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Literature review update: Student identity in relation to Science, Technology, Engineering and Mathematics subject choices and career aspirations

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Introduction

This literature review update builds on the comprehensive review undertaken by Tytler et al. (2008) of the supports and barriers to science, technology, engineering and maths engagement during the transition from primary to secondary school levels and the implications these have for students' career trajectories at the tertiary education level. The review reported here is framed around post 2008 research that seeks to clarify identity and attitude relations with regard to engagement with and learning in STEM related subjects. The underlying identity question to which the reviewed science education research literature offers a response is: How can the identity construct be understood as a useful pathway into students' school science priorities and future career aspirations?

Background and context

The reported continued decline in student engagement in science, technology, engineering and maths (STEM) fields of study in the later secondary school years, and the flow-on implications this has for young people's participation in STEM-related careers, has captured world-wide education research attention in recent times (European Union, 2012; Tytler et al., 2008). Faced with the urgent need for creative and technologically sophisticated responses to sustainability pressures, governments globally are concerned that reported declines in STEM engagement will adversely impact the growth and development of innovative science- and technology-based industries relied upon to provide effective solutions to a wide range of environmental and health-related problems. Further, in a highly competitive global economic context, declining participation in these industries puts at risk a nation's strategic competitive capability and its capacity to sustain long-term socio-economic growth (Tytler et al., 2008; Eurydice, 2012).

The publication of education policy reports including, within the European community, the Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA) and within the United States', the National Center for Education Statistics' (NCES) Trends in International Mathematics and Science Study (TIMSS), provide key data for governments and make possible international collaboration in the design and implementation of STEM-specific education policy (see OECD, 2010). In addition, the Eurydice network established by the European Commission in 1980 constitutes a strategic mechanism for the provision of key education data at all levels. The network's 2011 thematic reports on mathematics (Eurydice, 2011a) and science education (Eurydice, 2011b) provide a comparative analysis of teaching approaches to mathematics and science and further contribute to European and national debate on how to engage students in STEM education and the crucial role teacher education plays in this.

The Eurydice (2011a) mathematics thematic report points out ways mathematics teaching can enhance student performance and engagement and highlights the significance of context in mathematics learning. Key findings are framed around the following themes:

- The translation of mathematics curricula into classroom practice through a learning outcomes-based approach that allows teachers greater autonomy to support and be more responsive to learners' needs;
- The application of a range of teaching approaches such as active problem-based learning grounded in real-world contexts that have greater relevancy to students' everyday experiences;

- Teacher support in the effective administration of more innovative forms of assessment such as project-based, portfolio, ICT or self/peer-based assessment;
- The establishment of targets, monitoring systems, and effective educational strategies to address low mathematics achievement levels;
- The use of targeted initiatives to increase student motivation and engagement with mathematics, particularly in relation to girls' participation;
- Meeting challenges related to improving mathematics teachers' qualifications and balancing the gender profile of the mathematics teaching profession, particularly during the formative early primary school years; and
- The promotion and embedding within schools of evidence-based policies around proven mathematics teaching methods.

In its cross-Europe mapping of organisational policies and strategies to both improve and promote science teaching and learning, the Eurydice (2011b) science report throws light on:

- The rarity of coordinated strategies (e.g., school science partnerships with science-related professions) to in general, promote scientific culture, knowledge and research and in particular, to raise girls' interest in science;
- Evidence from countries' steering documents that point out the integrated nature of science education during the primary school years and the subject split that occurs in the early secondary school years resulting in separate science-related subjects: biology, chemistry and physics;
- Increased attention to context-based contemporary societal issues such as 'environmental concerns and the application of scientific achievements to everyday life' (2011b, p.126) that may serve to increase students' interest in and motivation towards science;
- The promotion through steering documents of varied forms of collaborative learning activities and participatory inquiry opportunities beginning at the primary level onwards and designed to embrace the 'European key competences' approach to science education (2011b, p.127);
- The lack of a specific policy to address the needs of low achievers in science subjects;
- The prevalence of traditional assessment methods that see written/oral examinations and assessment of students' classroom performance and project work as the most frequently recommended methods; and
- Policy makers concerns related to strengthening teacher competences through a combined professional development, in-school lesson evaluation and co-teaching approach in view of recent renewed focus on more complex inquiry teaching methods.

The Eurydice mathematics and science report findings reflect other STEM-related researchers' concerns that consistently lower levels of girls' engagement with and participation in STEM subjects in the later secondary years have significant implications for gender equity and representation in science-related careers (Hill et al., 2010; Boe, 2011; Christidou, 2011; Cerinsek, 2012). The issue of gender re-emerges in the context of students' science identities later in the review update.

Research responses to the public policy reports outlined above include the five nation Interests and Recruitment in Science collaborative research project (IRIS), designed to explore young people's educational choices, success factors, and reasons why students choose, or not, STEM education and career pathways (Anastasiou & Dillon, 2010; Bøe et al., 2010; Cerinsek, 2012). Based in Oslo, the ROSE (Relevance Of Science

Education) cooperative research project also invites wide international participation in the investigation of young students' attitudes to and motivation towards STEM-related study, and future career aspirations and priorities (Sjøberg & Schreiner, 2010). Through the cooperative development of the ROSE questionnaire, rich data on students' attitudes, interests, and scientific worldviews on the value of science to society make a significant contribution to science education policy and curriculum (Sjøberg & Schreiner, 2010; Cerinsek et al., 2012).

Further, the ROSE project's focus on the affective domain of young students' learning complements cognitive approaches taken by PISA assessments and as such suggests grounds for more broadly conceptualising students' inclinations or not, towards science-related study and later science-based career choices to incorporate students' personally significant science-related interests and perspectives. Indeed, as Olsen et al. (2011) suggest, 'The extension of the PISA framework towards an assessment of interest in science can improve our knowledge and understanding of students' interest in science, and it can also help to promote new research approaches in science education' (Olsen et al., 2011, p.2).

Broader perspectives from which to view student's attitudes and interests in science arise within key findings from the Tytler et al. (2008) review that point out as a key theme, 'the question of identity as a major framework to understand students' responses to STEM' (2008, p.136). In this current review, Tytler's et al. (2008) identity 'question' is explored through a review of post 2008 theoretical identity literatures informing identity-focused science education research practice. In such research, questions to do with 'who I am', 'who I want to become' underpin the centrally significant question: Why do students at upper secondary levels choose or not, STEM-related studies as pathways to future STEM-related career options? The notion of identity as an analytical lens through which to better understand students' choices with a view to inform education policy, and curriculum and pedagogical interventions, also comes to prominence in Osborne, Shirley, & Tytler's 2009 update on science attitudes (Osborne et al., 2009) and in Tytler and Osborne's recent work on students' attitudes and aspirations towards science (2012). These works shed light on a significant body of research focused on how identity plays into both students' subject choices and future career-related decisions and that further, illustrates how 'educational choice is an identity choice' (Schreiner and Sjøberg, 2007, in Tytler et al., 2008, p.92). This assertion is taken as the starting point for a review of post 2008 literatures that foregrounds the notion of identity in science education and research and re-visits the notion of attitudes as the more frequently used 'measure' of students' science interests, motivations and dispositions towards STEM-related careers pathways.

Methodology of the review update

The key findings of the Tytler et al. (2008) review provided a starting point for a closer examination of the identity construct as a tool to explore and understand students' participation and engagement or not, in STEM-related subject choices and students' career aspirations. Related works by Osborne et al. (2009) and Tytler and Osborne (2012) provided further direction in relation to firstly, possible key search terms and secondly, to a range of targeted reference sources (e.g., key journals, texts, government STEM agencies). The work of authors identified through these sources was followed up through author searches through Deakin University library's search resources and through these authors' affiliated institutions (e.g., publication data).

Key terms: student attitudes in/to science; students' science interests; students' science engagement participation; STEM; identity; identity research; identity research in science education; gender issues in science education; international science education; IRIS; PISA; ROSE; TIMSS.

From these initial prior literature directions, on-line strategies included the use of the Deakin University library catalogue and databases, including EBSCOhost, ERIC, Expanded Academic ASAP, SpringerLink, Taylor and Francis, Wiley Online Library Journals, and Google Scholar.

From these searches, two Endnote (X5) libraries, inclusive of all files, were compiled:

- A master library - reflective of post 2008 sources related to STEM participation factors, international comparisons, and identity and attitudes relations; and
- An 'identity' library - reflective of post 2008 identity research in science education.

The Endnote libraries were used to generate further searches of most recent sources.

Literature review process: Exemplar research papers were interrogated using the following points as a general heuristic to illuminate how the identity construct opened up, or not, the nature of students' relationship to science-related subjects and their aspirations towards STEM-related careers:

- Research aims;
- Research question(s);
- Identity conceptualisation;
- Articulation of theoretical framework;
- Methodologies and methods;
- Key findings;
- Research challenges;
- Contribution to STEM research;
- Future directions;
- Suggested interventions to promote STEM participation and engagement at all levels of education; and
- Comparisons between identity-related studies.

Engagement with STEM related subjects: Attitudes and identity

In this section, the use of the attitude construct in STEM-related research is re-visited with a view to locating this within the broader context of identity theory. The identity focus is then introduced through a review of current perspectives that tease out the multifaceted concept of identity from different theoretical standpoints. From this, the review reports on recent exemplars of science education research that reflect researchers' use of a diverse range of identity theories in order to open up questions to do with students' attitudes towards and interest in STEM studies, their identification (or not) with different science disciplines (i.e., mathematics, physics, chemistry, biology), and students' future career aspirations.

Attitudes: towards a holistic identity perspective

The use of the affective construct attitudes over the past three to four decades in STEM related education research is reflected in previous STEM reviews (Tytler et al., 2008, Osborne et al., 2009; Tytler & Osborne, 2012), and in recent science education research (Masnick et al., 2010; Welch, 2010; Zain et al., 2010; Chang et al., 2011; Desey et al., 2011; DeWitt et al., 2011; Hemmings et al., 2011; Mamlok-Naaman, 2011; Oliver &

Venville, 2011; Yee & Chapman, 2011; Ainley & Ainley, 2012; Mavrikaki, 2012; Tomas et al., 2012). Assumptions underlying attitudinal research in science education include ideas that:

- Attitudes provide a window into a range of complex feelings and dispositions (Chang et al., 2009);
- Positive science attitudes are an essential precursor to develop an interest in science (Desey et al., 2011; Mamlok-Naaman, 2011; Tomas et al., 2011);
- Student attitudes toward science correlate with achievement in the science classroom (Welch, 2010);
- A predictive relationship exists between attitudes and intentions (Ainley & Ainley, 2012); and
- Attitudes can be reliably measured through quantitative measures such as Fraser's 1978 *Test of Science Related Attitudes* (see Welch, 2010), Germann's 1988 *Attitude Toward Science in School Assessment* and Gogolin and Swartz' 1992 *Attitudes Towards Science Inventory* (see Desey et al., 2011).

These assumptions locate the notion of attitudes within the behavioural realm of traditional psychological research epistemologies within which scientific methodologies are employed to generate objective, or value-free knowledge claims. In this context, attitudes assume an individualistic and deterministic influence on students' subject choices and career aspirations and thus blinker subjective realities that play into the historicised formation of attitudes and their expression in different contexts over time. Tytler and Osborne (2012) make the case for recognising inherent complexities in attitudinal research to do with deciding what the attitude construct actually means and in what context, and with how to develop valid and reliable attitude-measuring instruments. Further, Aschbacher et al.'s (2010) research findings point to factors that may undermine otherwise interested students' efforts to achieve in science, such as gender, socio-economic status, parents' perceptions of the value of science, and school issues (e.g., class room climate, numerous substitute teachers). Simple correlations between science interest and achievement likely occupy unstable ground in this research context.

In noting common criticisms levelled at attitude scales, including a limited capacity to illuminate generative mechanisms of attitude development, Tytler and Osborne (2012) point to recent growth in the use of qualitative methodologies that offer methods and analytical strategies capable of generating more richly nuanced insights into the many facets of students' science subject and future career decisions (Tytler & Osborne, 2012; see Rattansi & Phoenix, 2005; Chetcuti & Kioko, 2012). Later in this review, innovative qualitative methods employed by identity-focused science education researchers are further elaborated.

A shift away from traditional or classical psychological research approaches in attitude studies is identified in Saleh and Khine's (2011) edited text *Attitude Research in Science Education: Classic and Contemporary Measurement*. In this, critical perspectives on the use of attitudinal research in science education blend classical approaches, grounded in scientific psychological disciplines with more contemporary social psychological and culturally-sensitive interpretive approaches and assert the need to consider the socially situated nature of attitudes in contemporary society. From the literature reviewed, the intention of classical attitudinal research is to determine relationships between complex interacting variables such as student behaviour, motivation, and achievement. However, these variables may reasonably extend to students' interests and experiences, personal and school achievements, significant relationships including family, peers, and teachers (Cerinsek et al., 2012), socio-economic status (Christidou, 2011) and community engagements (Lamb et al., 2011) to reflect Lamb's et al. (2011) 'science interest' survey findings that 'extrinsic factors such as family, community, and schools might be more influential than intrinsic attitudes toward science interest' (2011, p.643). From Krogh and Andersen's (2012) standpoint, the exploration of a broad range of variables in STEM-related science education research might provide insights into how students' 'internalise [or not] science into their personal value systems' (2012, n.p). With increased interest in the more holistic identity construct as a way into students' construction of their 'science' selves and their relationships with science subjects, attitudes may play a more productive role if considered within the complex experiential landscape of students' contingent science interests, passions and future aspirations. As Hazari et al. (2010), assert , 'We believe that this [identity] focus provides a basis for understanding students' long-term personal connection to physics and is a more meaningful measure than a general assessment of students' attitudes' (2010, p.979). Lee (2012) claims that through the lens of identity we may gain a clearer view into students' agent-centered development, and into their 'sense of belonging and affiliation, and engagement with learning' (2012, p.35).

Identity: an emergent focus in STEM-related science education research

Three key points arising from the Tytler et al. (2008) review give broad general direction to the shape of this review in relation to how the identity construct might be understood and engaged with in specifically STEM-focused science education research to explore the nature of both students' relationships to science-related subjects and their future aspirations (or not) towards STEM-related careers:

- Aikenhead's (2006) assertion that an appreciation of science stems from identity work that makes possible meaningful science learning (2006, in Tytler et al, 2008, p.61);
- The argument that any analysis of the complex domain of student's study- and career- related decision-making is a complicated undertaking due to the myriad dynamic factors that shape decisions over time in multiple contexts; and
- The significance of recognising and '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 their educational pursuit of STEM' (2008, p.61).

In their update of attitudinal research in science education, Osborne et al. (2009) acknowledge the emergence of a 'rising body of work grounded in the theoretical construct of 'identity' which has been used as an analytic lens to explain students' choices' (2009, p.2). These authors also make the case for giving more thought to both students' 'complex and varied histories, and to the nature of the science curriculum' to engage students in more meaningful ways in school science (2009, p.11). This last point is given further emphasis in Tytler and Osborne's (2012) claim that through increased interest in the identity construct, responses to the science curriculum by indigenous or gender groupings might be more fruitfully explored. Taking the perspective of girls at the middle-school level, Barton et al. (2012) add to the conversation here: 'girls view possible future selves in science when their identity work is recognised, supported, and leveraged towards expanded opportunities for engagement in science. This process yields layered meanings of (possible) selves and of science and reconfigures meaningful participation in science' (2012, n.p; see Harrell-Levy & Kerpelman, 2010). Ulriksen's et al. (2010) critical review of the literature focused on understandings of student retention in science, technology and mathematics (STM) in higher education programs, notes an emergent more specific focus on identities as an analytical framework for understanding why young people chose to leave. However, despite the reported rising tide of identity research specifically in science education (Carlone, 2012; Lee, 2012; Varelas, 2012), relatively few studies explicitly foreground the concept of identity as the major construct of research interest such that the term ‘identity’ is located in the research report title or selected as a key word (see Tytler et al., 2008; Osborne et al., 2009; Tytler & Osborne, 2012). As such, identity-related science education research may be made less visible in the literature search process. However, as Varelas’ (2012) points out, although a reference to a construct in the paper’s title may be absent, this does not necessarily imply that the construct is irrelevant or unimportant. Nonetheless, the presence of key constructs of interest within the title and key words ‘strongly positions a paper as addressing ... identity and/or identity work’ (Varelas, 2012, p.2).

Identity focused STEM research: Framing the identity literature

In this section the report sketches the contested theoretical and empirical ground occupied by the identity construct in the social sciences (Rattansi & Phoenix, 2005) as the context for ways researchers conceptualise and justify the engagement of identity in science education research.

Identity: Theoretical frameworks

An abundant well-established identity literature in multiple disciplines, including anthropology, education, environmental education and feminist studies (Ulriksen et al., 2010) has done much to bring issues around young people’s identity and its relationship to their everyday lives to the fore. Reflecting recent interest in identity research in education is research by Moss (2008), Holt (2008), and Al-Mahmood (2008). In environmental education, identity research has longer standing (Thomashow, 1995; Macnaghten & Urry, 1998; Clayton & Opotow, 2003; Pederson & Viken, 2003). However, as Ulriksen et al. (2010) note, identity-focussed research in science education is rare. Varelas (2012) goes some way to address the scarcity of science education identity research through her edited text *Identity Construction and Science Education Research.* In this, theoretical understandings related to identity and identity development from anthropological, sociological and socio-cultural perspectives are expanded, and reports of empirical identity research bring methodological issues and analytical foci to the fore. Selected in this review update for its key relevance to informing growing interest in identity in science education research, the work of Rattansi and Phoenix, (2005), Harrell-Levy and Kerpelman (2010), and McLean and Pasupathi (2012) is drawn on here to give some brief background and context to contemporary identity theory. Lee (2012) brings a closer examination of the theoretical basis of identity concepts and frameworks evident in identity-based science education research. Rattansi and Phoenix’ (2005) theoretical exposition on youth identities represents a rare exemplar within identity research literatures in its attention to theoretical and empirical concerns and in its contribution to the debate swirling around ‘proper’ identity conceptualisations and research strategies. Harrell-Levy and Kerpelman (2010) offer a detailed account of the role of teachers as identity agents through transformative pedagogical practice. McLean and Pasupathi (2012) argue the value of identity narratives as a process to explore and reflect upon possible identities and future commitments. In what follows, identity theorists come into conversation with science education researchers to give some flavour to how these researchers draw on diverse theoretical identity perspectives within their STEM-related research practice.

Conceptualising identity

Asserting that young people are the creative makers of their own identities, Rattansi and

Phoenix (2005) offer identity perspectives and conceptualisations that reflect the postmodern view of a general ‘disembedding’, ‘detraditionalisation’ and erosion of older more stable collective identities. Identity understood from a postmodern perspective as always in process, open, provisional, relational and exploratory, allows scope for understanding creative hybridised identities that allow young people to ‘borrow and mix’ multiple elements from a range of identities’ (Rattansi & Phoenix, 2005; Mclean & Pasupathi, 2012). Perceived as embedded in culture and social discourses of power at all levels of society, identity finds home in the philosophical works of Foucault, Deleuze, and Leotard (Ulriksen et al., 2010). The need to recognise significant relationships between students and their family, teachers, peers, and others within STEM subject and career decision making contexts (Tytler et al., 2008) resonates with the notion of identity embedded in relational social contexts and ‘managed through one’s personal reflexive choices’ (Taconis & Kessells, 2009, p.1117). In their investigation of student’s individual ‘fit’ to science culture, Taconis and Kessels (2009) claim that in late modern societies identity has become ‘an individual’s personal project requiring deliberate effort’ (2009, p.1117). Within science education contexts, Varelas (2012) offers:

> Identity is a multidimensional, multifaceted, and complex construct ... The multiple identities that students and teachers bring with them *and* further construct and re-construct in classrooms and out-of-school settings allow them to be, and be recognised as, particular types of people, [to] act in certain ways, encounter opportunities and barriers, and, thus, experience successes and challenges in learning (2012, pp.2-3; original emphasis)

Lee’s (2012) ‘rough guide’ to the identity terrain examines theoretical roots of identity and how these have ‘energised’ science researchers in recent times. The guide summarises the underlying theoretical premises of the more frequently used identity frameworks in science education: figured worlds and practice theories; discursive stances; and activity theory. According to Lee (2012), ‘figured worlds and practice theories’ lie within critical research traditions and inspire the notion of agentic control in situations that at first glance may seem to deny such privilege (see Barton et al., 2012). Informed by the work of Bourdieu, Bakhtin, Vygotsky, and Mead, these theories posit that identities are ‘situated achievements’ and that identity can be conceived of as a verb in the sense of the work of ‘self’’ (2012, p.37). On their use of ‘narratives of figured worlds’ to explore African American children’s identification with science and scientists, Varelas et al. (2012) argue: ‘Narratives, oral or written, can take many shapes and forms and have various functions. Narratives are born out of experience and give shape to experience, thus being inseparable of [from] who people are’ (2012, p.569). Barton et al. (2012) understand figured worlds to be:

> structured simultaneously at the macro, meso, and micro levels. For example, science class can be viewed as a complex web of figured worlds, including the world of whole class activity with historical and cultural norms for participation and good studenting and the world of small group interactions as peers move in and out of different associations due to classroom tasks and social activity (Barton et al., 2012, p.7)

In a similar vein, ‘Discursive stances’ as an identity theory puts the use of language centre stage in the identity project. As a form of thematic discourse, the discursive stance also draws on the resources of narrative and focus groups discussions to generate meaning, ‘such as clusters of science sense-making’ (Lee, 2012, p.39). As a practice exemplar, Moreau’s et al. (2010) intention to understand how 14-15-year old UK science and humanities students’ discursively construct representations of mathematics and mathematicians concluded with findings asserting that ‘while the mathematically able are constructed as ‘other’ and ostracised in the discourses of popular cultures, these discourses seem to constrain the way learners think of mathematicians and of mathematical routes’ (2010, p.34). Activity theory assumes identity is an outcome of dialogical engagement with practical activity; a purposeful meaningful life project (2012, p.39). However, less enthusiastically, Lee (2012) warns that with the possibility of identity change in the crossing from one activity to another, activity theory remains a ‘daunting framework of choice’ for identity-based science education researchers (2012, p.39).

In recent years, Eccle’s ‘expectancy-value’ theory, based on identity conceptualised in terms of two sets of self perceptions: perceptions related to *skills, characteristics, and competencies*, and perceptions related to *personal values and goals* (Brophy, 2009; Eccles, 2009; Bøe, 2011), has found its way into identity-based and STEM- related science education research (Aschbacher et al., 2010; Bøe et al., 2010; Hill et al., 2010; Lyons & Quinn, 2010; Riegle-Crumb et al., 2010; & Bøe, 2011; Bøe et al., 2011; Andrée and Hansson, 2012; Cerinsek et al., 2012). For Eccles (2009), these sets of perceptions inform an individual’s expectation of success and the significance of ‘becoming involved in a wide range of tasks’ (2009, p.78). Resident within traditional psychological epistemologies, Eccles (2009) argues that individual expectations of success, self-confidence to succeed, and personal efficacy, have long been held to be key ‘mediators of behavioural choice’ (2009, p.81): ‘I believe that task/activity/behaviour choices are influenced by the intraindividual’s hierarchy of success expectations and personal efficacies. We predict that people select those activities for which they feel most efficacious ... By and large evidence supports this prediction’ (2009, p.81). On Bøe’s (2011) understanding, Eccle’s model predicts that students will likely choose courses they feel competent in and that hold high value for them. If so, then the reported tendency of girls to ‘put more emphasis than boys on idealistic values, such as helping other people’ may be predictive of girls ‘not choosing careers related to physical science’ (Bøe, 2011, p.13; see Cerinsek, 2012).

Given the disciplinary divisions between traditional psychological approaches, social psychology and sociology, debates that simmer over both the individual/society dichotomy and the agency/structure duality (Lee, 2012), along with a plethora of identity theories and different interpretive approaches, attempts to definitively conceptualise identity are likely fraught: ‘everybody it seems is talking about identities, but it is not at all clear that they are talking about the same thing’ (Rattansi & Phoenix, 2005, p.98). Rattansi and Phoenix (2012) go on to argue that traditional forms of identity theorisation productive of ‘a strong individual/society dichotomy obscure understanding of the complex ways in which identities are formed and operate dynamically in different social contexts” (2005, p.101). Science education researchers Barton et al. (2012) concur with the identity’s methodological problematic:

> identity studies are inherently complex. Who one is and who one desires to be at any given moment is always under negotiation and is contingent upon the resources one has access to and the social, cultural, and historical context in which one seeks to author oneself with ... identities are always in the making and are always socially negotiated, they are impossible to isolate or to name, raising questions about how to study them. In our work, we find it productive to focus on identity *work* rather than identities themselves (2012, p.2; author’s emphasis)

Methodological considerations: the challenge of identity measurement

Rattansi and Phoenix (2005) go some way to respond to Barton’s et al. (2012) question related to how to study identities by asserting that studies of young people cannot be reliant on methodologies such as attitudinal survey research at the expense of ethnographically rich descriptions of ‘myriad ways ... identities are constructed and re-worked in different social contexts’ (2005, p.107). McLean and Pasupathi (2012) argue for the use of identity narratives to chart identity trajectories over time in different place locations. In accord with narrative approaches taken by Moreau et al. (2010) and Varelas et al. (2012), Rattansi and Phoenix (2005) suggest that newer theorisations of identity can find modes of empirical substantiation within a ‘combination of methodologies, including ways of eliciting nuanced narratives of self and locale’ (2005, p.111). From Thomoshow’s (1995) ecological identity research perspective, collaborative text strategies that stimulate dialogue around students’ environmental interest in and engagement with environmental issues at local and global levels, offer a creative way to generate multi-layered self-narratives.

In recent times creative visual methodologies have come to the fore as a way to explore the identity construct and to elicit self-narratives in identity-related sociological and educational research (see Holt, 2008; Moss, 2008). As such, it was surprising that, with the exception of Olitsky et al. (2010) whose research employed video vignettes, explicitly identity-focused science education literature reviewed here made no mention of the potential for visual strategies to broaden theoretical understandings of identify or provide an active and personal way for students to explore the notion of a science identity and what science might mean to them.

Identity focused STEM research: An empirical overview

The empirical identity-based science education research unearthed in this review update reflects significant diversity in relation to: research questions and aims, identity conceptualisations, underpinning identity frameworks, methodologies, research settings, participants’ ages, gender, ethnicities, and socio economic status. Such diversity across multiple dimensions makes any attempt to draw study comparisons fraught. Furthermore, the extent to which the identity construct is at the forefront in these studies varies considerably. In some, identity constitutes the central construct of research interest (see Archer et al., 2010; Aschbacher et al., 2010; Hazari et al., 2010; Olitsky et al., 2010; Barton et al., 2012; Krogh & Andersen, 2012; Wong, 2012). In others, identity gains presence for example as an informant of the research questions (see Cerincek et al., 2012), in its emergence from the data (see Moreau et al., 2010), or to inform recommendations (see Lyons & Quinn, 2010). Moreover, it was not always clear how identity was being theorised. The lack of critique by researchers of selected theoretical frames in terms of challenges and opportunities these present for identity-related science education represents a gap in this research field. Nonetheless, the diverse identity related studies reported here have in common an interest in exploring questions to do with ‘Is science me?’ (see Aschbacher et al., 2010), and further understanding student assertions such as ‘I may be clever enough to do it’ (see Krogh & Anderson, 2012), and ‘I’m the kind of kid who needs a good teacher to get ahead’ (see Aschbacher et al., 2010, p.571).

The following overview of empirical identity-focused STEM research is structured around firstly, recent methodological trends and secondly, key findings from selected research practice exemplars. Brief snapshots of key findings are framed around some of the themes identified in the Tytler et al. (2008) STEM review as critical to increasing student participation and engagement in STEM: the socially constructed nature of science and scientists; girls participation in STEM; and factors influencing students’ subject choices and career aspirations. Reflective of current identity-related science education research generally, and identity research specifically, these (and other) themes are understood to always exist in complex interplay.

Recent methodological trends

The trend towards increased interest in qualitative research approaches, either as mixed methods or solely qualitative studies, noted in the STEM review (Tytler et al., 2008) is reflected in some of the reviewed literature here. Within this, exemplars of qualitative studies describe data generation strategies, including:

- Interviews and individual text-based participant ‘portraits’ (Barton et al., 2012);
- Individual participant identity trajectory narratives (Krogh & Andersen, 2012);
- Video and audio taped vignettes (Olitsky et al., 2010);
- ‘Norms and values’ card sort interviews (Carlone, 2012);
- Individual case study vignettes (Wong, 2012); and
- Focus group discussions (Chetcuti & Kioko, 2012).

Data generated through these strategies have a capacity to tease out the complex contextualised strands of students’ science-related experiences and as such bring to view in a hermeneutic sense, the uniqueness of both the ‘parts’ and the in-progress ‘whole’ of students’ science identities.

However, the use of large-scale survey questionnaire approaches remain both pervasive and useful for generating different types of data and for providing the basis for further studies (see DeWitt et al., 2010; Hazari et al., 2010; Reigle-Crumb et al., 2010; Cerinsek et al., 2012; Krogh & Andersen, 2012; Regan & Dillon, 2012). Notably, survey approaches were frequently mentioned in mixed methods studies (Aschbacher et al., 2010; DeWitt et al., 2012; Krogh & Andersen, 2012). Not surprisingly, many of the studies located are wholly or in part, longitudinal, as a necessary design requirement to better understand the ongoing formative character of identity development and to track this at different points in time and place (see Aschbacher et al., 2010; Hazari et al., 2010; Cerinsek et al., 2012; Barton et al., 2012; Krogh & Andersen 2012). Cerinsek et al. (2012) reflect: ‘in our case, more in-depth and longitudinal research would need to be conducted in order to identify ‘indirect’ connections and patterns between parents’ perceptions of science, parents’ perceptions of their children’s abilities in science, children’s interests and self-efficacy beliefs, and, finally, their choice of studying STEM’ (2012, p.20).

The social construction of science and scientists

Bringing attention to culturally produced representations of science and science careers generated for the most part by popular media, studies by Archer et al. (2010), Moreau et al. (2010) and DeWitt et al. (2012) bring new insights into ways such representations may play into students’ participation and engagement with STEM and later career aspirations.

Beginning with Archer’s et al (2010) five-year longitudinal study, this focused on primary school students’ constructions of science from feminist poststructuralist and critical sociological identity perspectives. From these standpoints, ‘a sense of self is constructed as much through a sense of what/who one is not, as much through the sense of who/what one is’ (Archer et al., 2010, p.619). According to the authors, the literature base related to children’s gendered science identities, or sense of self, is substantive. However, Archer et al. (2010) argue that the ways children’s science identities are constructed requires exploration at greater depths to reveal not only the mechanisms of gendered constructions but also how social class and ethnicities play into the science identity construction project.

Data generated through focus group discussion with 10-11 year old children revealed constructions of science as ‘hard’/‘brainy’, ‘natural’/‘natural ability’, and scientists as ‘boffins’. According to Archer et al. (2012), the children’s descriptions of scientists as ‘boffins’ resonate with popular stereotypes of mathematicians (see Moreau et al., 2010). That the children’s visions of scientists embrace notions of eccentricity, maleness, and madness has significant implications for ways girls might imagine themselves as scientists or aspire to a career in science: ‘When I hear science I usually think of this man with a big moustache ... with hair all round his head’ (boy participant, Archer et al., 2010). According to Archer et al. (2010), such findings present a dilemma for educators in that although both girls and boys demonstrate interest and enjoyment in science in the middle childhood years, these positive dispositions wane in later years as children transition into secondary school (Archer et al., 2010; DeWitt et al., 2012; Tytler & Osborne, 2012). From this research, narrow constructions of science as ‘too hard’ and scientists as ‘unattractive’ are unlikely to change without more fully understanding the mechanisms related to how and why such constructions persist.

Motivated by the science education dilemma earlier raised, DeWitt’s et al. (2012) longitudinal UK study drawn from the larger ASPIRES (Science Aspirations and Career Choice: Age 10-14) project, provides insights into both children’s and their parents’ perceptions of science. Responding to a perceived lack of research focused on children’s perceptions of ‘science-keen peers’, DeWitt et al. (2012) used interview data to identify the types of science discourses children and their parents may invoke to give shape to ways children (and parents) construct their own science identity. Study findings revealed a number of discourses, including the ‘highly visible’ stereotypical ‘geek nerd’ scientist congruent with the white male and modifying or qualifying discourses that position scientists as ‘clever’ specialists (DeWitt et al., 2012, n.p). These findings suggest that both discourses are likely to position those who aspire to a science career as ‘other’, and are likely to ‘act against student ... willingness to take up a science identity’ (DeWitt et al., 2012, n.p).

Looking specifically to constructions of mathematicians in popular culture through school and university students’ narratives, Moreau’s et al. (2010) UK study resonates with that of DeWitt et al. (2012). With an aim to understand how popular cultural images of maths and mathematicians are deployed in learners’ identity narratives, Moreau et al. (2010) conducted group and individual interviews with 14-15 year old students and second and third year university undergraduates. Following NVivo coding of the interviews, the data was further thematically analysed to identify the nature of the discourses in the group interviews. Findings from this study point out a ‘complex relationship in which individuals do draw on popular cultural images of mathematicians, while simultaneously being aware of their clichéd nature’ (Moreau et al., 2010, p.34). Moreau et al. (2010) also note that participants’ responses warn that it is very difficult to predict the way people will read popular cultural images, and that the relationship between the image and viewer is ‘not deterministic’ (2010, p.35). The researchers suggest wider representations of mathematicians than those conveyed through the white male stereotype are needed to ensure that ‘mathematical futures become more thinkable’ (Moreau et al., 2010, p.35).

Girls participation in STEM

On the issue of underrepresentation of girls in STEM education and in science-related careers, specifically within physics and maths disciplines, Tytler et al. (2008) assert:

> There are particular social factors that operate to support or discourage the participation of women in STEM. These are linked with identity and self efficacy issues and the support offered both within science and mathematics classrooms, but also to broader patterns that shape identity. Cultural stereotypes about gender have an impact on students' career aspirations and subject choices (Correll, 2001, 2004). Female students are more likely to aspire to non-STEM careers (2008, p.93).

Decades on from the pioneering work by Spender, Weiner and Walkerdine into gender inequities in education and career choice (see Tytler et al., 2008, p.94), significant gender differences in STEM participation rates and science-related career aspirations stubbornly endure. Four studies reviewed here make some attempt to unravel the nature of these differences from different theoretical perspectives to offer suggestions why this is so.

Revisiting Archer's et al. (2010) study for insights into possible reasons for gender imbalances in STEM participation, their findings draw attention to intriguing gender differences suggesting that girls and boys have distinctly different views of science, depending on the context in which science is 'done'. For girls, home and primary school are perceived as settings for doing 'safe' science, while the real world of science work is understood as 'dangerous'. Boys in this study anticipated 'doing' more dangerous science at secondary school: 'it's better because they trust you with more dangerous chemicals, stuff like that' (participant, Archer et al., 2010, p.623). Such perceptions are likely to play some part in shaping children's interest and enthusiasm for science and their aspirations towards science-related careers as they transition to secondary school. However, in arguing for a new vision of science education that embraces a notion of science careers as 'personally fulfilling, worthwhile and rewarding', the authors acknowledge that in the face of other constraints (e.g., negative media representations of science and scientists), such visions may not be enough. The significance of Archer's et al. (2010) study lies in teasing out of 'complex identity processes to reveal deep-seated, often trenchant, resistance to interventions' designed to increase young people's, and in particular girls, positive engagements with science (Archer et al., 2012, p.637).

Acknowledging that gender differences in participation in physics disciplines have 'troubled' educators for over four decades, Hazari et al. (2010) draw on data from a large-scale US Persistence Research in Science and Engineering (PRiSE) survey project to examine ways students' physics identities are shaped by class room experiences: 'The lack of sufficient growth in both female and overall participation makes it an imperative to reexamine our approach to the teaching and learning of physics' (2010, p.979). The theoretical approach used by the researchers, based on Carlone and Johnson's (2007, in Hazari et al., 2010) centralising framework that purports to predict how students, 'particularly females', situate themselves with regard to physics within four domains: interest, recognition, performance and competence. From the study findings, Hazari et al. (2010) identify how high school physics teachers could positively influence student's physics identity through: a sharper focus on conceptual understanding, making physics contextually relevant to the real world, contesting negative cultural stereotypes of physics and physics careers, and encouraging students' active participation as 'experts' within classroom discussions. In a nutshell, Hazari et al. (2010) identify a classroom-based intervention premised on the need for teachers to 'provide opportunities for recognition, recognise students themselves, and to focus on practices ... that will not only increase competency but also feelings of competency' (2010, p.998).

Moving to qualitative approaches, Barton's et al. (2012) study, located within social practice theory and feminist writings on intersectionality, and Wong's (2012) case study, informed by the notion of identity as ‘performativity’ and Bourdieu’s notion of ‘*habitus*’ (2012, p.43; original emphasis) both present rich narrative data on girls’ science identities. Sharing Hazari’s et al. (2010) concerns about long term STEM underrepresentation of girls, Barton et al. (2012), through a longitudinal study, explore the nature of science identity work performed by girls in their middle school years. Cognisant of the ‘cumulative and contentious’ nature of this work, the researchers hoped to identify and better understand the mechanisms that produce critical shifts in girls’ identity trajectories. Findings from this study suggest that middle-level girls’ identity work in science reveals ‘multiple and conflicting identity trajectories ... responsive to and defiant of the figured worlds in which they participate’ (2012). Further, these researchers argue that the way girls will likely view their possible future selves in science is contingent upon their identity work being ‘recognised, supported, and leveraged towards expanded opportunities for engagement in science’ (2012, n.p).

Wong’s (2012) findings, explicated in the form of two 13-year old girls’ case study vignettes speak to minority ethnic girls’ science aspirations. Although both are high achievers in their science classes, only one aspired to study ‘triple’ science while the other planned to become famous. The girls’ vignettes demonstrated both different forms of identity performativity related to being recognised as intelligent and being famous, and different ‘educationally orientated’ long-term and short-term notions of *habitus* (2012, p.61). Through the application of Bourdieuian theory, Wong (2012) hopes the findings can contribute to fresh insights into the ‘complex processes and negotiations, between identities and cultural discourses’ that actively shape girls’ career aspirations (2012, p.61).

Factors influencing students’ subject choices and career aspirations

The literature based on identifying and understanding students’ subject choices and career aspirations reviewed in this update includes work by Aschbacher et al. (2010), Krogh and Andersen (2012), and Cerinsek et al. (2012). Here the review focus is on three distinctly different approaches to understanding students’ science identity trajectories: a mixed methods ‘community of practice’ approach influenced by Eccle’s expectancy-value identity theory (Aschbacher et al., 2010); a mixed methods approach informed by a Late Modern conception of identity (Krogh & Andersen, 2012); and a large scale survey project informed by Eccle’s ‘expectancy-value’ identity theory (Cerinsek et al., 2012).

Firstly, premised on the assumption that ‘science understanding is an increasingly precious resource throughout the world’, Aschbacher et al. (2010) draw on the science pipeline metaphor to follow an ethnically and economically diverse sample of 33 high school girls. This study posed the research question: Why do some students interested in science during middle and early high school decide to leave the science, engineering, and medical (SEM) pipeline by the end of high school while others opt to persist? The identity theory in this study found home in the notion of communities of practice in which identity is informed by situated everyday social interactions (Aschbacher et al., 2010). To better understand student’ science identity trajectories, the researchers looked to Eccle’s ‘expectancy-theory’ model to link the students’ educational and career decisions to expectations of success and to the value priorities of possible career options. The attraction of this model centred on its emphasis on significant people in students’ lives and their role in shaping how students ‘access, interpret, and evaluate their lived experiences, in turn, affecting their short- and long-term goals, attitudes, values and priorities’ (Aschbacher et al., 2010, p.566).

From the interview data analyses, three groups emerged: ‘High Achieving Persisters’, ‘Low Achieving Persisters’, and ‘Lost Potentials’. The findings identified some of the contributing factors to these outcomes suggesting that these lie within each group’s diverse social ‘microclimates’ as shapers of students’ science identities and their perceptions of their study capabilities, career options and expected success:

> Our students’ experiences suggest that the value of communities of science practice lies partly in the depth and personal meaning of the activities and interactions there, and that identity within a community is deepened by competence and positive assessments by self and others ... more students might be interested in careers involving ... science if they were aware of them and if the learning process were more personally meaningful, acknowledged what they bring to science, and provided the chance to enact who they might want to be (Aschbacher et al., 2010, p.579).

Second, Krogh and Andersen’s (2012) longitudinal study drawing on a Late Modern conception of identity focused on a group of Danish A-level maths students’ science identity trajectories during their final secondary school years as they participated in a university mentorship program. In this study the researchers attempted to find responses to two key questions:

- What characterizes students’ identity narratives in relation to science and academic education? and
- How can students’ science related trajectories be understood and hypothesized in terms of a set of identity constructs identified in the narratives?

From a hermeneutic analysis of the students’ narratives, the researchers applied their Four Factor Framework model to characterise the students’ science identity trajectories comprising the factors: identity process orientations, personal values, subject self concept, and subject interest (see Krogh & Andersen, 2012, n.p., Table 1). These analyses highlighted ‘personal values’ as a distinctive characteristic of the narratives. In particular, Krogh and Andersen (2012) note ‘Social relationships, recognition, family, knowledge, excitement/challenge were among the core values found ‘ (2012, n.p.).

Krogh and Andersen’s (2012) research report is a rare exemplar of identity-based science education research in its comprehensive accessible justification of each phase of the study. They acknowledge: ‘Since our methodology and our particular group of students’ differ from most identity studies in science education our achievements are not easily contrasted. However, with minor modifications we imagine that our Four Factor Framework would work well with a broader group of students’ (Krogh & Andersen, 2012, n.p).

As the third exemplar of research focused on factors influencing students’ subject choices and career aspirations, Cerinsek’s et al. (2012) study is responsive to the lack of STEM-related research in Slovenia (2012, p.7). This research, as part of a larger project within IRIS, employed the IRIS Questionnaire to gather data from all first year students enrolled in STEM degrees at three large Slovenian universities. In this study four questions framed the study’s two main objectives to:

- Identify male and female STEM students’ future career priorities; and
- Identify different important factors (i.e., key persons, previous school and out-of-school experiences) influencing STEM study choices.

Drawing on Eccle's 'expectancy-value' identity model, the researchers teased out the following key findings from the students' questionnaire data:

- There is evidence students aspire to interesting and fulfilling careers, hope for opportunities to develop themselves and earn a high income within a secure job;
- Girls were found to be more interested in pursuing careers contributing to sustainable development, protecting the environment, and helping others;
- In contrast to other studies reviewed, 'key persons' were not found to be important in terms of having an influence on students' STEM study choices. However, mothers and good teachers were found to have an influence on girls' STEM choices more than boys; and
- Different in- and out-of-school experiences can be considered as significant mediators in the level of interest students' demonstrate.

From this glimpse into the diverse ways researchers conceptualise and design identity-based science education research, what emerges is a mosaic of research approaches reflective of strong and passionate interest in research addressing participation and engagement in STEM-related school science and students' future career aspirations.

Conclusion

This review reported on post 2008 STEM-related literatures that build on Tytler's et al. (2008) comprehensive review of research that seeks to clarify identity and attitude relations with regard to engagement with and learning in STEM-related subjects. As a synthesis of selected literature related to diverse literature fields around identity, science education, and STEM interests, this review update attempted to respond to the question:

How can the identity construct be understood as a useful pathway into students' school science priorities and future career aspirations? This review:

- Looked at the literature related to repositioning dominant attitudinal only approaches within broader holistic identity research frameworks;
- Opened up a literature conversation around the meaning, theorisation, measurement, and research application of the identity construct; and
- Illuminated diverse identity-related science education research approaches.

Drawing on STEM-related literatures reviewed for this report, the following summarises possible ways forward in both identity-related science education research and in school-based science education teaching and learning contexts.

Research methodologies

Given the dearth of qualitative research approaches in science education research more generally and in attitude- and identity-focused research specifically, Archer et al. (2010), Aschbacher et al. (2010), Barton et al. (2012), Carlone (2012), Krogh and Andersen (2012), Varelas (2012), and Wong (2012) make significant contributions to this literature field. From the literature reviewed, qualitative approaches are epistemologically coherent with late modern sociological identity theorisations, and are well situated, through the generation of rich contextualised understandings, to get behind the nature of students' identity relationships to and with upper secondary level subject choices and future career aspirations and priorities. The notable absence in the science education literature reviewed of the use of creative participative visual strategies flags a future methodological direction for science education researchers. In contrast to interview approaches, visual strategies hand over greater control and subject ownership to participants and as such may spark their deeper engagement with and exploration of the 'subject' of identity. Further, dialogues around participants' own photographs within unstructured interview contexts have the potential to open a window to participants' interests, curiosities, passions, and future hopes (Banks, 2007; Rose, 2009; Pink, 2011).

School-based science education teaching and learning

That students' science identities are shaped by complex dynamic interactions between gender, culture, socio-economic status, science education curricula and pedagogy, teacher characteristics, students' school and out-of-school science experiences within their family, school, and peer social networks, suggests significant challenges for educators to find ways of increasing young people's participation in and engagement with STEM at all school levels. From a teacher education perspective, Reigle-Crumb et al. (2012) call for high quality professional development activities and the use of pedagogical techniques that promote students' science learning and enjoyment through active and cooperative learning activities. Carlone (2012) suggests the use of an anthropological lens through which science education teachers develop with their students ethnographies of personhood to promote students' critical thinking about science and reflection on its meaningfulness to their everyday lives (see Christidou, 2009). In the context of communities of practice, Aschbacher et al. (2010) argue for education programs that can help educators, families, students and others 'appreciate and value science ... [and] at the same time transcend the narrow vision of the culture of power in science education that alienates or counsels too many youth away from learning and enjoying science' (2010, p.580). More pointedly, Christidou (2011) asserts the need to promote

> a more accurate and updated image of science as an interesting and attractive activity, combined with a more realistic and humane image of scientists, their professions, and personalities, liberated from negative and gender stereotypes ... and providing relevant role models to young people – and especially girls – to encourage their engagement in science related studies and careers (2011, p.152)

On the issue of students' direct practical engagement with science, the literature reviewed suggests initiatives designed to tap into students' interests in personally relevant and meaningful science and science-related career aspirations have potential to promote STEM engagement and participation. Initiatives may include: school-based seminars, excursions, and 'hands on' projects (Masnick et al., 2010; Welch, 2010; Eurydice, 2011b); secondary school-university science enrichment programs (Oliver & Venville (2011), student-scientist mentoring programs and internship opportunities (Aschbacher et al., 2010); science-related work experience; promotional campaigns (Andrée & Hanson, 2012); and 'science-in-the-community' initiatives. As Aschbacher et al. (2010) note, such initiatives 'allow students to explore identity connections to science in their own individuals ways' (2010, p.580).

In conclusion, Ulriksen's et al. (2010) salient question, 'Will it be possible for STM programmes to convince future and present students that being integrated into a STM discipline is an attractive perspective for a young individual trying to find out who she or he is, and what direction her or his life should take?' (2011, p.239) keeps the STEM conversation alive.

References

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

Al-Mahmood, R. (2008). En/visioning online learning: Identity and spatiality performances. In J. Moss (Ed.), *Researching education: Visually, digitally, spatially* (pp.147-18). Rotterdam: Sense Publishers.

Anastasiou, P., & Dillon, J. (2010). IRIS Working document 4.1a: Review on young people's (particularly girls educational choice for choosing (or not choosing) STEM. Retrieved 17 October 2012, from http://iris.fp-7.org/reports-publications/

Andrée, L., & Hansson, L. (2012). Marketing the 'Broad Line': Invitations to STEM education in a Swedish recruitment campaign. *International Journal of Science Education*. Retrieved 5 November 2012 from http://dx.doi.org/10.1080/09500693.2012.695880

Archer, L., Dewitt, J., Osborne, J., Dillon, J., Willis, B., & Wong. (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*, 617-639.

Aschbacher, P., Li, E., & Roth, E. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, *47*, 564-582.

Banks, M. (2001). *Visual methods in social research.* London: Sage.

Barton, A., Kang, H., Tan, E., O'Neill, T., Bautista-Guerra, J., & Brecklin, C. (2012). Crafting a future in science: Tracing middle school girl's identity work over time and space. *American Educational Research Journal*. Online First DOI: 10.3102/0002831212458142

Bøe, M. (2011). Science choices in Norwegian upper secondary school: What matters? *Science Education*, *96*, 1-20.

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 – 71.

Brophy, J. (2009). Connecting with the Big Picture. *Educational Psychologist*, 44, 147-157.

Carlone, H. B. (2012). Methodological considerations for studying identities in school science: an anthropological approach. In M. Varelas. (Ed.) *Identity construction and science education research: Learning, teaching, and being in multiple contexts* (pp.9-25). Rotterdam: Sense Publishers.

Cerinsek, G., Hribar, T., Glodez, N., & Dolinsek, S. (2012). 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*. Retrieved 17 September 2012 from http://dx.doi.org/10.1080/09500693.2012.681813

Chang, S-N., & Yeung, Y-Y., & Cheng, M. (2009). Ninth graders' learning interests, life experiences and attitudes towards science and technology. *Journal of Science Education and Technology*, *18*, 447–457.

Chetcuti, D., & Kioko, B. (2012). Girls' attitudes towards science in
Kenya. *International Journal of Science Education*, *34*, 1571-1589.

Christidou, V. (2011). Interest, attitudes and images related to science: Combining students' voices with the voices of school science, teachers, and popular science. *International Journal of Environmental & Science Education*, *6*, 141-159.

Clayton, S. & Opotow, S. (Eds.) (2003). *Identity and the natural environment: The psychological significance of nature*. Cambridge: The MIT Press.

Desey, E., Peterson, S., & Brockman, V. (2011). Gender differences in science-related attitudes and interests among middle school and high school students. *Science Educator*, *20*, 23-30.

DeWitt, J., Archer, L., Osborne, J., Dillon, J., & Willis, B., & Wong, B. (2011). High aspirations but low progression: the science aspirations–careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education*, *9*, 243-271.

DeWitt, J., Archer, L., Osborne, J. (2012). Nerdy, brainy and normal: Children's and parents' constructions of those who are highly engaged with science. *Research in Science Education.* DOI: 10.1007/s11165-012-9315-0

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist*, 44 (2), 78-89.

Eurydice. (2011a) *Mathematics Education in Europe: Common Challenges and National Policies*. Brussels: ECAEA/Eurydice. Retrieved 26 October 2012, from http://eacea.ec.europa.eu/education/eurydice/thematic_reports_en.php#2011

Eurydice. (2011b). *Science Education in Europe: National Policies, Practices and Research.* Brussels: ECAEA/Eurydice. Retrieved 26 October 2012, from http://eacea.ec.europa.eu/education/eurydice/thematic_reports_en.php#2011

Eurydice. (2012). *Key Data on Education in Europe* 2012. Brussels: ECAEA/Eurydice. Retrieved 26 October, 2012, from *http://eacea.ec.europa.eu/education/eurydice/.../key_data_series/134en.pdf*

Harrell-Levy, M. K., and Kerpelman, J. L. (2010). Identity process and transformative pedagogy: Teachers as agents of identity formation. *Identity: An International Journal of Theory and Research*, *10*(2), 76-91.

Hazari, Z., Sonnert, G., Sadler, P., & 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*, 978-1003.

Hemmings, B., Grootenboer, P. & Russell, K. (2011). Predicting mathematics achievement: the influence of prior achievement and attitudes. *International Journal of Science and Mathematics Education*, *9*, 691-705.

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics.* Washington, DC: AAUW.

Holt, B. (2008). Research beyond words: Exploring identity though photographs with metropolitan university students from rural areas. In J. Moss (Ed.), *Researching education: Visually, digitally, spatially* (pp.127-146). Rotterdam: Sense Publishers.

Krogh, L., & Andersen, H. (2012). "Actually, I may be clever enough to do it". Using identity as a lens to investigate students' trajectories towards science and university. *Research in Science Education*. DOI: 10.1007/s11165-012-9285-2

Lamb, R. L., Annetta, L., Meldrum, J., & Vallett, D. (2012). Measuring science interest: Rasch validation of the science interest survey. *International Journal of Science and Mathematics Education*, *10*, 643-668.

Lee, Y. J. (2012). Identity-based research in science education. In: B. J. Fraser., K. Tobin., and C. J. McRobbie (Eds.) *Second international handbook of science education* (34-45). Dordrecht: Springer.

Lyons, T., & Quinn, F. (2010). Choosing science. Understanding the declines in senior high school science enrolments. Research Report to the Australian Science Teachers Association. Armidale: University of New England. Retrieved 8 September, 2012, from *http://www.une.edu.au/simerr/pages/projects/131choosingscience.pdf*

Macnaghten, P., & Urry, J. (1998). *Contested natures*. London: Sage.

Mamlok-Naaman, R., Korpershoek, H., Kuyper, H., Bosker, R., & Van Der Werf, G. (2011). How can we motivate high school students to study science? *Science Education International*, *22*, 5-17.

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*, 653-667.

Mavrikaki, E., Koumparou, H., Kyriakoudi, M., & Papacharalampous, I., & Trimandili, M.

(2012). Greek secondary school students’ view about biology. *International Journal of Environmental & Science Education*, *7*, 217-232.

McLean, K., and Pasupathi, M. (2012). Processes of identity development: Where I am and how I got there. *Identity: An International Journal of Theory and Research*, *12*(1), 8-28.

Moreau, M-P., Mendick, H., & Epstein, D. (2010). Constructions of mathematicians in popular culture and learners’ narratives: A study of mathematical and non-mathematical subjectivities. *Cambridge Journal of Education*, *40*, 25-38.

Moss, J. (2008). Education researchers – Working visually, digitally, spatially. In J. Moss (Ed.), *Researching education: Visually, digitally, spatially* (pp.1-20). Rotterdam: Sense Publishers.

OECD. (2010). PISA 2009 results: What students know and can do—Student performance in reading, mathematics and science. Retrieved 5 October 2012 from *http://dx.doi.org/10.1787/9789264091450-en*

Olitsky, S., Loman, L., Gardner, J., and Billups, M. (2010). Coherence, contradiction, and the development of school science identities. *Journal of Research in Science Teaching*, *47*(10), 1209–1228.

Oliver, M., & Venville, G. (2011). An exploratory case study of Olympiad students’ attitudes towards and passion for science. *International Journal of Science Education*, *33*, 2295-2322.

Olsen, R. V., Prenzel , M., & Martin, R. (Eds.). (2011). Interest in Science: A many-faceted picture painted by data from the OECD PISA study. [Special issue]. *International Journal of Science Education*, *33*(1), 1-178.

Osborne, J., Simon, S., & Tytler, R. (2009). Attitudes towards science: An update. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, California, April 13 -17.

Pedersen, K., & Viken, A. (2003). Nature and identity- an introduction. In K. Pedersen & A. Viken (Eds.), *Nature and identity*: *Essays on the culture of nature* (pp.10-30). Bergen: HøyskoleForlaget.

Pink, S. (2011). A multisensory approach to visual methods. In E. Margolis & L. Pauwels (Eds.), *The Sage handbook of visual research methods* (pp.601-614). London: Sage.

Rattansi, A., and Phoenix, A. (2005). Rethinking youth identities: Modernist and postmodernist frameworks. *Identity: An International Journal of Theory and Research, 5*(2), 97-123.

Regan, E., & Dillon, J. (2012). Undergraduate students' narrations of gender and choice – a focus group study. Retrieved 14 October from www.heacademy.ac.uk/assets/documents/stem

Riegle-Crumb, C., Moore, C. & Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education*, *95*, 458-476.

Rose, G. (2007). *Visual methodologies: An introduction to the interpretation of visual materials*. London: Sage.

Saleh, I. M., & Khine, M. S. (2011). (Eds.) *Attitude Research in Science Education: Classic and Contemporary Measurements*. Charlotte, NC: Information Age Publishing, Inc.

Sjøberg, S., & Schreiner, C. (2010). The ROSE Project: An overview and key findings. Oslo: Naturfagsenteret.

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

Thomashow, M. (1995). *Ecological identity: Becoming a reflective environmentalist*. Cambridge, MA: The MIT Press.

Tomas, L., Ritchie, S., & Tones, M. (2011). Attitudinal impact of hybridized writing about a socioscientific issue. *Journal of Research in Science Teaching*, *48*(8), 878–900.
Tytler, R., Osborne, J., Williams, G., Tytler, K., & Clark, J. C. (2008). Opening up pathways: Engagement in STEM across the primary-secondary school transition. Retrieved 5 September 2012, from *http://nla.gov.au/nla.arc-88047*
Tytler, R., & Osborne, J. (2012). Student attitudes and aspirations towards science. In *Second international handbook of science education* [electronic resource] Barry J. Fraser, Kenneth Tobin, Campbell J. McRobbie (Eds.) Dordrecht; New York: Springer.
Ulriksen, L., Møller Madsen, L., & 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.
Varelas, M. (Ed.). (2012). Identity construction and science education research: Learning, teaching, and being in multiple contexts. Rotterdam: Sense Publishers.
Varelas, M., Kane, J., & Wylie, C. (2012). Young black children and science: Chronotopes of narratives around their science journals. *Journal of Research in Science Teaching*, *49*, 568–596.
Welch, A. (2010). Using the TOSRA to assess high school students' attitudes toward science after competing in the FIRST Robotics competition: An exploratory study. *Eurasia Journal of Mathematics, Science and Technology Education*, *6*, 187-197.
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*, 43-65.
Yee, L. S., & Chapman, E. (2011). Using history to enhance student learning and attitudes in Singapore mathematics classrooms. *Education Research and Perspectives*, *37*, 110-132.
Zain, A. N., Samsudin, M. A., Rohandi., & Jusoh, A. (2010). Using the Rasch model to measure students' attitudes toward science in "Low Performing" secondary schools in Malaysia. *International Education Studies*, *3*, 56-63.