unpick and understand this phenomenon more deeply. Much of this work has used student attitudes to science as a starting point, given the links between attitudes and choice. Other work has focused on psychological constructs underpinning the act of choosing, such as identity (also a construct in sociology) and interest. Taken together, research conducted over the years has consistently identified a number of factors related to school (pedagogy/teaching, curriculum, type of school, teachers), family background (parental support and resources), and individual characteristics (age, attainment and, critically, gender), as well as widely-held images of science and scientists, as influencing STEM choice.

Given the complexity of these factors in and of themselves, as well as their interrelationships, it is perhaps not surprising that attempts to integrate the findings from this enormous body of research have been relatively limited. Of those that have, a number have originated in motivational psychology, rather than science education, suggesting that theorisation in this area has further room for development. Studies such as the IRIS project have a role to play in this theorisation but even then, they face challenges in achieving a truly broad view of the landscape. Nevertheless, doing so is critical if we are going to make significant progress in developing interventions with the potential to address the multifaceted issues around post-compulsory STEM choice, including the seemingly intractable one of gender. Thus, while the response of young people to STEM courses and careers remains a policy priority across many nations the search for insights into the factors affecting participation, attitudes, interest and choice will continue.

# References

Adamuti‐Trache, M., & Andres, L. (2008). Embarking on and persisting in scientific fields of study: Cultural capital, gender, and curriculum along the science pipeline. *International Journal of Science Education, 30*(12), 1557-1584.

Aikenhead, G.S. (2001). Students’ ease in crossing cultural borders into school science. *Science Education, 85*(2), 180-188.

Ainley, M. (2007). Being and feeling interested: transient state, mood, and disposition. In P. A. Schutz & R. Pekrun (Eds.), *Emotions in Education*. New York: Elsevier.

Ainley, J., Kos, J., & Nicolas, M. (2008). *Particiaption in science, mathematics and technology in Australian education*. Camberwell, VIC: Australian Council of Educational Research (ACER).

Ainley, M. , & Ainley, J. (2011a). A Cultural perspective on the structure of student interest in science. *International Journal of Science Education, 33*(1), 51-71.

Ainley, M. , & Ainley, J. (2011b). Student engagement with science in early adolescece: The contribution of enjoyment to students’ continuing interest in learning about sciences, *Contemporary Educational Psychology*, *36*(1), 4-12

Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology*, *52*, 27-58

Allport, G. W. (1946). Effect: A secondary principle of learning. Psychological Review, 53(6), 335-347.

Archer, L., Hollingworth, S., & Halsall, A. (2007). ‘University’s not for me – I’m a Nike person’: Urban, working-class young people’s negotiations of ‘style’, identity and education. *Sociology*, *41*, 219-237.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B.. (2010). “Doing” science versus “being” a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education, 94*(4), 617-639.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal, 49*(5), 881-908.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B.. (2013). ‘Not girly, not sexy, not glamorous’: primary school girls’ and parents’ constructions of science aspirations1. *Pedagogy, Culture & Society, 21*(1), 171-194.

Archer, L., DeWitt, J., & Wong, B. (2014). Spheres of influence: what shapes young people’s aspirations at age 12/13 and what are the implications for education policy? *Journal of Education Policy*, *29*(1), 58-85.

Atherton, G., Cymbir, E., Roberts, K., Page, L., & Remedios, R. (2009). *How young people formulate their views about the future*. Department for Children, Schools and Families: London.

Ayalon, H. (1995). Math as a gatekeeper: Ethnic and gender inequality in course taking of the sciences in Israel. *American Journal of Education*, *104*(1), 34-56.

Baker, D., & Leary, R. (1995). Letting girls speak out about science. *Journal of Research in Science Teaching, 32*(1), 3-27.

Ball, S.J., Maguire, M. & Macrae, S. (2000). *Choice, pathways and transitions post-16. New youth, new economies in the global city*. London: Routledge Falmer.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Barmby, P., Kind, P.M., & Jones, K.. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education, 30*(8), 1075-1093.

Barnes, G., McInerney, D.M., & Marsh, H.W. (2005). Exploring sex differences in science enrolment intentions: an application of the Genderal Model of Academic Choice. *The Australian Educational Researcher, 32*(2), 1-23.

Bennett, J., & Hogarth, S.. (2009). Would you want to talk to a scientist at a party? High school students’ attitudes to school science and to science. *International Journal of Science Education, 31*(14), 1975-1998.

Bennett, J., Lubben, F., & Hampden-Thompson, G.. (2013). Schools that make a difference to post-compulsory uptake of physical science subjects: Some comparative case studies in England. *International Journal of Science Education, 35*(4), 663-689.

Blickenstaff, J.C. (2005). Women and science careers: leaky pipeline or gender filter? *Gender and Education, 17*(4), 369-386.

Blenkinsop, S. McCrone, T., Wade, P. & Morris, M. (2006). How do young people make choices at 14 and 16? Slough, UK: National Foundation for Educational Research.

Bøe, M. V., & Henriksen, E. K., (2013). Love it or Leave it: Norweigan students’ motivations and expectations for postcompulsory physics. *Science Education*, *97*(4) 550-573.

Bøe, M.V., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: Young people’s achievement‐related choices in late‐modern societies. *Studies in Science Education, 47*(1), 37-72.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching*, *45*(8), 955-970.

Brotman, J.S., & Moore, F.M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching, 45*(9), 971-1002.

Buccheri, G., Gürber, N.A. & Brühwiler, C. (2011). The impact of gender on interest in science topics and the choice of scientific and technical vocations. *International Journal of Science Education, 33*(1), 159–178.

Buck, G.A., Plano Clark, V. L., Leslie-Pelecky, D., Lu, Y., & Cerda-Lizarraga, P. (2008). Examining the cognitive processes used by adolescent girls and women scientists in identifying science role models: A feminist approach. *Science Education, 92*(4), 688-707.

Bull, A., Gilbert, J., Barwick, H., Hipkins, R., & Baker, R. (2010). *Inspired by science: a paper commissioned by the Royal Society and the Prime Minister's Chief Science Advisor*. Wellington, New Zealand: New Zealand Council for Educational Research.

Burton, L. (1990). *Gender and mathematics: An international perspective*. London: Cassell Educational.

Byrne, E. (1993). *Women and science: The snark syndrome*. Bristol, PA: Falmer Press.

Calabrese Barton, A. (1998). Teaching science with homeless children: Pedagogy, representation, and identity. *Journal of Research in Science Teaching*, *35*(4), 379-394.

Calabrese Barton, A., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching, 46*(1), 50-73.

Carlone, H.B. (2003). (Re)producing good science students: Girls’ participation in high school physics. *Journal of Women and Minorities in Science and Engineering, 9*(1), 17-34.

Carlone, H. B. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of Research in Science Teaching, 41*(4), 392-414.

Carlone, H. B, &. Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187-1218.

Cerini, B., Murray, I., & Reiss, M. (2004). Student review of the science curriculum. London: Planet Science.

Cerinsek, G., Hribar, T., Glodez, N., & Dolinsek, S. (2013). Which are my future career priorities and what influenced my choice of studying science, technology, engineering or mathematics? Some insights on educational choice – Case of Slovenia. *International Journal of Science Education*, *35*(17), 2999-3025.

Cleaves, Anna. (2005). The formation of science choices in secondary school. *International Journal of Science Education, 27*(4), 471-386.

Colley, A., & Comber, C. (2003). School subject preferences: age and gender diferences revisited. *Educational Studies, 29*(1), 59-67.

Collings, J., & Smithers. A. (1984). Person orientation and science choice. *European Journal of Science Education*, *6*(1), 55-65.

Cȏté, J. E. & Levine, C.G. (2002). Identity Formation, Agency, and Culture: A Social Psychological Synthesis. New York: Psychology Press.

Crano, W.D. & Prislin, R. (2006) Attitudes and persuasion. *Annual Review of Psychology*, *57*, 345-374

Dalgety, J., & Coll, R. K. (2004). The influence of normative beliefs on students’ enrolment choices. *Research in Science & Technological Education*, *22*(1), 59-80.

Dalgety, J., Coll, R. K., & Jones, A. (2003) The development of the Chemistry Attitudes and Experiences Questionnaire (CAEQ). *Journal of Research in Science Teaching,* 40(5), 649–668.

Davies, P., Telhaj, S., Hutton, D., Adnett, N., & Coe, R. (2008). Socioeconomic background, gender and subject choice in secondary schooling. *Educational Research, 50*(3), 235-248.

DeWitt, J., Archer, L., & Osborne, J. (2013). Nerdy, brainy and normal: Children’s and parents’ constructions of those who are highly engaged with science. *Research in Science Education*, 43(4), 1455-1476.

DeWitt, J., Osborne, J., Archer, L., Dillon, J., Willis, B., & Wong, B. (2013). Young children’s aspirations in science: The unequivocal, the uncertain and the unthinkable. *International Journal of Science Education*, 35(6), 1037-1063.

DeWitt, J., Archer, L., & Osborne, J. (2014). Science-related aspirations across the primary–secondary divide: Evidence from two surveys in England. *International Journal of Science Education*, DOI: 10.1080/09500693.2013.871659

Ehle, M.J. (1989). Self-Perception and Learning*. Education and Society*, *7*(1) 46-51.

Eurydice (2012). *Key Data on Ediucation in Europe 2012*. Brussels: Eurydice.

European Commission (2010). *Europe 2020. A European strategy for smart, sustainable and inclusive growth*. Brussels: European Commission.

Fensham, P.J. (2008). *Science education policy-making: Eleven emerging issues*. Paris: UNESCO.

Fishbein, M. and I. Ajzen, (1975). *Belief, Attitude, Intention and Behaviour: An Inroduction to Theory and Research*. Reading, Massachusetts: Addison-Wesley Publishing Company.

Fouad, N. A. (1995). Career linking: An intervention to promote math and science career awareness. *Journal of Counseling & Development*, *73*(5), 527-534.

Francis, B. (2000). The Gendered Subject: Students' subject preferences and discussions of gender and subject ability. *Oxford Review of Education, 26*(1), 35-48.

Francis, B., Hutchings, M., Archer, L., & Melling, L. (2003). Subject choice and occupational aspirations mong pupils at girls' schools. *Pedagogy, Culture & Society, 11*(3), 425-442.

Gainor, K. A., & Lent, R. W. (1998). Social cognitive expectations and racial identity attitudes in predicting the math choice intentions of Black college students. *Journal of Counseling Psychology, 45*, 403–413.

Gardner, P.L. (1975). Attitudes to science: A review. *Studies in Science Education*, *2*(1), 1-41.

George, R. (2006). A Cross‐domain analysis of change in students’ attitudes toward science and attitudes about the utility of science. *International Journal of Science Education, 28*(6), 571-589.

Gill, T., & Bell, J.F. (2013). What factors determine the uptake of A-level physics? *International Journal of Science Education, 35*(5), 753-772.

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: a research report*. Canberra: Department of Education, Training and Youth Affairs.

Greenfield, T.A. (1997). Gender- and grade-level differences in science interest and participation. *Science Education*, *81*(3), 259-276.

Halpern, D.F., Benbow, C.P., Geary, D.C., Gur, R.C., Hyde, J.S., & Gernsbacher, M.A. (2007). The science of sex differences in science and mathematics. *Psychological Science in the Public Interest*, *8*(1), 1-51.

Hampden-Thompson, G., & Bennett, J. (2013). Science teaching and learning activities and students' engagement in science. *International Journal of Science Education, 35*(8), 1325-1343.

Haraway, D. (1988). Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies, 14*(3), 575-599.

Harding, S. (1998). Women, science, and society. *Science, 281*(5383), 1599-1600.

Haste, H. (2004). *Science in my future: A study of the values and beliefs in relation to science and technology amongst 11-21 year olds*. London: Nestle Social Research Programme.

Haussler, P. & Hoffman, L. (2002). An intervention study to enhance girls’ interest, self-concept, and achievement in physics classes. *Journal of Research in Science Teaching*, *39*(9), 870-888.

Hazari, Z., Sonnert, G., Sadler, P.M., & Shanahan, M-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*(8), 978-1003.

Heilbronner, N. N. (2011). Stepping onto the STEM pathway: Factors affecting talented students' declaration of STEM majors in college. *Journal for the Education of the Gifted, 34*, 876-899.

Hernandez‐Martinez, P., Black, L., Williams, J., Davis, P., Pampaka, M., & Wake, G. (2008). Mathematics students’ aspirations for higher education: class, ethnicity, gender and interpretative repertoire styles. *Research Papers in Education*, *23*(2), 153-165.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, 60*(4), 549--571.

Hidi, S., & Renninger, K.A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111-127.

HM Treasury. (2006). *Science and Innovation Investment Framework: next steps*. London: HMSO.

Holmegaard, H.T., Madsen, L.M., & Ulriksen, L. (2014). To Choose or Not to Choose Science: Constructions of desirable identities among young people considering a STEM higher education programme. *International Journal of Science Education*, *36*(2), 186-215.

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

Hyde, J.S., & Linn, M.C. (2006). Gender similarities in mathematics and science. *Science*, *314*(5799), 599-600.

Jenkins, E. W. (2006). Student opinion in England about science and technology. *Research in Science & Technological Education*, *24*(1), 59-68.

Jenkins, E.W., & Nelson, N. W. (2005). Important but not for me: Students’ attitudes towards secondary school science in England. *Research in Science & Technological Education, 23*(1), 41-57.

Jensen, F., & Sjaastad, J. (2013). A Norwegian out-of-school mathematics project's influence on secondary students' STEM motivation. *International Journal of Science and Mathematics Education, Published online March 2013*.

Jones, G., Howe, A., & Rua, M. (2000) Gender differences in students’ experiences, interests, and attitudes towards science and scientists. *Science Education*, *84*(2), 180-192.

Kaya, S., & Rice, D.C. (2010). Multilevel effects of student and classroom factors on elementary science achievement in five countries. *International Journal of Science Education*, *32*(10), 1337-1363.

Kelly, Alison. (1988). *Getting the GIST: A Quantitative Study of the Effects of the Girls Into Science and Technology Project*. Manchester: University of Manchester.

Khoo, S.T. & Ainley, J. (2005) *Attitudes, intentions and participation*, Research Report 41, Australian Council for Educational Research: Camberwell, Victoria

Kind, P.M., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures, *International Journal of Science Education*, *27*(7), 871-893.

Krapp, A. (2002). An educational-psychological theory of interest and its relation to self-determination theory. In E. Deci & R. Ryan (Eds.), *The handbook of self-determination research* (pp. 405-427). Rochester, NY: University of Rochester Press.

Krapp, A. (2003). Interest and human development: An educational-psychological perspective. *British Journal of Educational Psychology, Monograph Series II (2) Development and Motivation: Joint Perspectives*, 57-84.

Krapp, A. & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education*, *33*(1), 27-50.

Krogh, L.B., & Thomsen, P.V. (2005). Studying students’ attitudes towards science from a cultural perspective but with a quantitative methodology: Border crossing into the physics classroom. *International Journal of Science Education, 27*(3), 281-302.

Lamb, S., & Ball, K. (1999). *Curriculum and careers: the education and labour market consequences of year 12 subject choice*. LSAY Research Reports. Longitudinal surveys of Australian youth research report; n.12.

Lawler, S. (2008) Identity: Sociological Perspectives. Cambridge: Polity Press.

Lemon, N. (1973). *Attitudes and Their Measurement*. London: B.T. Batsford Ltd.

Lent, R. W., Lopez, F. G., & Bieschke, K. J. (1993). Predicting mathematics-related choice and success behaviors: Test of an expanded social cognitive model. *Journal of Vocational Behavior, 42*, 223-236.

Lent, R. W., Lopez, A. M., Lopez, F. G., & Sheu, H. (2008). Social cognitive career theory and the prediction of interests and choice goals in the computing disciplines. *Journal of Vocational Behavior, 73*, 52-62.

Lent, R. W., Sheu, H., Gloster, C. S., & Wilkins, G. (2010). Longitudinal test of the social cognitive model of choice in engineering students at historically Black universities. *Journal of Vocational Behavior, 76*, 387-394.

Lindahl, B. (2007). *A longitudinal study of students' attitudes towards science and choice of career*. Paper presented at annual meeting of the National Association for Research in Science Teaching. New Orleans, LA, April.

Lyons, Terry. (2006). The Puzzle of falling enrolments in physics and chemistry courses: Putting some pieces together. *Research in Science Education, 36*(3), 285-311.

Lyons, T., & Quinn, F. (2010). *Looking back: Students’ perceptions of the relative enjoyment of primary and secondary school science*. Paper presented at the STEM in Education Conference, Queensland University of Technology, Brisbane, Australia, 26–27 November.

Malone, J.A., & Cavanagh, R.F. (1997). The influence of students’ cognitive preferences on the selection of science and mathematics subjects. *International Journal of Science Education*, *19*(4), 481-490.

Maltese, A.V., & Tai, R.H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685.

Maltese, A.V., & Tai, R.H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education*, *95*(5), 877-907.

Masnick, A.M., Valenti, S.S., Cox, B.D., & Osman, C.J. (2010). A multidimensional scaling analysis of students’ attitudes about science careers. *International Journal of Science Education*, 32(5), 653-667.

McEwen, A., Knipe, D., & Gallagher, T. (1997). Science and arts choices at A-level in Northern Ireland: A ten-year perspective. *International Journal of Science Education*, 19, 761– 771.

Mead, M., & Metraux, R. (1957). Image of the scientist among high-school students. *Science*, *126*(3270), 384-390.

Mendick, H. (2005). Mathematical stories: why do more boys than girls choose to study mathematics at AS‐level in England? *British Journal of Sociology of Education, 26*(2), 235-251.

Millar, R., & Osborne, J. (2001). *Beyond 2000: science education for the future*. London: King's College London.

Mujtaba, T., & Reiss, M.J. (2012). What sort of girl wants to study physics after the age of 16? Findings from a large-scale UK survey. *International Journal of Science Education*, *35*(7), 2979-2998.

Munby, H. (1982) The impropriety of “panel of judges” validation in science attitude scales: A research comment. *Journal of Research in Science Teaching*, *19*(7), 617-619.

Munro, M., & Elsom, D. (2000). *Choosing science at 16: The influence of science teachers and careers advisers on students’ decisions about science subjects and science and technology careers*. Cambridge, UK: National Institute for Careers Ediucation and Councelling (NICEC).

Murphy, C., & Begg, J. (2005). *Primary science in the UK: A scoping study: Final Report to the Wellcome Trust*. London: Wellcome Trust.

Murphy, P., & Whitelegg, E. (2006*). Girls in the physics classroom: a review of the research on the participation of girls in physics*. London: Institute of Physics.

National Academy of Sciences (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academy of Sciences: Committee on Science Engineering and Public Policy.

National Foundation for Educational Research (NFER). (2011). Exploring young people’s views on science education. Slough: NFER.

Neuschmidt, O., Barth, J., & Hastedt, D. (2008). Trends in gender differences in mathematics and science (TIMSS 1995–2003). *Studies in Educational Evaluation, 34*(2), 56-72.

OECD (1997). Promoting public understanding of science and technology. Paris: OECD.

Ofsted (2011). *The annual report of Her Majesty’s Chief Inspector of Education, Children’s Services and Skills*. Norwich, UK: Ofsted.

Olsen, R.V., & Lie, S. (2011). Profiles of students’ interest in science issues around the world: Analysis of data from PISA 2006. *International Journal of Science Education, 33*(1), 97-120.

Olsen, R.V., Prenzel, M., & Martin, R. (2011). Interest in science: A many‐faceted picture painted by data from the OECD PISA study. *International Journal of Science Education, 33*(1), 1-6.

Olszewski-Kubilius, P., & Yasumoto, J. (1994). Factors affecting the academic choices of academically talented adolescents. *Talent Development*, *2*, 393-398.

Ormerod, B., & Duckworth, D. (1975). *Pupils' Attitudes to Science: A Review of Research*. Berkshire, UK: NFER Publishing Company.

Osborne, J., & Collins, S. (2001). Pupils’ views of the role and value of the science curriculum. *International Journal of Science Education, 23*(5), 441-467.

Osborne, J., Simon, S., & Collins, S.. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049-1079.

Pike, A.G., & Dunne, M. (2010). Student reflections on choosing to study science post-16. *Cultural Studies of Science Education, 6*(2), 485-500.

Ramsden, J.M. (1998). Mission impossible? Can anything be done about attitudes to science? *International Journal of Science Education*, *20*(2), 125-137.

Raved, L., & Assaraf, O.B.Z. (2011). Attitudes towards science learning among 10th‐grade students: A qualitative look. *International Journal of Science Education*, *33*(9),1219-1243.

Regan, E. M., & Childs, P.E. (2003). An Investigation of Irish students’ attitudes to chemistry: The Promotion of Chemistry in School Project. *Chemistry Education: Research and Practice, 4*(1), 43-51.

Reid, N. (2006). Thoughts on attitude measurement. *Research in Science & Technological Education*, *24*(1), 3–27.

Reid, N., & Skryabina, E.A. (2003). Gender and physics. *International Journal of Science Education, 25*(4), 509-536.

Reitz, J.G. (1973). The Flight from science reconsidered: Career choice of science and engineering in the 1950's and 1960's. *Science Education, 57*(2), 121-134.

Renninger, K.A., & Hidi, S. (2011). Revisiting the conceptualisation, measurement, and generation of interest. *Educational Psychologist*, *46*(3), 168-184.

Renninger, K.A., Hidi, S., & Krapp, A. (Eds.) (1992). *The role of interest in learning and development*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Roth, W-M., & Tobin, K. (2007). Aporias of identity in science: An Introduction. In W-M. Roth, & K. Tobin (Eds.) Science, learning, identity: Sociocultural and cultural-historical perspectives. Rotterdam: Sense Publishers.

Sadler, D. R. (2002). Interdisciplinarity in university teaching and research. Brisbane, Australia: Griffith Institute for Higher Education.

Sadler, P. M., Sonnert, G., Hazari, Z., &Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. Science Education, 96(3), 411-427.

Salmi, H. (2002). Factors affecting students' choice of academic studies: the motivation created by informal learning (Publication no. http://www.heureka.fi/portal/englanti/about\_heureka/research/factors\_affecting\_students%60\_choice\_of\_academic\_studies\_the\_motivation\_created\_by\_informal\_learning.\_/).

Scantlebury, K., & Baker, D. (2007). Gender issues in science education research: Remembering where the difference lies. In S. Abell & N. N. Lederman (Eds.), *Handbook of research on science education* (pp. 257-286). Mahwah, NJ: Lawrence Erlbaum.

Schibeci, R.A. (1984). Attitudes to science: an update. *Studies in Science Education*, *11*, 26–59.

Schibeci, R.A. (1986). Images of science and scientists and science education. *Science Education,* 70(2), 139–149.

Schreiner, C. (2006). *Exploring a ROSE-garden: Norwegian youth’s orientations towards science – Seen as signs of late modern identities*. Oslo: University of Oslo.

Schreiner, C. & Sjoberg, S. (2007). Science education and youth’s identity construction – two incompatible projects? In C. Corrigan, J. Dillon, & R. Gunstone (Eds.), *The re-emergence of values in the science curriculum*. Rotterdam: Sense Publishers.

Shanahan, M‐C. (2009). Identity in science learning: exploring the attention given to agency and structure in studies of identity. *Studies in Science Education, 45*(1), 43-64.

Sikora, J., & Pokropek. A. (2012). Gender segregation of adolescent science career plans in 50 countries. *Science Education*, *96*(2), 234-264.

Silvia, P.J. (2006). Exploring the psychology of interest. New York, NY: Oxford University Press

Sjaastad, J. (2012). Sources of inspiration: The role of significant persons in young people's choice of science in higher education. *International Journal of Science Education, 34*(10), 1615-1636.

Sjoberg, S. (2002). Science and technology education in Europe : current challenges and possible solutions. *Connect : UNESCO international science, technology and environmental education newsletter, 27,* 1-5.

Sjoberg, S., & Schreiner, C. (2005). How do learners in different cultures relate to science and technology? Results and perspectives from the project ROSE (the Relevance of Science Education). *Asia-Pacific Forum on Science Learning and Teaching*, *6*(2), 1-17.

Skelton, C. (2010). Gender and achievement: Are girls the “success stories” of restructured education systems? *Educational Review, 62*(2), 131-142.

Skelton, C., Francis, B., & Read, B. (2010). “Brains before ‘beauty’?” High achieving girls, school and gender identities. *Educational Studies, 36*(2), 185-194.

Skryabina, E. (2000). *Student attitudes to learning physics at school and university levels in*

*Scotland*. Ph.D. thesis, University of Glasgow, Glasgow, UK.

Smith, E. (2010a). Do we need more scientists? A long‐term view of patterns of participation in UK undergraduate science programmes. *Cambridge Journal of Education, 40*(3), 281-298.

Smith, E. (2010b). Is there a crisis in school science education in the UK? *Educational Review, 62*(2), 189-202.

Smith, E., & Gorard, S. (2011). Is there a shortage of scientists? A re-analysis of supply for the UK. *British Journal of Educational Studies*, *59*(2), 159-177.

Smyth, E., & Darmody, M. (2009). ‘Man enough to do it’? Girls and non‐traditional subjects in lower secondary education. *Gender and Education, 21*(3), 273-292.

Smyth, E., & Hannan, C. (2002). *Who chooses science? Subject choice in second-level schools*. Dublin: Liffey Press/ESRI.

Solomon, J. (1997). Girls' science education: choice, solidarity and culture. *International Journal of Science Education, 19*(4), 407-417.

Stagg, P. (2007) *Careers from science: An investigation for the Science Education Forum*. Warwick, UK: Centre for Education and Industry (CEI).

Steinke, J., Applegate, B., Lapinski, M., Ryan, L., & Long, M. (2012). Gender differences in adolescents’ wishful identification with scientist characters on television. *Science Communication, 34(2)*, 163–199.

Stokking, K.M. (2000). Predicting the choice of physics in secondary education. International Journal of Science Education, 22(12), 1261-1283.

Taconis, R., & Kessels, U. (2009). How choosing science depends on students' individual fit to 'science culture'. *International Journal of Science Education, 31*(8), 1115-1132.

Tai, R.H., Liu, C.Q., Maltese, A.V., & Fan, X. (2006). Planning early for careers in science. *Science, 312*, 1143-1144.

Tai, R.H., Sadler, P.M., & Mintzes, J.J. (2006). Factors influencing college science success. *Journal of College Science Teaching, 36*(1), 52-66.

The Task Force on the Physical Sciences (2002). *Report and Recommendations*. Dublin: The Task Force on the Physical Sciences.

Thomson, S. (2008). Examining the evidence from TIMSS: Gender differences in Year 8 science achievement in Australia. *Studies in Educational Evaluation, 34*(2), 73-81.

Tripney, J., Newman, M., Bangpan, M., Niza, C., Mackintosh, M., & Sinclair, J. (2010). *Subject choice in STEM: Factors influencing young people (aged 14-19) in education about STEM subject choices: a systematic review of the UK literature*. London: EPPI.

Tytler, R., & Osborne, J. (2012). Student attitudes and aspirations towards science. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 597-625). Dordrech, The Netherlands: Springer.

Uerz, D., Dekkers, H. and Dronkers, J. (1999). Wiskunde en Taalvaardigheid als Voorspeller van B-Keuzen in her Voortgezet Onderwijs [Mathematics and language ability as predictors of science choices in secondary education]. *Pedagogische Studieën*, 76: 170–182.

Ulriksen, L., Madsen, L.M., & Holmegaard, H.T. (2010). What do we know about explanations for drop out/opt out among young people from STM higher education programmes? *Studies in Science Education, 46*(2), 209-244.

Ventura, F. (1992). Gender, science choice and achievement: a Maltese perspective. *International Journal of Science Education*, *14*(4), 445-461.

Venville, G., Rennie, L., Hanbury, C., & Longnecker, N.. (2013). Scientists reflect on why they chose to study science. *Research in Science Education*, 43(6), 2207-2233.

Vidal Rodeiro, C. L. (2007). *A level subject choice in England: Patterns of uptake and factors affecting subject preferences*. Cambridge, University of Cambridge: Local Examinations Syndicate.

Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, *50*(5), 1081-1121.

Warton, P.M. (1997). *Motivational goals, information sources and subject choice in adolescence*. Paper presented at the Biennial Meeting of the Society for Research in Child Development. Washington, D.C., April.

Warton, P.M., & Cooney, G.H. (1997). Information and choice of subjects in the senior school. *British Journal of Guidance & Counselling*, *25*(3), 389-397.

Watt, H. (2005) Exploring adolescent motivations for pursuing maths-related careers. *Australian Journal of Educational and Developmental Psychology*, *5*, 107-116.

Whitehead, J.M. (1996). Sex stereotypes, gender identity and subject choice at A-level. *Educational Research*, *38*(2), 147-160.

Wikeley, F., & Stables, A. (1999). Changes in school students’ approaches to subject option choices: a study of pupils in the West of England in 1984 and 1996. *Educational Research*, *41*(3), 287-299.

Wong, B. (2012). Identifying with science: A case study of two 13-year-old ‘high achieving working class’ British Asian girls. *International Journal of Science Education, 34*(1), 43-65.

Woolnough, B.E. (1994). Factors affecting students' choice of science and engineering. *International Journal of Science Education, 16*(6), 659-676.

Xu, J., Coats, L. T., & Davidson, M. L. (2011). Promoting student interest in science: The Perspectives of exemplary African American teachers. *American Educational Research Journal, 49*(1), 124-154.

Yazilitas, D., Svensson, J., de Vries, G., & Saharso, S. (2013). Gendered study choice: a literature review. A review of theory and research into the unequal representation of male and female students in mathematics, science, and technology. *Educational Research and Evaluation, 19*(6), 525-545.

Zeyer, A., & Wolf, S. (2010). Is there a relationship between brain type, sex and motivation to learn science? *International Journal of Science Education, 32*(16), 2217–2233.