Chapter 1

Models of scientific identity

Saima Salehjee*
School of Education, Strathclyde University, Glasgow, Scotland, UK

and

Mike Watts
Department of Education, Brunel Univeristy London, UK

ABSTRACT

This chapter examines a series of key science identity-based research models. Our purpose is to discuss the interplay of individual agency and social interaction through the lens of transformative learning. We critique those current identity-based models based on the importance given to either social structures and/or agency separately. We also review contemporary research on transformational learning and identity change, illustrating transformation or movement of learners towards, or away from, the study of science. The chapter is a contribution to the debates concerning the considerable impact of identity construction on learning, and the construction of 'science-identity' in particular. With this in mind, we examine the central issues in the light of the teaching and learning of science in schools and universities, as well as in the population at large.

Our core argument is that an understanding and analysis of these models and theories leads to the design of a conjugated theoretical model of 'science/ scientific identity' (Sci-ID) consisting of seven main interconnected and interlinked 'slices'. These seven slices represent the (i) global forces (GF: such as gender, ethnicity, race and class) experienced by learners, (ii) social agencies and agents (SA: such as schools, other institutes, parents and teachers) personifying global forces, (iii) transformational learning (TL) experiences (accidental and/or

An accepted author manuscript of the following book chapter: Salehjee, Saima ; Watts, Mike . / Models of scientific identity. Science and Technology Education: Perspectives, Opportunities and Challenges. editor / Steffen Pabst. [S.I.] : Nova Science Publishers, 2018.

planned events, triggers and interventions) shaping (iv) personal preferences, (v) meaning, and (vi) individual internal agency (IIA) directed by the inner most (vii) central core impacting upon individuals' subject and career choices. Our concluding summary encompass: (a) identities that are fluid and stable – with the journey towards stability depends on factors such as, for example, age, experiences, relationships, events, triggers etc., (b) identities that are not entirely fluid, where there are forms of stability, a kind of internal force or agency that empowers people in accepting or declining the influences from the external forces; and (c) the ways in which one's identity depends on the strength of certain GF, SA, TL experiences (events, triggers, interventions) and the strength of one's IIA that goes with it or against it.

Keywords: identity, agency, structure, science identity, stable identity, and fluid identity.

INTRODUCTION

This chapter is an attempt to understand why some students will continue with their studies of science while others do not. It builds on a considerable body of educational research on identity: in this case, being - or not being - a 'science person'. As Darragh (2016) points out, identity is a lens that is adjustable; one that can zoom in (Lerman, 2001) to the level of interactions between individuals or zoom out to look at the wider socio-political context (Stinson & Bullock, 2012). This highlights a significant division in the literature between 'zoomed out' social identity, how one believes others perceive you, and a 'zoom in' on personal identity, how one sees oneself. There are numerous factors that contribute to social forms of identity, which at first glance may seem to exist outside of formal (school- and university-based) science education – such as gender, race, religion, social class and socioeconomic status. It is clear from studies in this area (for example, Archer et al., 2016) that students in some social groups (for instance, middle class, Asian males) have easier experiences identifying as a science person than do others (by contrast, white, working class girls). In our review, however, we focus in and look rather harder at subjective, individual level of identity than the broadly social, and work to understand learners' personal relationships with science. No doubt their 'personal identity' interacts significantly with their 'social identity' – not least

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

through praise or disapproval by peers, parents, teachers, tutors. In this chapter, though, we have chosen to foreground the personal over the social. As Nunes et al. (2017) point out, studies using socio-cultural perspective to investigate the teaching and learning of science education for low socio-economic status (SES) pupils dominate the research. In this chapter, while we begin with a broad social sweep, we center very rapidly on to the individual formation of identity and its relation to a young person's sense of being 'sciencey'.

A distinct trend in studies of identity can be traced to Carol Dweck's work on 'self-theories' and 'mindset' (1999, 2008) so that young people are seen to have either an 'entity' (fixed) view of their abilities, or an 'incremental' (growth) view. Our own research (Salehjee & Watts, 2015; Salehjee, 2017) introduces a nuanced version of this. We also posit two kinds of students: the first type sees their 'science disposition' as stable – fixed either positively for or adamantly against science. These are students who, on the one hand, see themselves as determinedly (pro-) science or, on the other hand, avowedly non-sciencey. The second type of students are fluid in regards to science – their dispositions are much more malleable: they can go with it, side against it or stay openly neutral, depending on circumstances, contexts and experiences. In this chapter we review literature that has directed us towards this set of outcomes and, in the final sections, discuss a particular composite model of science/scientific identity (the Sci-ID model) that owes a good deal to Jack Mezirow's (2000) and Knud Illeris (2014) theories of transformational learning.

Reviews of the nature of identity

Identity-based research has a long tradition in education, and is mirrored in science education (Lee, 2012). At heart, the debate is neatly captured in the reflective paper by Albright et al. (2008): the extent to which the construction of

identity is an expression of 'internal' individual agency or of 'external' cultural and social forces. They make the obvious, but relevant point that identity is conceptualized and bounded by the theoretical frameworks used, with identity being 'a slippery eel to grasp when it comes to informing educational practice' (p. 146). The classical division here is whether a young person's early 'dispositions' or 'identity' are driven primarily by personal identity or social identity, that is by 'individual internal agency', or the greater 'global forces' of social structures. As Block (2013, p.126) has stated, the theoretical rigidity between structure and agency is a 'tension often mentioned but seldom explored in depth'. The third way, of course, is that such polarities are iniquitous, both sets of factors are vitally important. This third way is nicely captured by Giddens (1979) when he stated that 'structure enters simultaneously into the constitution of the agent and social practices, and 'exists' in the generating moments of this constitution' (Giddens, 1979, p. 5). Giddens (1991) does believe that, while there exists 'ontological security' that gives a 'sense of continuity and order in events', 'self' is not a passive entity, determined solely by external forces. In this manner, Giddens moves away from 'dualism' ('agent/agency' and 'structure/rules of resources' being viewed as the two distinctions) towards 'duality' where both agency and structure are viewed as a part of the same phenomenon (Ransome, 2010). Moreover, Giddens, in his book 'Modernity and Self-identity' (1991) highlighted that modernity features 'an interconnection between two extremes of extensionality and intentionality: globalising influences on one hand and personal dispositions on the other' (Giddens, 1991, p.1). He therefore avoids an extreme positioning of extensionality (socially constructed identity or structure) and intentionality (personal identity or agency), and considers these positions to be two sides of the same coin.

Our intention here is not to discuss further the various theoretical tension in relation to structure and agency identified by Block (2013) or Giddens, instead we are interested in exploring 'science identity' that is shaped by the internal individual

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

agency. In this chapter we focus on young people's broad experiences and personal dispositions in relation to science education and career preferences, and highlight science identity-linked research models that explore the stability and fluidity of identity in shaping one's science identity. In doing that, we explore the influences that are derived from 'social agents', linking an individual's personal identity with the externally shaped 'global forces' of society such as social class, race, religion, ethnicity, gender, institutional status etcetera.

Social agents

So who might be these social agents? By social agents we mean families, parents, peers, schools, teachers, churches, clerics, youth centres, youth workers, employment, and employers and many more besides. These are social agents that are situated - and that intercede - between individual agency and the larger social forces. In this section, we highlight some of the literature on the impact of parents, school science and science teachers on individuals' science identities that allow them to countenance a science-based education and career.

(i) Parents and families

Numerous studies have identified parental involvement as an important ingredient in promoting academic success (for example: Jeynes, 2010; Seginer, 2006). In this vein, we note that parental influence varies on the basis of ethnicity, race, class, gender etc. For example, Bourdieu and Passeron (1990) have indicated the importance of the:

> *disposition, which middle class students or middle rank teachers, and a fortiori, students whose fathers are middle rank teachers, manifest towards education (p. 192).*

In a similar vein, Gilmartin et al.'s (2006) research, conducted in Southern California working with 1126 tenth grade students (age 15-16), has reported on the importance of 'family science orientation' ('students' perception of family interest

in and value of science'). In their case, this depends heavily on the family's ethnicity. In their work they have argued that Latino and Asian-American students' science career aspirations were strongly linked to perceptions of family support - rather more so than was the case for White and Black/African American students. They have suggested that the reasons for this difference in ethnicity/race are not clear but that, in Latino and Asian/ American families, parents certainly seem to have considerable power and influence in family decision-making. Gilmartin et al. (2006) indicated that these parents commonly make very clear their likes and dislikes about routes to study and prospective career choices.

Archer et al.'s (2012, 2013, 2104) ASPIRES important work has used a strong Bourdieusian framework to indicate that a family's 'science capital' refers to science-related qualifications, understanding, knowledge (about science and 'how it works'), interest and social contacts (e.g. knowing someone who works in a science-related job). Their (2014) analysis indicates that young people's aspirations are:

> *not simply individual cognitions residing within children's heads, unaffected by their social contexts. Rather, children's aspirations and views of science careers are formed within families, and these families play an important, albeit complex, role in shaping the boundaries and nature of what children can conceive of as possible and desirable and the likelihood of their being able to achieve these aspirations (p. 902).*

They point out that those families with higher levels of science capital (a derivative of Bourdieu's social, cultural and economic capital) tend to be middle-class - although this is not always the case, and not all middle-class families necessarily possess that much science capital. For this reason, in their final analysis, they recommend that 'there is a strong case to be made for the implementation of strategies designed to increase science capital within the UK families, to help make science (and hence science aspirations) more 'known' and familiar within families'

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

everyday lives' (p. 189). Archer et al. (2013) also indicate that the majority of the parents felt that:

> *science careers are associated with masculinity and held a perception of science as being an area that more men than women study and work in…. over half did view the sciences as dominated by men, although views differed considerably among parents as to the reasons for this imbalance, being divided between biological/genetic arguments and socio-cultural/structural arguments…' (p. 181).*

This sense of gender inequality was also seen by the students but not as intensely as by their parents.

Parental power has also been illustrated through Chinese parenting styles (Tao, 2016) – such as the concept of Chinese 'Tiger mother', which refers to mothers with very high power over their children's academic achievements. These mothers exert their power through setting explicit targets for their children, and expecting their children to attain the highest levels of achievement despite their ability range and the child's personal ambitions. In contrast, in the context of the USA, Ing (2014) noted that such external motivation driven by the parents tends to be short-lived and does little to help to push forward levels of attainment. For this reason, parents who generate intrinsic motivate in their children (Ing, 2014) achieve better, and generate greater student's persistence in a subject (in this case mathematics), than overtly extrinsic motivation. Jungert and Koestner (2015) also believe that parents should support students intrinsically in order to have a long-lasting effect. Moreover, as Hyde et al. (2016) point out, this relies upon effective communication (rather than one-way direction) between parent and the child about future subject and career choices. To shade this slightly, Jungert and Koestner (2015) have reported that 'parental autonomy support' for high school students (age 15-16) was seen to be most helpful largely for students who already with 'an intrinsic disposition in a domain' (p. 376).

(ii) School science and science literacy

From our perspective, it is quite clear that schools - and their school science curriulums - have considerable influence in mediating between home and wider social cultures. We believe the role of school science is vitally important. There is a considerable body of work addressing the nature and importance of school science itself (for example, Hulleman & Harackiewicz, 2009; Yeager & Walton, 2011), and the ways it influences science identity and students' aspirations towards future science education and career (Pike & Dunne, 2011). For example, Stuckey et al. (2013) see 'socio-scientific issues within science teaching' as highly relevant in the sense that classroom discussions of the societal dimension broadly influence perceptions of science and science education. The sense here is that students will have a positive attitude towards science if they can relate to daily-life science and 'real-life problem solving' (Mandler et al., 2012).

Beyond this, a positive influence of the school science curriculum means a positive view of 'science literacy for all'. Because the majority of the students will not (and cannot) become mainstream scientists, they can all, however, become science literate citizens (Hassard & Dias, 2009). This is recognised by many science educators as a worthwhile goal because they believe that pre-professional and established science is not as important as a broadly-based humanistic science-literate approach. As Archer et al. (2014) have emphasised in the context UK science education, the provision of scientific literacy and discussions of the nature of science (NoS) in the science classrooms, are important because:

> *widening participation in STEM is not only beneficial for the STEM "pipeline" (the supply of professionals to work within STEM fields of employment) and the UK's economy, but also for increasing the scientific literacy of the general UK population. Both are desirable because scientific literacy is viewed as an important form of symbolic capital (Archer et al., 2014[a], p. 22).*

Chapman and Feldman (2016) adapted their research from Carlone and Johnson (2007) and showed that student's active participation in school science - with a

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

focus on enquiry-based science learning (EBL) and teaching - can be extremely fruitful in both establishing and polishing individuals' science identity. For this kind of reason, Osborne (2014) designed a model for school science based on 'scientific activity', his model being composed of three phases: 'investigation', 'evaluation' and 'developing explanations and solutions'. In addition to 'scientific investigation', Osborne (2014) also indicated the incorporation of literacy in teaching and learning science, of 'writing science, talking science, reading science, doing science and representing scientific ideas' (p. 188). In supporting his model, Osborne criticised general science classrooms for failing to give more importance to investigative laboratory work that incorporates enquiry based teaching and learning. Moreover, he recommended that mathematics should act as a 'core feature' to incorporate NoS in the science classrooms and stated that 'avoiding the opportunity to use mathematical forms and representations is a failure to build students competency to make meaning in science' (Osborne, 2014, p. 187).

Nevertheless, MacDonald (2014) points out that such attempts to make school science sufficiently aspiring for students have failed. In this respect, Archer et al. (2014) also lament the fact that, 'despite the rhetoric of scientific literacy for all students, science in schools remains virtually unchanged; students are confronted with basic facts and theories' (p. 5). Similarly, Hassard and Dias (2009) chide science teachers for emphasising too heavily the 'science content objectives (traditional approach) as compared to NoS and application objectives (humanistic approach)' (p 45). These critiques and suggestions indicate that it is important to develop (i) scientific literacy for all (ii) students' personal science aspirations and appreciate (iii) students' cultural diversity in the classroom.

(iii) Science teachers

Archer and DeWitt (2016) see the role of the science teacher as one of the main social agents in helping students to identify themselves as people for whom

'science is for me'. Teachers, MacDonald (2014) says, play a vital role in nourishing the individual agency of a student - rather than simply labelling students in terms of ethnicity, gender, academic achievement and so on. Like Reid and McCallum (2014), she recommends that:

> *teachers and schools must engage in discussions with students about their aspirations to consider how their learning connects with significant people and places in their communities (p. 205).*

However, not all science teachers manage this level of engagement and, more generally, the school system in the UK, as in many other places, fails to incorporate cultural diversity and equality (Hattam and Zipin, 2009) within discussions of science careers. To tackle these issues, Elmesky and Seiler (2007) suggested that the fundamental requirement is to generate successful social interactions through a positive emotional climate in the science classroom - a climate, they say, that is key to establishing individuated science identity. In a similar vein, Lewis (2008) recommends that science educators, schools and teachers:

> *give emotions the same status as cognitions. Just as cognitions can lead to emotions, emotions can lead to cognitions. The theory implies no status difference (p. 745).*

In this light, Hampden-Thompson and Bennett (2013) found the effect of emotions in altering science engagement to be quite obvious – particularly where teachers cater for these aspects, these 'triggers', in the classroom. This is because they believe that, when a student's inner sense of self (self-schema) comes in contact with the field of science within a positive science classroom, this leads to nurtured emotional energy which, in turn, results in an approving emergent identity. Lock et al. (2013) report that students with a positive science identity (in their case physics identity) believe that their physics teacher sees them – and treats them - as a 'physics person'. On the other hand, negative emotions (fear, anger, lack of focus, failing tests) can result in a 'hardening of cultural boundaries' (Carambo, 2015, p. 161), when for example a student's inner 'sense of self is disrespected' by the

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

teachers and/or school. As Kane (2012) and MacDonald (2014, p. 6) have pointed out, ‘teachers often have lower (stereotypical) expectations of under-represented groups in STEM reinforcing their non-STEM identity’.

From what we have said so far, we see science teachers as having a duty to (i) see and respect their students as individuals rather than differentiating and grouping them on the basis of perceived biological differences, (ii) capture the essence of the student as (potentially) a sciencey person, and (iii) nurture classroom environments by incorporating positive emotions and aspirations towards science education and future career choices. There are numerous other possible solutions that have been researched in association with science teachers, such as addressing the lack of specialist teachers (for example, Taylor, 2009), providing support and training (for example, the UK’s House of Commons Children, Schools and Families Committee, 2010), encouraging the appropriate use of teaching resources (Beauchamp & Parkinson, 2008; Wood & Ashfield, 2008; Tissenbaum et al., 2012) - and remedying many other ‘improper’ teaching practices - over which we draw a veil in this chapter.

Models of identity

So far, we have acknowledged the power of global forces, broad social structures, and seen how these might shape young people through the actions of many of the social agents in their immediate zones of activity. We now move to consider the stability and change of individual identities and the nature of a core identity. We set out our stall at the start of the chapter: from our own research (Salehjee & Watts, 2015, Salehjee, 2017) we see clear indications of stability in science identity (fixed propensities both for and against science). Between these ‘poles of fixity’, we also see degrees of fluidity, where young people are yet to consolidate their thoughts and opinions, and remain relatively open to being a

'sciencey person'. We offer some cases of this in action towards the end of the chapter. There are many, though, who would challenge this view of a stability and/or fluidity at the core of people's identity.

We divide the discussion to follow in two ways: first to consider the challenge that there is no stability to identity, that individuals are chameleon-like and present different identities in different social situations, that the situational context determines the facet of identity being presented. Second we consider the challenge that, whether there is stability or not, it is (global) structural social forces that dominate in the formation of identity, and not the individual's (core) personal agency and dispositions.

(i) Discussions of stability

Writers like Gee (2000), Carlone and Johnson (2007) and Brickhouse and Potter (2011) indicate that identities are not fixed at any point and, instead, develop over time in response to particular social contexts. The primary social agents recognized by Gee and Carlone and Johnson mainly include institutions (school, science industries), teachers, peers/ faculty members and government agencies. This approach acts to preclude – or at least minimize - the individual agency that we believe is important.

We begin with Gee (2000) who uses the term 'socially situated identity' to illustrate the multiple identities people adopt in different practices and contexts, and argues that identity can be viewed in four different modes:

(i) *Nature-identity*, which refers to a state developed from what we have termed 'global forces'. Gee believes that identity provided by 'nature' lies outside the control of individuals and gives an example of an 'African American' label, which he believes can be understood as being a biological construct

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

(ii) *Institution-identity*, a position controlled by authorities within institutions. Here Gee indicates a form of identity where the control of institutions overshadows individuality. For example, a passport number, national health number, employment payroll number, military assignation or a 'prisoner number' can be used to 'institutionally identify' people

(iii) *Discourse-identity*, where an individual trait is recognised through discourse/dialogue with 'rational' social agents such as schools, teachers, youth workers and governments. 'Passive discourse identity' is an act of acquiescence by the individual; whereas 'active discourse identity' exhibits some form of control over this, though largely to please others in order to achieve something better in life. An example might be an individual making false claims on his or her inability to work due to poor health conditions in order to receive public funding from the government

(iv) *Affinity-identity*, which refers to the experiences shared in the practice of 'affinity groups'. For example, according to Gee (2000, p. 100), African American people could identify themselves in relation to their 'participation in certain practices' (p. 109). Involvement and sharing with these groups shape strong personal agency in developing personal and group identities.

That is, Gee's (2000) sense of identity is guided principally by social agents and agencies such as institutes, schools, families and groups of people, peers etcetera. The four modes above serve to 'enact' the global forces (ethnicity, race etc.) in shaping one's identity. He defines self-identification only as 'the kind of person one is seeking to be and enact in the here and now' (p.13). In this respect, Gee rejects a *definitive* core of identity, not least because any such core is never fully formed - or always has a tendency to change.

Carlone and Johnson (2007) have extended Gee's viewpoints on identity directly into science education, to present three science identity trajectories: (i)

competence (‘knowledge and understanding of science content’), (ii) *performance* (‘social performances of relevant scientific practices’), and (iii) recognition (recognising oneself and getting recognised by others’). They do give some acknowledgement to a degree of personal agency in that they incorporate some individual identification of competence, performance and recognition. They argue, though, that identities are not built in isolation and state that ‘identity arises out of the constraints and resources available in the local setting’ (p. 1192), for example through families, career counsellors and institutions.

These authors’ classic work on ‘understanding the science experiences of successful women of color’ was published in 2007 and involved a longitudinal research for six years to establish the practical grounds of science identity in women. Their analysis developed three science identity trajectories that interacted the global forces of ethnicity, race and gender with social agents such as university faculty members. Their first category is that of ‘research scientists’, where the participants themselves - as well as the science faculty members - identify them as ‘sciencey people’. The second category were females with ‘altruistic science identity’ somewhat similar to Gee’s (2000) ‘nature identity’; the participants felt science to be an integral part of their ‘genetic makeup’ and, in addition, were recognised by others as sciencey ‘women of colour’. The last category emerged as ‘disrupted scientist identity’, where the participants were not recognised as ‘sciencey’ by the others. Although these women were successful in their scientific careers, they were largely excluded from being ‘science people’ in terms of gender, ethnicity and racial factors. So, despite their ‘disrupted scientist identity’, women, black and other ethnic communities can, and do, survive and retain some science identity. In a later paper, Johnson et al. (2011) acknowledged that successful women of colour have succeeded in science careers through working harder than white male peers (with similar or even with less ability) to achieve recognition. Therefore these ‘disrupted scientists’ succeeded in their science careers by avoiding

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

negative identities attached to them by others, and by putting themselves in a place where gender/ racial identity can successfully intersect with science identity.

From this perspective, Carlone and Johnson take their influences directly from Gee (2000). For example, they state that while 'cultural production' allows the 'possibility of the women transforming meanings of "science people" and what it means to be a woman of colour' (p. 1192), in actuality their female participants 'were not free to develop any kind of science identity'. This indicates a considerable reliance on the fixity of broad global forces and social agents in the system.

Brickhouse et al. (2000) discuss different 'kinds of people'. They point to students who 'forge identities in communities of practice' (p. 443), and they take the view that identity is certainly not 'stable or single' (p. 443) – that a person can be actively involved in different communities of practice at the same time and identify as a different person in each case. Within this, there are some 'kinds of people' who are positive in adopting scientific explanations, interpretations, understanding, and who exhibit strong engagement with science. Similarly, Kelman (2006) defines identity by saying that 'an individual accepts influence from another person or a group in order to establish or maintain a satisfying self-defining relationship to the other' (p. 3). In addition, people accept and/or decline certain decisions to please a particular social agent or a group, in order to achieve certain reward (or approval) and avoid punishment (or disapproval) from other (s).

Unlike Gee and Carlone and Johnson, though, Brickhouse et al. (2000) do give some credence to stability of identity in their discussions. They adopt Lave and Wenger's (1991) 'identity in practice' as a means of discussing transformation in the process of learning. They illustrate this by addressing the global forces experienced by one of their students, Ruby (Brickhouse & Potter, 2001). They describe how Ruby's African American heritage had a significant impact on her

movement from a suburban middle school to an urban high school. The central feature of Ruby's story is that, in order to transform her African American girl identity, she needed to challenge and overcome negative self-perceptions (for example: African American girls' restricted identity). Ruby broke the norms of feminism and African American identity by choosing to interact in school with a wide crossection of people from a variety of ethnic and gendered backgrounds. She rejected the easy route of simply being a stereotypical black girl in the school. From this example, Brickhouse and Potter (2001) illustrate a duality model where personal constructions of identity work in concert with other people's (peers, teachers and parents) perceptions of ethnicity and gender related to that individual.

While there are many cases where people 'go along with prevailing forces', there are numerous other examples of people who 'go against the grain' as Archer et al. (2014[b]) note. For instance, Amal - a thirteen year-old female student in a chemistry lesson (Salejhee, Ludhra & Watts, 2018) - is not only enthusiastic about separating chlorophyll (pigment) colours on a chromatogram in chemistry, she also describes herself as a person who loves chemistry even in a non-school context indicating a 'kind of person who understands the world scientifically'. This identity stays with her and exhibits a form of Gidden's 'ontological security' over time. 'Being sciencey', though, may not be sustained outside of the school classroom or community. So, in contrast, another student (Fiza), with similar enthusiasm within the lesson, might identify herself to her peers outside the school science laboratory as a person who 'hates chemistry' (Salejhee, Ludhra & Watts, 2018). We see something of this at the individual level: not all children within a 'high science capital family' will aspire to a future in science and some will 'rebel'. Equally, some within a 'low science capital family' do find a route into science. Moreover, in a separate paper, Brickhouse and Potter (2001) go on to recommend that teachers and schools have a responsibility to address the issues of diversity and identity in

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

classrooms and to provide clear opportunities and space for students' individual identity constructions in relation to their multicultural backgrounds.

(ii) Increasing degrees of personal autonomy

Hazari et al. (2015) followed Carlone and Johnson's (2007) model using the three dimensions of recognition, performance and competence, initially based on Gee's identity construct. Here, these authors are critical of Gee's (2000) emphasis on external recognition and his neglect of individual agency control – in particular, the role of personal thoughts, emotions, cognition and learning. Therefore, to further incorporate greater individuality, they added a fourth dimension of 'interest' in their model. They consider this to be 'critically relevant in influencing the decision of who and what a student wants to be?' (Hazari et al., 2010, p. 982). We understand interest here as a verb that exhibits individual agency, one that shapes one's preferences, choices and/or decisions. Moreover, Hazari et al. believe 'performance, perceptions of competence, the perception of others, and interest all influence a focal construct' (p. 998) in developing - in their case - 'physics identity'. To this extent, they believe that students with physics identity have a strong desire to enter into careers in physics. Their work also included testing different teaching strategies to promote physics identity in female students, where they found a strategy of 'discussion on under-representation of women in physics' to be significant enough to foster physics identity in female students (Hazari et al., 2013). Their sense is that teachers and educators need to cater for individual students' cultural identities in the science classrooms. Moreover, Lock, Hazari and Potwin (2013) maintain that the key contributors towards physics career choices involve recognition of the 'interest dimensions' of students' science identity trajectories. Hazari et al. (2013) also suggest that physics identity can be developed through the mediation of social agents with an emphasis on teachers and teaching strategies. In these instances we see, in comparison to Gee (2000) and Carlone and Johnson (2007), that Hazari and her colleagues are inclined more towards individual agency

than global forces. Their dimension of recognition involves both self-recognition and recognition by others; moreover the aspect of 'interest' is quite individually-centered.

Carlone and Johnson's (2007) work is also evident in Kane's (2012) study of *competence*, *performance* and *recognition*. In his empirical research he included students' self-narrated interviews involving 'their experiences in school and science with their performances of self in the midst of complex, spontaneous classroom engagements with their peers and teacher' (p. 457). Kane's work (2012) highlights such ingredients to the individual agency as interest, self-confidence, self-ability and understanding of self as a good student. These factors were found to be of different degrees and were valued differently by the students themselves, their peers and their teachers. In making recommendations to educators and teachers, Kane believes that, for African American children for example, identities need to be given special corrective attention because teachers and wider society often do not take students' individual competence, performance and recognition into consideration and, rather, it sees such learners as being 'at risk'. Moreover, Kane (2012) and Rodrigues (2014) have suggested the need to appreciate the multicultural diversity that students bring to science classrooms - and to change the culture in order to prevent the marginalisation of so-called stigmatised groups. Kane (2012) also suggested that educators need to consider the multiple identities of individuals not only as science students, but as overall students - for example, where a 'brainy' student might position himself/ herself within a 'sciencey' group. Therefore, Kane (2012) emphasises individuality alongside the impact of social agents in developing science identities – in this case, in African American children. In our opinion, Kane, like Brickhouse before him, believes that social agents (schools, teachers, peers and educators more generally) 'enact' global forces in shaping science identity.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

Going further, Robnett et al. (2015) view 'identity as a scientist' as a core component of an individual's identity. They also acknowledge the work by Estrada et al. (2010) by arguing that there will be some students, though not all, who will continue with science studies because of positive exposure to academic science, not least through – say - science outreach programmes. In this vein, they give considerable emphasis to individuals deciding who they are and with which communities of practice they wish to participate, and less emphasis on the communities deciding the individual's position in society. Like Hazari and her colleagues (2015), 'interest' features strongly, and Robnett et al. argue for self-efficacy that acts as a mediator between positive science research experiences and science identity. They understand 'science self-efficacy' to originate from sources such as 'mastery experiences' and vicarious (mediated) learning which they see as being prominent, particularly within undergraduates. However, these authors have also reported that the association between 'research experience', 'science self-efficacy' and 'identity as a scientist' – showed little if any significant differences in relation to gender and ethnicity. They did indicate, though, that students from over-represented ethnic backgrounds (Asian American or European American) exhibited 'more variance in identity as a scientist' as compared to students from underrepresented ethnic backgrounds (African American, Latino or Native American). We take from this that Robnett et al. (2015) are further inclined towards individual agency than others we have discussed so far. So, while external forces, such as outreach programmes do enhance an individual's experience and willingness to engage with science, self-efficacy is centrally important in filling the gap between positive science experiences and science identity.

(iii) Global social structures are dominant?

In science education, Archer and her colleagues (2010; 2013; 2016) have extended the work of Bourdieu on identity and developed the term 'science identity'. Bourdieu's work has been widely used in identity-based research and 'the

two key constructs fundamental to Bourdieu's understanding of structure and agency are *habitus* and *field'* (Block, 2013, p.136). The habitus provides space where agents act in a specific 'field' or context, utilising *capital* or resources (economic, cultural, social or symbolic). Broadly, Bourdieu (1986) describes three main types of capital: economic, social and cultural. Economic capital involves goods, money and could be institutionalised in property rights, which Bourdieu believes to be the basis of the other capitals. Social capital is described as 'the aggregate of actual or potential resources linked to possessions of a durable network of essentially institutionalised relationships of mutual acquaintance and recognition' (Bourdieu, 1986, p. 248). In other words, it involves social obligations or connections that can be converted into economic capital. Cultural capital exists in the following three states:

(i) *Embodied*: It is the state in which the habitus (individual dispositions) is quite automatic and pre-reflexive and does not involve conscious control. Any possible change or transformation of this state is quite limited (Claussen & Osborne, 2012). An embodiment relates to something that is learned in life and emerges in different occasions as an automatic response/ action. Here we understand 'embodied' as a construct of individuality because Bourdieu (1990) stated that the embodied state 'is an active subject confronting society as if society were an object constituted externally' (p. 70)

(ii) *Objectified*: This is the state that 'takes the form of cultural goods (pictures, books, dictionaries, instruments) and can easily be transmitted in its materiality. However, this form requires embodied capital to fully appreciate and use it beneficially' (Claussen and Osborne, 2012, p. 62). Certain cultural goods can be of benefit and can reach the embodied state. That said, not all the students will actually turn out to be scientists with all the essential cultural goods and with an understanding of the value of becoming a scientist

(iii) *Institutionalised*: which resemble Gee's (2000) institutional identity. Institutions provide 'a certificate of cultural competence which confers on its

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

> holder a conventional, constant, legally guaranteed value with respect to culture' (Bourdieu, 1986, p. 50). Here the emphasis is on social agencies like schools to reward and enhance the person's credentials

Jenkins (1992) and DiMaggio (1982) criticised Bourdieu's concept of habitus as being deterministic, with insufficient emphasis on consciousness and agency. King (2000) believes that, while Bourdieu did acknowledge subjectivism with objectivism in regards to meaning-making processes, he also saw that:

> *Bourdieu has failed to take his own greatest insight seriously, and he has slipped into the very objectivism whose poverty he has done so much to highlight' (p. 431).*

Sullivan (2002) has been more scathing, in that 'Bourdieu's theory has no place not only for the individual agency but even individual consciousness' (p. 163). Sullivan also criticised Bourdieu's distinction and strength of cultural capital over other forms of capital (social, economic) as being unclear. Moreover, Erel (2010) indicated that 'Bourdieu has rarely explored how forms of capital are activated for resistant purposes' (p. 647). Block (2013) has been more generous, in seeing that 'Bourdieu constantly navigated the line between determining the social structure and individual agency in his work spanning some 40 years' (p. 136).

In their extensive work in science education, Archer and her colleagues (Archer et al., 2010) lay the root causes of girls', and young people of low socio-economic status', non-participation in science as lying largely outside of the girls themselves (Archer et al, 2014[b]). They have used the idea of Bourdieu's capitals in science education and referred to this as 'science capital' - which deals with 'science related qualifications, understanding, knowledge, interest and social contacts' (p. 3). Their three main forms of science capital are as follows:

(i) Science linked to social/symbolic capital (for example: gender, ethnicity, social class, science communicated in social networks; interacting and/or idealising people with scientific knowledge and/or science related jobs)
(ii) Science linked to cultural capital (for example: science qualifications, scientific literacy, and understanding about nature of science)
(iii) Science linked to economic capital (for example: money to gain science capital and opportunities like visiting events and science centres) (Archer & Dewitt, 2016).

Archer and her colleagues also come subject to the same criticism as discussed above in regards to Bourdieu's work itself. In this form, Archer et al.'s (2014) science capital resembles an over-riding argument that identity as a sense of self is predominantly socially constructed within social settings (Spillane, 2000), and resembles an outcome of dialectical engagement with practical social activity, rather than being an innate property of individuals (Roth, 2007). In addition, Archer et al. have also been critiqued for their derivation of science capital from the cultural capital. As Claussen and Osborne (2012) indicate, it is not clear whether Archer's science capital is intrinsically justified or it dominates because of socio-historical contexts. Jensen and Wright (2015) have been critical, too, in that they see science capital to be distinct from cultural capital – Bourdieu's approach is to offer a much broader range of concepts that foster social mobility in an inherently unjust socio-cultural system. This is much more than 'science capital' can manage. Moreover, like Bourdieu, the 'field' identified by Archer et al. (2015[b]) affecting the struggle over science capital is unclear.

(iv) A return to individuality and transformational change

We began this chapter in the clear belief that there is a clear role for individual agency, the propensity for a student to identify him- or herself as a science person - without the necessity to resort to discussions of science capital (social, cultural,

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

economic). There is a very long literature related to the nature of individualised identity in relation to agency and in relation to the others. Erikson (1973) called people ‘in-groupers’ and ‘out-groupers’. While this can be understood of teenagers in terms, say, of skin colour, or cultural backgrounds that could lead to self-labelling (stereotyping), self-beliefs and self-identifying people, it can also bee seen in their alliance with or against science and scientists, as ‘people like me’. Erikson views identity formation to be successful and stable when one identifies who he/she is, who he/ she wants to be within himself/ herself, and who he/she wants to be in a particular social context.

Knud Illeris (2014) acknowledges Erikson’s work. He links identity to Jack Mezirow’s theory of transformational learning, as he believes that ‘the concept of transformative learning comprises all learning that implies a change in the identity of the learner’ (Illeris, 2014, p. 40). Illeris views identity transformation in a similar vein to Mezirow (1990, 2009). He explicates two main terms in his theory, first is ‘meaning schemes’, which are ‘set of related and habitual expectations governing if-then, cause and effect, and category relationships as well as event sequences’ (Mezirow, 1990, p. 2). Second is ‘meaning perspectives’, which are ‘broad sets of pre-dispositions resulting from psycho-cultural assumptions, which determine the horizons of our expectations’ (Mezirow, 1991). His (2000) writing explores ‘frames of reference’ that encompass ‘structures of culture and language through which we construe meaning by attributing coherence and significance to our experience’ (Mezirow, 2009, p. 92).

Such frames elaborate the continuing conflicts in daily life that lead to the ‘learning of new frames of reference’ and eventually leading to self-development (D’Amato & Krasny, 2011). A frame of reference consists of ‘two dimensions - habits of mind and resulting points of view’ (Mezirow, 2009, p. 92). Habits of mind constitute a specific way of individual’s thinking or feeling that results in a set of

codes, and specific habits of mind result in specific 'points of view' as an awareness through, belief, sustained as a memory and/ or attitude, the way of judging future related actions (Mezirow, 2009). For example, gender discrimination acting as a code can result in a point of view that science is 'not for me, because I am a girl'. This belief can remain in one's perception as a memory that, later in life, acts as a judgement/decision for not choosing science subjects in the future. Mezirow's theory sees identity to be fluid and subject to transformation but - at the same time – maintains that fluidity depends on some form of a disorienting dilemma, a possible dramatic life experience leading to transformation. As Mezirow (1978) states '…to negotiate the process of perspective transformation can be painful and treacherous… [one's] sense of identity and integrity…' can be challenged (p. 11) leading to transformed behaviours, feelings, beliefs, identity (Mezirow, 1991) values, attitudes, and perceptions (Jackson, 1986).

The primary link between Mezirow's theory and Illeris's (2014) identity model includes the 'meaning-making' process whereby individuals negotiate their understanding of self that shapes (transforms) their identity in certain social or cultural contexts. With similar intentions, Abes et al. (2007) introduced a 'meaning-making filter' as one of the main parts of their identity model in order to elaborate, extend or even transform the 'meaning-making capacity integrated' (p. 7) into a person's self-perceptions. This chimes with Mezirow's suggestion that transformational learning incorporates the 'making of meanings', and he describes the process as an intense, thoughtful journey of constructing the meaning of oneself through life experiences. The meaning-making process in a person's learning depends upon critical self-reflection on the experiences that have taken place within a particular context.

At first, a person's life experiences (rather than typical academic learning) act as the key initiators of change, and these depend on the varying contexts and time

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

at which the life changing experiences are practiced (Mezirow et al., 2009). These contextual life experiences have been visualised by Abes et al. (2007) in their 're-conceptualized model of multiple dimensions of identity' where 'a person experiences (his or) her life, such as family, sociocultural conditions, and current experiences' (p. 3). It is quite clear that not all the contextual influences/ life experiences will be life-changing, and Illeris (2014) makes the case that life experiences (and/or influences) need to be of 'higher order' and require considerable energy to create changes - especially if those changes interfere with strong pre-held affiliations towards something. These 'life changing transformational experiences' which includes events, triggers and interventions initiate 'discourse leading to critical examination of normative assumptions underpinning the learners … value judgments or normative expectations' (Mezirow 2000, p. 31). Such discourse elements lead to self-examination of pre-held assumptions, and are catered through dialogue with self and with others. Dialogue allows people to critically reflect on the contextual influences, and these evaluations require a 'critical and reflective lens to authenticate their reasons to adapt new actions' (Mezirow, 1996, p. 162). Through dialogue, one can determine the boundary that accepts or rejects certain life experience through 'continuous effort to negotiate contented meaning' (Mezirow, 2000, p. 3). When this meaning system is found to be inadequate in accommodating some life experience, it can be replaced with a new meaning perspective that exhibits change in habits of the mind, one that is 'more inclusive, discriminating, open, emotionally capable of change, and reflective'; in other words, more developed' (Mezirow, 2000, p. 7) which results in transforming points of view.

We believe that, for some people, a complete transformation in their meaning perspectives is possible and can happen. For example, there are numerous accounts of people undergoing life-changing events – after a significant illness or disability, a significant change in relationships, a major shift of occupation, and so on. For

some people smaller life changes might have a higher impact in choosing science or non-science discipline. For example, a love for physics (in general) at school might later occupy meaning of one's life after meeting a rocket scientist. Although, Mezirow's theory has been challenged for its individualistic mode of analysis, with few links to social action (Welton, 1995; Kegan, 2009).

In our view, this places Mezirow's theory principally within an individuated 'intentionality identity' rather than an extensionality 'global forces' approach. With Jarvis (2013), we view individuals as 'people' and their personality relates to the way they learn from the external culture. Jarvis believes that learning can be a 'lifelong process intrinsic to the living organism itself, whereby the individual internal life force experiences externality (through body and mind) and generates a permanent state of becoming in the human being' (2013, p.13). His 'internal life force' is the force derived from individuality and, in turn, identity then interacts with externality leading to identity formation; therefore Jarvis applies both intentionality (IIA) and external extensional forces (GF) to the construct of identity. The idea of 'being itself' resembles Abes et al.'s (2007) idea of core and 'externality meaning', when an individual is exposed to contextual influences. Jarvis also indicates the fluid nature of the person's learning processes, which eventually form an identity. Within this view of learning, Jarvis (2009) has criticised Mezirow's theory because it focuses mainly on adults, creating a gap between adult and children's learning, and fails to relate Jarvis's sense of lifelong learning as a whole. In contrast, Jarvis (2009) believes that it is not always the meaning-making process that transforms learning - it can be daily life experiences that can be transformed by learning.

Illeris (2014) views identity transformation in a similar way to Mezirow, and has stated that 'the concept of transformative learning comprises all learning that implies a change in the identity of the learner' (p. 40). In addition, Illeris (2014)

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

believes that 'identity involves learners' mental whole' (p. 39) and the important changes within person's mental whole can be taken as transformation that leads to alter one's identity in a way that we want ourselves and others to identify us (Illeris, 2014). Illeris has been critical of Mezirow's use of 'meaning perspectives and frames of reference', as being dominated by cognitive rather than affective learning. In answer to this critique, Mezirow recognised the importance of affective phenomena and believes that a frame of reference can have 'cognitive, conative and affective' functioning - consciously or unconsciously (Mezirow, 2009, p. 92). Even then, Illeris (2014) stated that while Mezirow (2000) links and understands emotions at the same time 'he understand emotions as a kind of concomitant or even distracting phenomenon in relation to what the real transformation is about, which is precisely meaning perspectives, frames of reference or as here our beliefs' (Illeris, 2014, p. 36).

Unlike Erikson (1982), Mezirow (2000) and Illeris (2014) are not certain that identity is constructed within the time frame of adolescence - and actually believe that transformation cannot *really* occur at the early stage of 'teenage'. While Illeris (2014) concedes that episodes of provisional identity might emerge in the early ages (even before the age of thirteen) and can form 'long lasting effect on identity' (p. 124), Mezirow (2000) believes that transformation is fully prominent in adults. Illeris's (2014) view is that identity development mainly takes place after adolescence and, therefore, after the compulsory age of school (science) education from ages 11 -16 years.

We believe that age, and the intensity of the triggers that might lead to a life-changing experience, vary among people even from within the same cultural, social and economic backgrounds. Such triggers could be planned to some extent (through outreach programs, meeting scientists and/or science community interventions to

inspire students towards science). Or they might be accidental. An example of accidental trigger could be 'trees', as Loehle (2010) has stated:

> *Some individuals find themselves fascinated with ants or birds or fossils from a young age. Why? I have never seen an explanation for this early attraction to a scientific subject. For me it was trees. I can remember the trees in the neighbourhood where I lived at age 7 so well I can still tell you what species they were and how tall (p. 13).*

Another example of an accidental trigger could be the death of a younger sibling that transformed the decision of a business student to become a child specialist. A planned trigger could be when a teacher designs a particular visit to a hospital (in one of the deprived areas in their country X) to incorporate students role as citizens. At the hospital, students came to know that - due to the lack of child specialists in their country – there are high mortality rates of children under the age of seven. This planned intervention along with a series of other planned interventions might transform some of the 'non-sciencey' students towards becoming a child specialist, a nurse, a laboratory technician or even someone who wants to build a children's hospital in country X.

Archer et al. (2012, 2013, 2015) indicate such triggers to be linked with 'science capitals' involving resources such as parents, schools, teachers. Abes et al. (2007) call these contextual influences, Illeris (2014) described them as 'conditions', and Mezirow (2000) sees them as 'experiences' leading to disorienting dilemmas. But, at the same time, from the above discussion based on self-identity subject to transformation, depends on the stability and fluidity of identity. When young adults are asked what subjects they will choose at A-level, they take time to answer and give their decision. This entails some kind of stable core that gives them positive and negative signals, where some students might take longer than others, where their identity is quite fluid and the core is challenged by both enjoyable and unpleasant experiences.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

The stability of core identities is always in question. It could be that the transformation takes place gradually as Heddy and Pugh (2015, p. 56) believe: that 'transformative experiences may be a way to facilitate micro changes in students that, when accumulated, lead to transformative outcomes'. Nohl (2015) argues that transformation need not necessarily start with a disorienting dilemma - it can start 'unnoticed, incidentally, and sometimes even casually, when a new practice is added to old habits' (p. 45) or, even sometimes, the process of transformation starts with great emotional experiences but then later the processes fail or even the new meaning-making process does not challenge the pre-held disorienting dilemma. People with 'fluid' science identities can - potentially - be more open to accidental and/or planned transformative interventions and widen their options, exhibiting transformation.

We now examine Illeris's (2014) and Abes's et al. (2007) models of identity to discuss two prominent models on identity and identity transformations as mentioned above.

(v) Illeris's model of identity

As noted above, Illeris's (2014) general structure of identity belongs within a framework of intentionality (IIA). His model exhibits a three-layered structure of identity that includes a core identity, personality layer and preference layer (Figure 1).

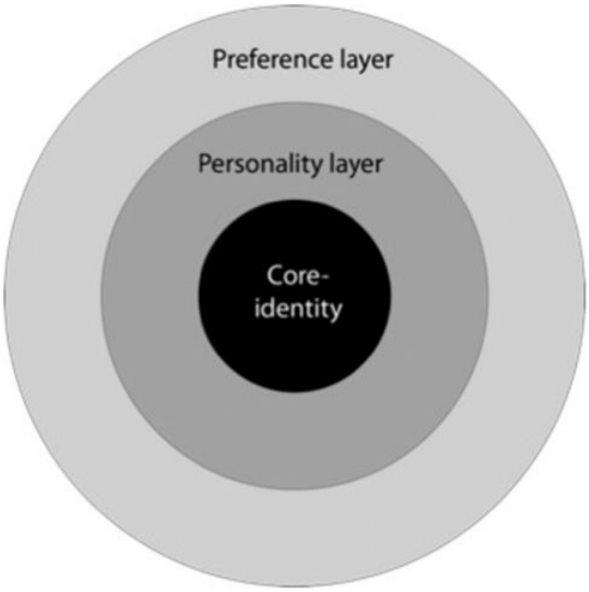

Figure 1: The general structure of identity (Illeris, 2014, p. 71)

Illeris termed the inner most-layer the 'core', the most stable and solid layer that controls the construction of the subsequent layers. He believes that the core identity is developed and extended during childhood by elements such as gender; family identity etc. and that change in the core is quite gradual unless it experiences a life changing event. Surrounding the core is the 'personality layer' where transformation is primarily apparent. Illeris (2014) believes that this layer includes 'who and how the individual wants to be and appears in relation to others and the surrounding world' (p. 72). This layer is susceptible to change 'in connection to important experiences, events, exchange of views and similar kind of interactions' (Illeris, 2014, p. 73). The impact of exchanges of views and social interactions resemble Gee's (2000) 'affinity identity', which is experienced through shared practices with 'elite' groups of people. This allows for free will in choosing a particular group to which an individual is attached. Rodogno (2012) describes this as 'attachment identity' (and is a 'deep' understanding of a notion of identity) that relies on expressions such as 'caring about', 'of importance', 'attachment to' and 'what matters to me'. That is, it is an identity ultimately anchored in a person's

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

attachments. Again Gee (2000) emphasises the free will exercised in choosing the group in accordance to the 'kind of person they are' (p. 106) – it is a freedom that might be restricted for those who 'lack access, networking and mobility' (p. 121). Illeris's outermost layer is the preference layer, where the individual chooses and acts without entailing too much effort (thinking, feeling or acting). The changes in the conditions (daily life activities) being experienced in this layer are somewhat independent of self-perceptions and involve minimal energy to make any change: 'whether we in the situation to have the energy to make such changes … [they] do not mean much to us, and we have long ago got used to the idea that we shall be open and ready for change' (Illeris, 2014, p. 73-74).

This identity model gives a general structure that exhibits the possibility of identity transformation interlinking both one's core identity and out-facing personality. It serves both external and internal forces and, in relation to external forces, involves an individual's participation, dialogue and/or discourse with social, cultural and/or economic 'capitals' or resources that can be linked to the personality layer. Illeris's (2014) core identity empowers the personality layer, which is more susceptible to transformation (through a conscious understanding of self in relation to others) than the core. Robnett et al. (2015) and Illeris emphasise the stability of core identity as being dominant over influences from others and surroundings. It is only very limited and strong life changing events that have the ability to transform the core identity. Robnett (2015) refers 'being a scientist' as part of the core component of identity construct.

In addition to the general structure above in Figure 1, Illeris (2014) extended his identity model to involve different 'part identities' such as work identity, family identity, everyday identity etc. (Figure 2). He believes this transverse model of part identities to be interlinked with the central identity (including core, personality layer and preference layer) and each different part identity comprises of all the three

layers identified as well. The idea of part identities working simultaneously is an appealing notion, because an individual can utilise part of – say – his or her work identity with cultural identity etc. Moreover, a person acts and reacts differently in different situations and the activation of various identities is evident when trying to accomplish different roles (Burke & Stets, 2009). So, in this case a particular identity (surrounding the central identity) can switch on/off due to the exposure to different situations, influences and/or experiences. And this switching on and off process might later affect the central identity. Therefore, Illeris's (2014) model of part identities combined GF (extensionality) and IIA (intentionality) ideologies resulting in a composite model (Figure 2).

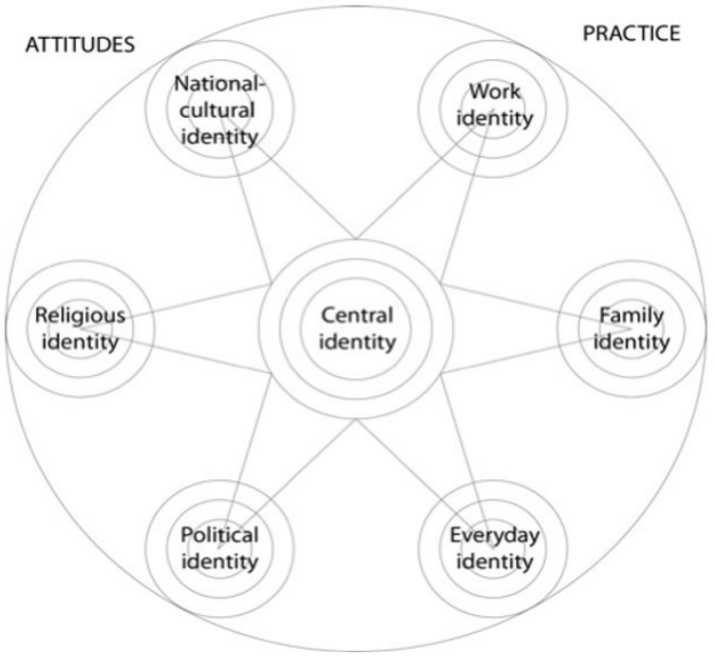

Figure 2: An example of part identity structure (Illeris, 2014, p. 76)

It is important here to note a few limitations to Illeris' model. First, in connection to his preference layer, Illeris is inexact about the everyday conditions that have an ability to transform parts of the personality layer and that might even transform the core. As Illeris (2014) himself believes, the boundary between the

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

personality layer and preference layer is unclear. Our sense of remedy here is to suggest a 'controlling filter' between the personality layer and preference layer. We see this controlling filter as a filter that controls the conscious conditions (like Kane's (2012) contested spaces) and/or objects (like Bourdieu's objects), a filter that permits or rejects the opposing conditions/ objects. This permission or rejection is based on the intensity of the conditions in relation to the automatic dispositions (embodied).

Second, while Illeris's (2014) transverse model does give an insight to part identities surrounding the central identity, again, the interlinking between one form of the outer structure identity to the central or to another form of identity seems unduly complex. It seems to be extraordinarily difficult to link the different identities to the central identity. For example, it is not straightforward to understand how Illeris's (2014) 'work identity' in its own orbit surrounds the core, personality and preference layers because, in this particular situation, work might not be of over-riding concern for the individual. But then, nor did 'work identity' fit in the preference layer, and so linking 'work identity' to the central three layered identity might prove difficult to adapt.

(vi) Models of multiple dimensions

Unlike Illeris's (2014) transverse identity, Jones and McEwen's (2000) model appears less complex in terms of picturing one core surrounding the multiple identities. Moreover, this model provides a distinction between multiple identities and contextual influences and, in our opinion, the presence of contextual influences provides an open space to capture social influences/ triggers – a space that is lacking in Illeris's (2014) general model. Jones and McEwen (2000) describe identity theories as 'representing the on-going construction of identities and the influence of changing contexts on the experience of identity development' (p. 408). They

propose a conceptual model (Figure 3), where they argue that there are two general parts to an 'identity' construct:

(i) The outer contextual layer includes influences from family background, socio-cultural conditions, current experiences, career choices, etc. The intersecting circles termed as identity dimensions placed around the core identity and within the premises of contextual ring. Moreover, the intensity of the 'relative salience of these identity dimensions is indicated by dots located on each of the identity dimension circles' (Jones and McEwen, 2000, p. 410). These include self-perceived dimensions such as gender, culture, faith, class etc.

(ii) The central core, which includes the 'inner personal identity' that we have for ourselves. This resembles Illeris (2014) core identity.

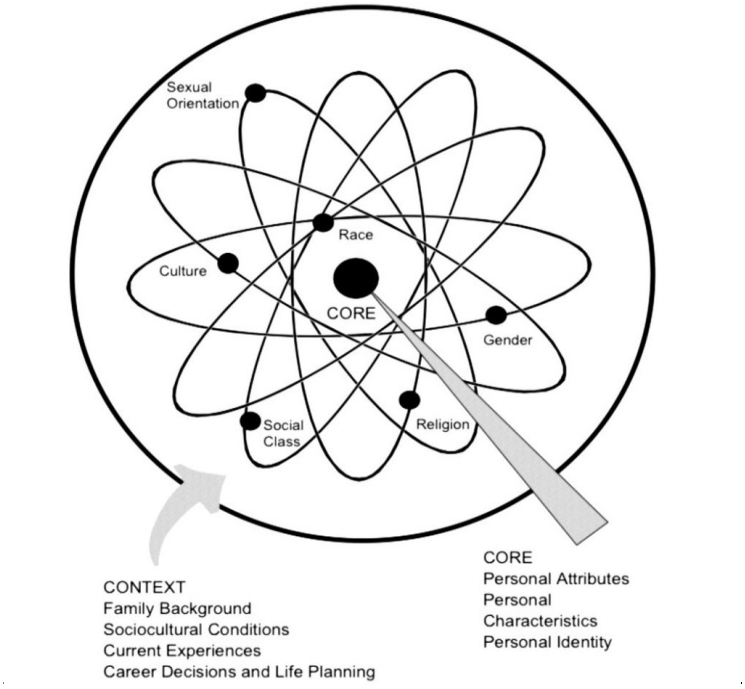

Figure 3: Model of multiple dimensions of identity (Jones and McEwen, 2000)

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

Later, in 2007, this model of multiple dimension of identity (MMDI) was reconceptualised by Abes, Jones and McEwens. They called their new 'advanced' model a 'Reconceptualised Model of Multiple Dimensions of Identity (R-MMDI)', utilising Kegan's (1994) ideas of meaning-making processes during identity development, and based on research on lesbian college students by Abes in 2004. In this work, (Abes, 2004) it was suggested that the inclusion of a meaning-making process in the MMDI was important because it allows the researcher to better understand the links between core and social identities as well as a relationship between contextual influences and the salience of identity dimensions. The results from Abes (2006) entail a 'meaning-making capacity served as a filter through which contextual factors are interpreted prior to influencing self-perceptions of (particular) identity and its relationship with other identity dimensions' (p. 6).

The re-conceptualised model (Figure 4) now consists of the following four main parts:

(i) The outer contextual influences, which are placed outside the identity circles. Illeris (2014) sees these as conditions

(ii) Social identity dimensions are now viewed in relation to personal perceptions of multiple identity dimensions. This resembles Illeris (2014) part identities

(iii) Meaning-making filter, this is placed between (i) and (ii). The filter depends on the depth and size of the mesh opening. Complex, meaning-making can be represented by increase thickness (increase depth) and smaller grid openings. Where meaning-making with less complexity is indicated as a thin filter (lower depth) and bigger grid openings. This resembles Mezirow's (2009) dialogue element of transformational learning and Gee's (2000) discourse identity, whereas such a filter is missing in Illeris (2014) identity model (Figure 1)

(iv)Finally core indicating self-identity resembling Illeris (2014) and Robnett et al. (2015) core identity.

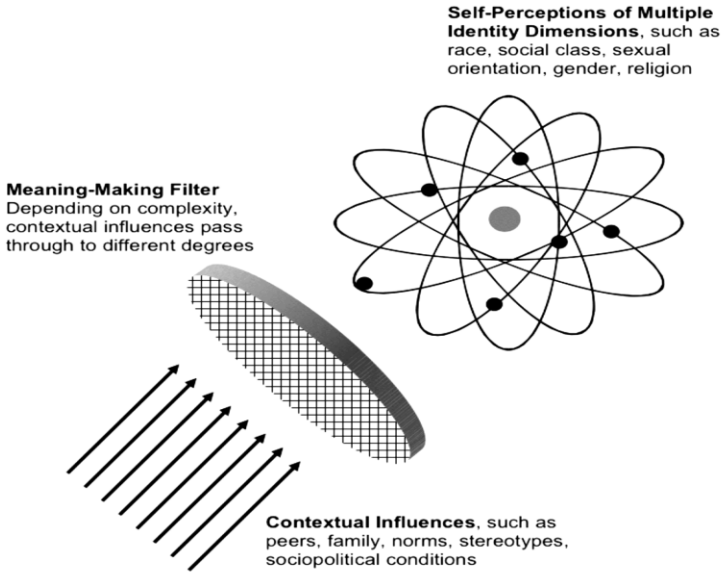

Figure 4: Reconceptualised model of multiple dimensions of identity (Abes, Jones and McEwen, 2007, p. 7)

In summary the above model (Figure 4) gives space to capture individual self-perception in the following ways:

(i) First, the meaning-making filter can allow us to capture the understanding of scientific concepts and procedures

(ii) Second, whether the meaningful positive/ negative science linked influences had an impact on their self-perception of single identity or self-perception of multiple identities at the same time

(iii) Third, whether these meaningful influences have transformed one's science or non-science core

(iv) Then, the basis of the outcome could also enable to distinguish between active or passive science and/or non-science identity formation during the lifetime of the individual.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

This discussion so far lead us to our own science/scientific identity model, the Sci-ID model (Salehjee, 2017). In the model (Figure 5) we envisage seven main parts:

1. ***Global forces (GF)****:* These involve external influences in relation to ethnicity, gender, race, religion, class etc., resembling Giddens's (1991) 'globalising influences'
2. ***Social agents (SA)****:* As above, these are the agents that mediate the global influences with the individual through interaction and relationships. For example: parents, school, teachers, peers, churches etc.
3. ***Transformational experiences*****:** These are the resultant experiences, events, triggers and interventions gained from the SA and/or GF which could have high, intermediate, low or no impact on individuals
4. ***Meaning-making filter***: We have introduced Abes et al. (2007) meaning-making filter (Figure 4), this part of the model involves an understanding of the scientific concepts. More complex meaning-making filter (a thick layer with small grid opening) allow little understanding and a less complex filter (thin layer with large grid opening) allows greater understanding of the scientific concepts being studied
5. **Preference filter**: We have introduced this layer from Illeris's (2014) identity model (Figure 1), which constitutes Mezirow's meaning schemes (Illeris, 2014). For us these meaning schemes are the TL experiences that have been sieved by the meaning-making filter (or not). Now a preference filter will actually select the preferred (liked) experiences that have the potential of some degree to interact with individual agency. More complex filter exhibits little or no preferences and less complex filter exhibits preferences/ likes towards science. The non-preferred experiences will not proceed further inside the identity model. This filter differs from Illeris identity model (Figure 1) first, it is represented as a filter and second, it forms the second layer in our model and

outermost layer in Illeris's model. As in our opinion Illeris is aware of meaning-making of the events as well as preferences however he has not separated both in his identity model

6. **Individual Internal Agency**: This part of the model involves personal 'drive', the ways in which people can go against transformative experiences, SA and/or GF – or go with them. This layer is quite stable unless exposed to life changing (high impact) transformative experiences leading to movement (transformation) into or away from science. This layer resembles Mezirow's meaning perspectives where the higher order of pre-held schemes can be transformed based on the experiences received from the previous layer (preference layer), where critical reflection is extended further (Illeris, 2014). Illeris named this layer as personality layer, where we did not, as the intention of this review is not to look deeply into the personality theories and huge number of personality issues but rather we are interested in self-perceptions of people towards science and non-science education and career

7. **Core**: It resembles Abes et al. (2007) and Illeris (2014) inner most central core. Which we believe could be stable or fluid. If the transformation in IIA layer is successful or individual layer is in ambivalence then there is a possibility that the pre-held transformed viewpoints could change the core identity. We understand it in such a way that if the core is stable then transformation at the core level is quite difficult and time consuming but if the core is fluid than the transformation is relatively easier and less time consuming.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

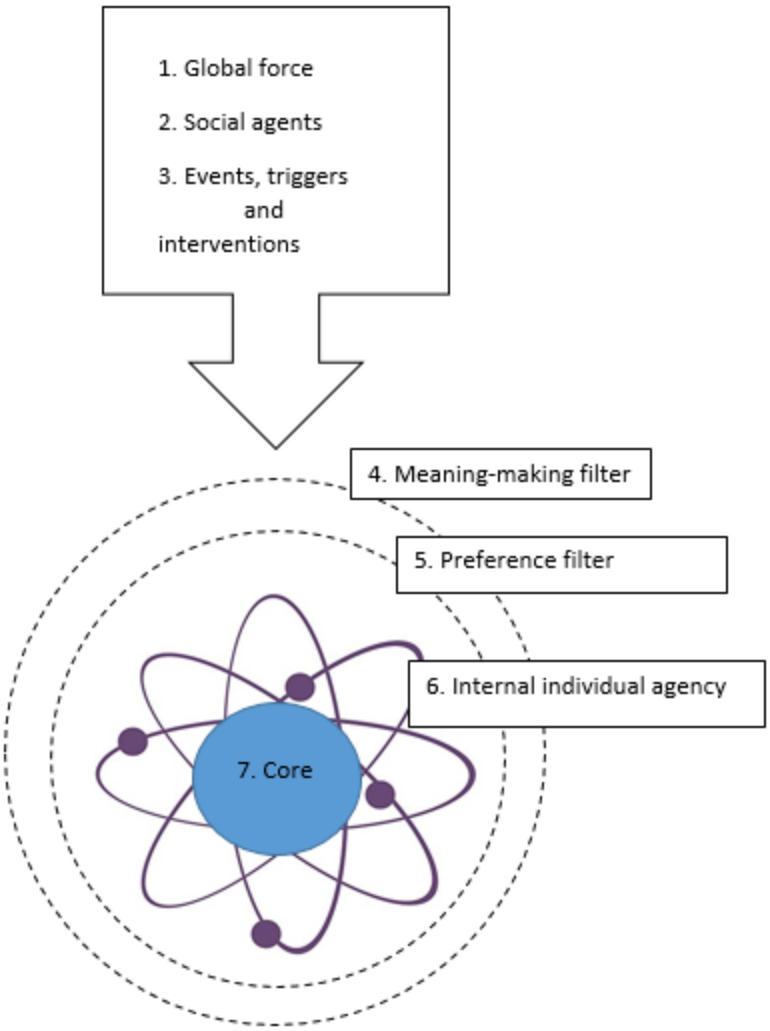

Figure 5: Sci-ID model

We use this model to map or chart a person's real and possible life journey, the main circumstances and events that have generated - or are in the process of generating - transformation(s) in people's identity into or away from science education and career choices. We see this mapping as useful in determining both the fluid and stable nature of an individual's identity construct and, hence, signalling possible interventions. Teachers, science educators, youth workers etc.

might meet individual's needs, motivations, self-believes in either strengthening or altering the migration of individuals towards science education, science careers and, most importantly, changing negative dispositions and helping people to become scientifically literate citizens. In this next sections, we illustrate its use (figure 6) to relate science/scientific identity model with the notions of stability and fluidity in the journey of constructing science and/or non-science identity.

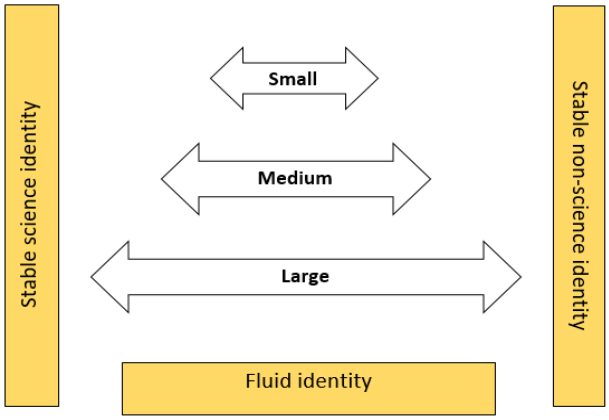

Figure 6: The migration of the people: small, medium or large movement

We depict the model as a 'migration of people', consisting of three main regions, two extreme 'poles' and a central region. The people at the extremes can be seen to have either stable science or non-science identity. Those who populate the space between have more fluid identities. As can be seen in the science/scientific identity model (figure 5), SA and GF could influence the movement of people towards or away from science through generating a series of external transformational learning (TL) experiences (events, triggers and interventions). These TL experiences can have a low, medium or high impact on different people. Variations in TL experience might be as follows:

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

(i) Large number generating a low, intermediate or high impact of TL experience (triggers, events, interventions)

(ii) Medium number generating low, intermediate or high impact of TL experiences (triggers, events, interventions)

(iii) Small number generating a low, intermediate or high impact of TL experience (triggers, events, interventions).

These variations depend on the stability of one's identity. Therefore, (i) people can either have stable science or non-science agency, exhibiting very small or no movement away from their respective extremes, unless exposed to a large, medium or a small number of TL experiences that generates a high impact. While (ii) people with fluid IIA exhibit medium or large movement towards or away from science because, they probably have an intermediate to high impact from a large, medium or a small number of TL experiences.

(vii) Kinds of identity transformations

In addition to Mezirow (2000), Illeris (2014) extended transformative learning theory into progressive, regressive and restoring transformations. We will now describe our viewpoints on the three kinds of science identity transformation with examples. Our intention here is not to include Illeris (2014) collective transformation in this study, which has the potential for further research. Our brief case studies below illustrate the science/scientific identity model and the 'migration of sciencey people' to describe the three kinds of Illeris's (2014) kind of transformation.

Progressive transformative learning involves goal oriented purposeful learning with awareness of self and others. It involves progression towards the intended goal and throughout the journey making learning improved, implying actions

appropriately and modifying identity accordingly to reach the desired position in life. This leads to identity change 'into something better, more proper, more promising or more rewarding', which Illeris (2014) termed progressive transformation (Illeris, 2014, p. 93). An example is as follows:

> Sam, a 40 year-old engineer, belongs to Black and Minority Ethnic (BME) community. From primary school age he believed himself to be a 'brainy person' and, reflecting on this, he sees himself to be a 'sciencey person'. This stability in science identity coincides with the segregation that current researchers and educators have indicated in relation to ethnicity, gender, race and religion (for example Archer et al. 2013). We view, Sam's intention of being sciencey to be loosely shaped by global influences - he rejected the influence of being the only BME student in his physical engineering class and the only BME employee in his department whilst, at the same time, fulfilling his aspirations. Social agents had low impact in his 'science life' - for example, he believes that his parents were quite 'far behind' in understanding the education system, and his science teachers were less than keen in promoting science education and science careers in school. Unlike his siblings, who attended swimming lessons on every Saturday, Sam attended science club on a voluntary basis because he perceived it to be an open, independent and an un-stressful platform to fulfil his aspirations of working as an engineer.
>
> At the time of subject selection - aged 19 - his chosen option were biology, chemistry, physics and mathematics i.e. all within the sciences. At no point did he consider opting for any non-science (humanities) subjects. Later, he decided to continue specifically with mathematics and physics, and so his meaning making filter and preference filters became increasingly focussed on these two specialisms, progressing to become a 'physical engineer'. For us, this illustrates a stable science identity and a stable belief in being a 'sciencey person'.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

In summary, Sam exhibits little or no movement away from science. His identity remained securely within the domain of science and science education. His self-belief in being a 'sciencey person' made the largest impact on his developing life. Most of the movement in his choices (taking science-based school subjects, joining a science club) were impervious to larger global forces that might have taken him away from science.

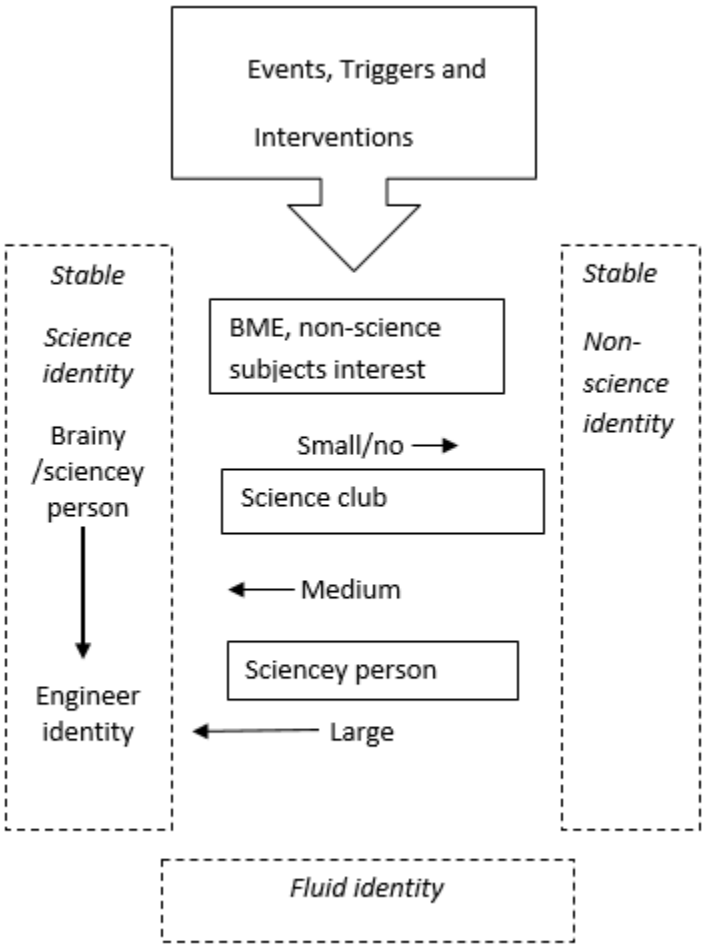

Figure 7: Charting Sam's progressive transformation

Regressive transformations, on the other hand, involve individuals who enrol themselves in an activity or in a situation where transformation is necessary. These

could be intended or situational transformations, and people might withdraw from the progressive changes despite having all the necessary challenges and support that are provided in the form of contextual influences. In this situation a progressive transformation could be experienced, say, as too demanding and unbearable despite the individual's attempts to keep up with expectations. This withdrawal leads to what Illeris terms 'regressive transformation' (Illeris, 2014). An example is as follows:

> Sarah, aged 35, is an Asian working-class woman. Her father worked in a leather factory and mother as a house wife. At the age of 15, as a part of school-based work experience, she became involved in helping local authority-assigned health professionals to improve the health conditions for children. The combination of being both an Asian working class girl (GF) aspiring to be a health professional (SA), and carrying out work experiences in helping the local community (TL), gave some meaning to her life. She eventually saw medical science as a 'dream profession'. In addition, she found one of her science teachers (SA) to be very inspirational, a teacher who always encouraged Sarah's ambition to continue with biological sciences. Moreover, one of her school's interventions was to highlight social media campaigns in bringing working class women into science education and science professions. Accordingly, Sarah's journey in constructing an identity as a medical doctor grew stronger, along with her belief that a university degree in science would provide better career opportunities, earn respect and money.
>
> At the decision-making age of 16, Sarah chose biology and English as major subjects for pre-university A-levels. English was her second choice because she loved reading and writing non-fiction stories and autobiographies. Her interest in biology as well as English exhibits a fluid nature where, at this age, she exhibited some movement towards biology and in becoming a doctor. During A-levels, Sarah struggled to pass the biology examinations and, after

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

retaking the exam, she passed though with low grades. This gave pause for thought, she realised she was unable to live up to her own expectations and subsequently found it too difficult to continue with medical sciences. Sarah was upset by this fairly sudden regression and therefore took up her second choice and enrolled in an English course. However, she failed again. This led Sarah to move completely out of education as well as from helping her local community, thus exhibiting a fairly regressive transformation. She began work in a local grocery shop from age 22 - where she is working to date.

Sarah's core cannot be described as stable or sufficiently forceful to make her fight against failure. Instead, failure rooted quite deeply in her identity. This regressive TL towards education seems to have paralysed, even if opportunities/ resources became available.

In summary, Sarah has exhibited movement into and away from science at different stages of her life, both movements guided by external forces and her failure in exams. She constructed a meaning for herself as 'education is not for me' resulting in regressive transformation (Figure 8).

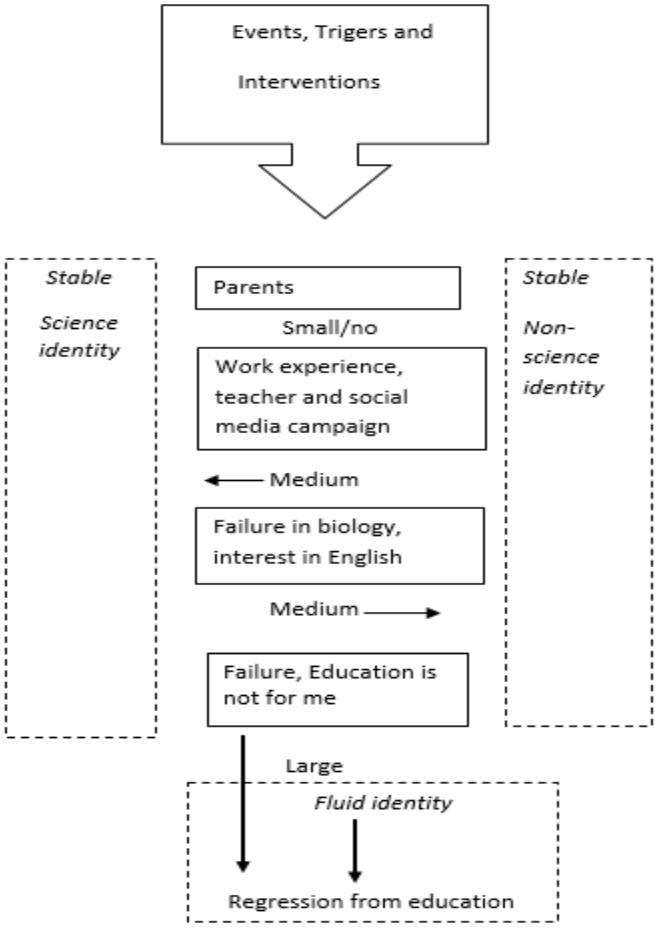

Figure 8: Charting Sarah's regressive transformation

Third we use 'restorative transformation' as a combination of progressive and regressive transformation. The regressive transformation above could have been sudden upsetting change but could be useful and progressive in the long run. The regression towards these adverse experiences might be useful later in life, which could act as the first step towards the initiation of progressive transformation. This type of transformation is termed by Illeris (2014) as 'restoring transformation' where we call it as reconstructive transformation because we believe progression after regression will allow a person to accept quite different TL experiences incorporated through a certain drive/or force (IIA). A theoretical example is as follows:

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

Deborah aged 55, is a white middle class woman. She was expected to do a degree in chemistry, as both her parents were working in the field of chemistry and were much respected in the family and immediate community. She never felt that school science and science teachers had an influence in developing aspiration towards science. Even though, Deborah's science results were always quite impressive, she was equally good in music, arts, literature and history. At the age of 17, she found herself as sitting at a cross roads, exhibiting fluid and ambivalent feelings towards science and non-science studies. She preferred chemistry over arts because of her family influences and entered chemistry undergraduate studies at university, although she later said, her 'heart was not into it'. She therefore struggled to maintain interest in chemistry classes, felt burdened and demotivated, all of which which resulted in regressive transformation and movement away from the study of chemistry. While discussing this with her personal tutor, she realised that chemistry was simply 'not for her'. After a thoughtful journey, Deborah realized that her real interest lay in creative and imaginative arts. At the age of 20, her movement towards studying arts grew stronger and her identity constructs develop towards stability in arts. This resulted in a progressive transformation in accordance with her sense of individual agency. Currently, she is a university lecturer in modern arts.

In summary, Deborah exhibited movement into and away from science at different stages of her life. At the initial stages she exhibited fluid nature - where parental and community influences guided her choice of chemistry. Later, feeling detached from chemistry, she identified herself as 'an arty person' resulting in progression into arts after a regression from chemistry (Figure 8).

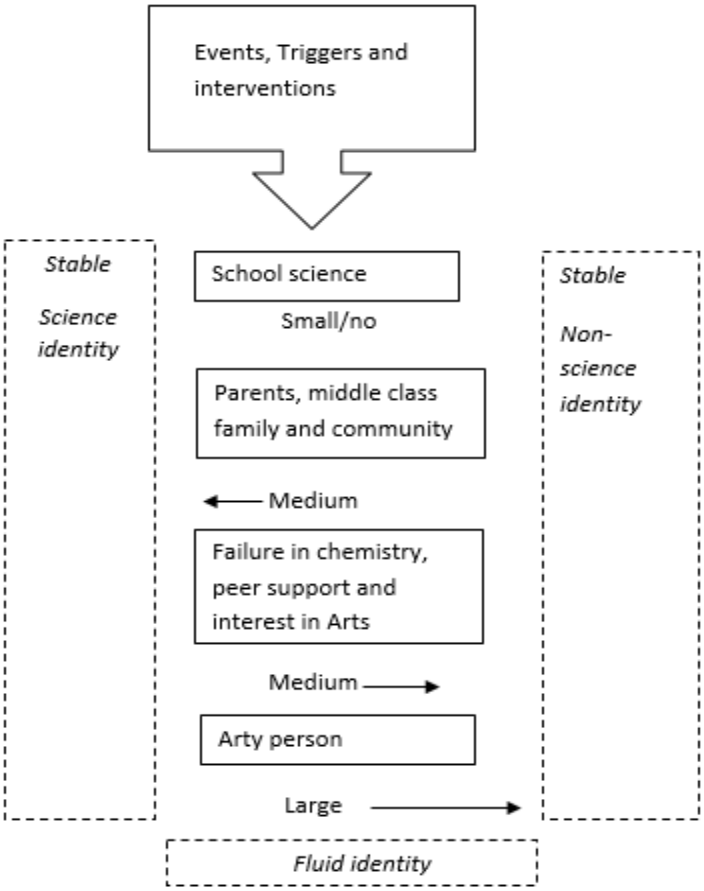

Figure 9: Charting Deborah's reconstructive transformation

Similar to the above examples of Sam, Sarah and Deborah, Salehjee (2017) has tested the models to chart science lives of twelve science and non-science professionals (Salehjee & Watts, 2015), 123 university students and thirty girls. For future research, we are determined to map science lives of people from different stages of their lives and help to device specific interventions to avoid regression and movement away from science.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

Some conclusions

In this chapter we have reviewed and analysed the aspects of global forces (GF), social agents (SA), Transformative learning (TL) experiences, Individual Internal Agency (IIA) and their incorporation in a few key science identity research models. We also discussed the transformation of identities using identity models and kinds of transformation. Moreover, researchers in the area of science education also need to promote public understanding of science and evaluate ways that stop students 'closing science doors' too early in their lives. We recommend that researchers use the Sci-ID model and adapt it to explore the duality of external forces and agency in individuals from schools, colleges, universities, science and non-science-based professional workplaces etc.

From our discussions of identity and identity transformations, it is quite clear to us that there in a gap in promoting lifelong learning in science. As school pupils pass the age of compulsory education, and later gain science or non-science based careers, their identities become quite stable either towards science or to non-science. Some are anti-science, some pro-science and we can identify them as 'sciencey' or 'non-sciencey' people. Moreover, to cater for this, various intervention strategies have been employed in the UK - for example, the ASPIREs project. However, we believe that schools ignore or neglect the vast majority - the young people who are fluid in their aspirations. In our view, schools and teachers need to find simple ways of implementing 'science interventions' to cater for students with both stable pro-science and those with fluid identities. There is a clear need for well researched and evaluated strategies/ interventions to encourage fluidity in non-science students, and work towards incorporating stability among those fluid students. They need to consider the meaning-making of science content along with the preferences, enjoyment and the fun element of laboratory work, out of school visits etc. Therefore, we strongly encourage science teachers to carryout action research involving not only designing and implementing interventions but

also evaluating and modifying their plans. They need to identify stable and fluid people, which requires effort in talking to people or communities - understanding their stories, life journey, finding out what are the things that move them away or towards science and design simple interventions accordingly for the schools and teachers (Watts, 2015, 2018).

For example, John is 38 years old and does not have a university degree, works in a local shop, hated science in school. However, he follows Tim Peake's journey to the International Space Station and is fascinated by space and rockets. In this respect, his fascination is similar to Sam's case above. However, he did not have the same opportunities as Sam, and his fascination could not translate into a force that would allow him to become a scientist. Even though he is not in the field of science his fascination is well and alive, and the question is: What can be done to foster and support this interest? Like Falk (2005), we see the promotion of mechanisms and funding as essential to enabling lifelong learning in local communities, churches, mosques, libraries, museums, community centers, science fairs in local parks, and so on. This strategy would raise public awareness could encourage local people to gain more scientific knowledge in their field of interest, perhaps even encourage more towards gaining a qualifications. Moreover, it stands to encourage people to actually re-consider and challenge any anti-science predispositions that 'science is not for them'. That is, we need to find ways to help people to 'light their motivational fuse' into sciences by talking to people about their 'science lives, school choices and natural tendencies' (Salehjee & Watts, 2015).

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

REFERENCES

Abes, E.S., Jones, S.R. and McEwen, M.K. (2007). Reconceptualizing the model of multiple dimensions of identity: The role of meaning-making capacity in the construction of multiple identities. *Journal of college student development*. *48*(1), pp.1-22.

Abes, E.S. & Jones, S.R. (2004). Meaning-making capacity and the dynamics of lesbian college students' multiple dimensions of identity. *Journal of college student development*. 45(6), pp.612-632.

Albright, J., Towndrow, P.A., Kwek, D. & Tan, A.L. (2008). Identity and agency in science education: reflections from the far side of the world. *Cultural Studies of Science Education*. 3(1), pp.145-156.

Archer, L. & DeWitt, J. (2016). *Understanding Young People's Science Aspirations: How students form ideas about 'becoming a scientist'*. New York, N: Routledge.

Archer, L., Dawson, E., Seakins, A., DeWitt, J., Godec, S. & Whitby, C. (2016). "I'm Being a Man Here": Urban Boys' Performances of Masculinity and Engagement With Science During a Science Museum Visit. *Journal of the Learning Sciences*, (just-accepted).

Archer, L. & DeWitt, J. (2015). Science aspirations and gender identity: Lessons from the ASPIRES project. In Henriksen, E.K., Dillon, J. and Ryder, J. *eds. Understanding student participation and choice in science and technology education.* Dordrecht: Springer, pp. 89-102.

Archer, L., Dewitt, J. & Osborne, J. (2015[a]). Is science for us? black students' and parents' views of science and science careers. *Science education*. 99 (2), pp. 199-237.

Archer, L., Dawson, E., DeWitt, J., Seakins, A. & Wong, B. (2015[b]). Science capital: A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching. 52*(7), pp.922-948.

Archer, L., DeWitt, J. & Willis, B. (2014[a]). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*. *51*(1), pp.1-30.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. & Wong, B. (2014[b]). *ASPIRES. Young people's science and career aspirations, age 10 –14.* London: Kings College.

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), pp.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), pp. 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 aspirations. *Pedagogy, Culture & Society*. 21 (1), pp. 171-194.

Beauchamp, G. & Parkinson, J. (2008). Pupils’ attitudes towards school science as they transfer from an ICT-rich primary school to a secondary school with fewer ICT resources: Does ICT matter?. *Education and Information Technologies*. *13*(2),pp.103-118.

Block, D. (2013). The structure and agency dilemma in identity and intercultural communication research. *Language and Intercultural Communication*.*13* (2), pp.126-147.

Bourdieu, P., & Passeron, J. C. (1990). *Reproduction in education, society and culture*. 2nd edition. London: Sage.

Bourdieu, P. (1990) *In other words: Essay towards a reflexive sociology*. Cambridge: Polity.

Bourdieu, P. (1986). The forms of capital. In J. C. Richardson. ed. *Handbook of theory and research for the sociology of education*. New York: Greenwood Press, pp.241-258.

Bourdieu, Pierre (1986). The Forms of Capital. In John Richardson, Ed. *Handbook of Theory and Research for the Sociology of Education*. New York: Greenwood Press, pp.241-258.

Bourdieu, P., & Passeron, J. C. (1977). *Reproduction in education, society and culture*. Beverly Hills: Sage.

Brickhouse, N.W. & Potter, J.T. (2001). Young women's scientific identity formation in an urban context. *Journal of research in science teaching*.38 (8), pp.965-980.

Brickhouse, N.W., Lowery, P. & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of research in science teaching*.*37*(5), pp.441-458.

Burke, P. J. & Stets, J. E. (2009). *Identity theory*. New York NY: Oxford University Press.

Carambo, C. (2015). Social, Cultural and Emotional Contexts of Transformative Learning Environments. In Milne, C., Tobin, K. and DeGennaro, D. eds. *Sociocultural Studies and Implications for Science Education*. Netherlands: Springer. pp. 155-180.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

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), pp.1187–1218.

Chapman, A. & Feldman, A. (2016). Cultivation of science identity through authentic science in an urban high school classroom. *Cultural Studies of Science Education*, pp.1-23.

Claussen, S., & Osborne, J. (2012) Bourdieu's notion of cultural capital and its implications for science curriculum. *Science Education*. 97(1),pp. 58-79.

Darragh, L. (2016). Identity research in mathematics education, Education Studies in Mathematics, 93:19–33 DOI 10.1007/s10649-016-9696-5

D'Amato, L. G., & Krasny, M. E. (2011). Outdoor adventure education: Applying transformative learning theory to understanding instrumental learning and personal growth in environmental education. *Journal of Environmental Education*. 42(4), pp.237–254.

DiMaggio, P. (1982). Cultural capital and school success: The impact of status culture participation on the grades of US high school students. *American sociological review*. 47(2), pp.189-201.

Dweck, C. S. (1999). *Self-theories: Their role in motivation, personality and development*. Philadelphia: Psychology Press.

Dweck, C. (2008). Mindsets and math/science achievement. New York, NY: Carnegie Corporation of New York, Institute for Advanced Study, Commission on Mathematics and Science Education.

Elmesky, R. & Seiler, G. (2007). Movement expressiveness, solidarity and the (re) shaping of African American students' scientific identities. *Cultural Studies of Science Education*. *2*(1), pp.73-103.

Erikson, E. H. (1982) *The lifecycle completed*. New York, USA: Norton.

Erel, U. (2010). Migrating cultural capital: Bourdieu in migration studies. Sociology. 44(4), pp.642-660

Erikson, E. (1973) Eight ages of man. In Bowman, C.C., 1973. *Humanistic sociology; readings*. McGraw-Hill Primis Custom Publishing. p. 68 -82.

Erikson, E. H. (1968). *Identity: Youth and crisis*. New York: Norton.

Estrada, M., Woodcock, A., Hernandez, P. R., & Schultz, P. W. (2010). Toward a model of social influence that explains minority student integration into the scientific community.

Journal of Educational Psychology. [Accessed 09/10/14]. 103(1),pp. 206–222. doi: 10.1037/a0020743.

Falk, J. H. (2005). Free-choice environmental learning: framing the discussion. Environmental education research, 11(3), 265-280.

Gee, J.P. (2000). Identity as an analytic lens for research in education. *Review of research in education*, *25*, pp.99-125. [Online] [Accessed 09/10/17]. Available from:http://rre.sagepub.com/content/25/1/99.full.pdf+html

Giddens, A. (1991). *Modernity and self-identity: Self and society in the late modern age*. Stanford: Stanford University Press.

Gilmartin, S.K., Li, E. & Aschbacher, P. (2006). The relationship between interest in physical science/engineering, science class experiences, and family contexts: Variations by gender and race/ethnicity among secondary students. *Journal of Women and Minorities in Science and Engineering*, *12*(2-3). [Online] [Accessed 20/11/2014]. Available from:10.1615/JWomenMinorScienEng.v12.i2-3.50.

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.

Hassard, J. & Dias, M. (2009) *The Art of Teaching Science: Enquiry and innovation in middle school and high school.* 2nd Ed. New York and London: Routledge.

Hattam, R. & Zipin, L. (2009). Towards pedagogical justice. *Discourse: Studies in the cultural Politics of Education*. 30(3), pp.297-301.

Hazari, Z., Cass, C. & Beattie, C. (2015). Obscuring power structures in the physics classroom: Linking teacher positioning, student engagement, and physics identity development. *Journal of Research in Science Teaching*. *52*(6), pp.735-762.

Hazari, Z., Potvin, G., Lock, R.M., Lung, F., Sonnert, G. & Sadler, P.M. (2013). Factors that affect the physical science career interest of female students: Testing five common hypotheses. *Physical Review Special Topics-Physics Education Research*. 9(2),pp.020115.

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), pp.978-1003.

Heddy, B. & Pugh, K. (2015). Bigger is not always better: Should educators aim for big transformative learning events or small transformative experiences?. *Journal of Transformative Learning*. 3(1), pp.52-58.

House of Commons Children, Schools and Families Committee (2010). *Training of Teachers: Fourth report of session 2009 – 10*. Volume 2 [Online]. [Accessed 20 July 2010].

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

Available from: http://books.google.com/books?id=c7aIl38yPtUC&pg=PA178&dq=ofsted+continuing+professional+development+for+teachers+in+schools&hl=en&ei=zvVSTPCNKJSI4gbS9fTgAw&sa=X&oi=book_result&ct=result&resnum=4&ved=0CEIQ6AEwAw#v=onepage&q=ofsted%20continuing%20professio.

Hulleman, C. S., & Cordray, D. S. (2009). Moving from the lab to the field: The role of fidelity and achieved relative Intervention strength. *Journal of Research on Educational Effectiveness*. 2(1),pp. 88–110.

Hyde, J.S., Canning, E.A., Rozek, C.S., Clarke, E., Hulleman, C.S. & Harackiewicz, J.M. (2016). The Role of Mothers' Communication in Promoting Motivation for Math and Science Course-Taking in High School. *Journal of Research on Adolescence*. [Online]. [Accessed 12/12/2016]. Available from: doi:10.1111/jora.12253.

Illeris, K. (2014). *Transformative learning and identity*. London and New York: Routledge.

Ing, M. (2014). Gender differences in the influence of early perceived parental support on student mathematics and science achievement and STEM career attainment. *International Journal of Science and Mathematics Education*. *12*(5), pp.1221-1239.

Jackson, P. W. (1986). The practice of teaching. New York: Teachers College Press

Jarvis, P. (2013) Learning to be a person East and West. *Comparative Education*. [Online]. 49(1), pp. 4-15. [Accessed 20/10/15]. Available from: doi: 10.1080/03050068.2012.740216

Jarvis, P. (2009). *Learning to be a person in society*. London and New York: Routledge.

Jenkins, R. B. (1992). *Pierre Bourdieu*. London: Routledge.

Jensen, E. & Wright, D. (2015) Critical Response to Archer et al. (2015). "Science Capital": A Conceptual, Methodological, and Empirical Argument for Extending Bourdieusian Notions of Capital Beyond the Art. *Science Education*. 99 (6), pp.1143-1146.

Jeynes, W.H. (2010). Parental involvement and encouraging that involvement: Implications for school-based programs. *Teachers College Record*. 112(3), pp. 747–774.

Jones, S.R. & McEwen, M.K. (2000). A conceptual model of multiple dimensions of identity. *Journal of college student development*. 41(4), pp.405-414.

Jungert, T. & Koestner, R. (2015). Science adjustment, parental and teacher autonomy support and the cognitive orientation of science students. *Educational Psychology*. *35*(3), pp.361-376.

Kane, J.M. (2012). Young African American children constructing academic and disciplinary identities in an urban science classroom. *Science Education*. *96*(3), pp.457-487.

Kegan, R. (2009). What "form" transforms; A constructive developmental approach to transformative learning. In Illeris, K. ed. *Contemporary theories of learning: learning theorists... in their own words*. London and New York: Routledge, p. 35-52.

Kegan, R. (1994). *In Over Our Heads: The Mental Complexity Of Modern Life*. Cambridge MA: Harvard University Press.

Kelman, H.C. (2006). Interests, relationships, identities: Three central issues for individuals and groups in negotiating their social environment. *Annu. Rev. Psychol..57*, pp.1-26.

King, A (2000) Thinking with Bourdieu against Bourdieu: A 'Practical' Critique of the Habitus. *Sociological Theory.* 18(3), pp. 417-433.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lee, Y.-J. (2012). Identity-based research in science education. In B. Fraser, K. Tobin, & C. McRobbie. eds. *Second international handbook of science education*. Dordrecht: Springer, pp. 35–45.

Lerman, S. (2001). Cultural, discursive psychology: A sociocultural approach to studying the teaching and learning of mathematics. Educational Studies in Mathematics, 46(1/3), 87–113. doi:10.2307/3483241

Lock, R.M., Hazari, Z. & Potvin, G. (2013). Physics career intentions: The effect of physics identity, math identity, and gender. In *2012 Physics education research conference* . 1513(1), pp. 262-265. AIP Publishing.

Loehle, C. (2010). *Becoming a successful scientist. Strategic thinking for scientific discovery*. Cambridge: Cambridge University Press.

MacDonald, A. (2014). *"Not for people like me?" Under-represented groups in science, technology and engineering. A summary of the evidence: the facts, the fiction and what we should do next.* Women in science, technology and engineering (WI S E). [Online]. [Accesed 10/10/16]. Available from: http://www.equalityanddiversity.net/docs/not_for_people_like_me.pdf

Mandler, D., Mamlok-Naaman, R., Blonder, R., Yayon, M. & Hofstein, A. (2012). High-school chemistry teaching through environmentally oriented curricula. *Chemistry Education Research and Practice*. 13(2), pp. 80–92.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

Mezirow, J. (2009). Transformtive learning theory. In Mezirow, J., Taylor, W. and associates. *Transformative learning in practice: Insights from community, workplace, and higher education*. San Francisco, CA:Josey-Bass.

Mezirow, J. (2000). Learning to think like an adult. In J. Mezirow (Ed.), *Learning as transformation: Critical perspectives on a theory in progress*. San Francisco, CA: Jossey Bass.Midgley, M. (2013). *Science and poetry*. Routledge, pp. 3–34.

Mezirow, J. (1996). Transformation theory of adult learning. In M. R.Welton. ed. *In defence of the lifeworld*. New York: SUNY Press, pp. 39–70.

Mezirow, J. (1991). *Transformative dimensions of adult learning*. Jossey-Bass, 350 Sansome Street, San Francisco, CA 94104-1310.

Mezirow, J. (1990). How critical reflection triggers transformative learning. Fostering critical reflection in adulthood. 1, p.20. [Online]. [Accessed 10/10/17]. Available from:http://s3.amazonaws.com/academia.edu.documents/30281715/critical-reflection.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1484429283&Signature=PZ7Ofi3jCBXeU2IZJKauMsuWKxc%3D&response-content-disposition=inline%3B%20filename%3DHow_critical_reflection_triggers_transfo.pdf

Mezirow, J. & Marsick, V. (1978). *Education for perspective transformation: Women's re-entry programs in community colleges.* New York: Center for Adult Education, Teachers College, Columbia University.

Nohl, A.M. (2015). Typical Phases of Transformative Learning: A Practice-Based Model. *Adult Education Quarterly*. 65 (1), pp.35-49.

Nunes, T., Bryant, P., Strand, S., Hillier, J., Barros, R. & Miller-Firedmann, J. (2017). Review of SES and Science Learning in Formal Educational Settings. A Report Prepared for the Education Endowment Foundation and the Royal Society. Oxford, University of Oxford.

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*. *25*(2), pp.177-196.

Pike, A. G., & Dunne, M. (2011). Student reflections on choosing to study science post-16. [Online]. *Cultural Studies of Science Education. 6*, 485–500. Available from: doi:10.1007/s11422-010-9273-7.

Reid, A. & McCallum, F. (2014). 'Becoming your best': student perspectives on community in the pursuit of aspirations. *The Australian Educational Researcher*. *41*(2), pp.195-207.

Rodogno, R. (2012). Personal Identity Online. *Philosophy and Technology*. 25(3),pp. 309–328.

Robnett, R.D., Chemers, M.M. & Zurbriggen, E.L. (2015). Longitudinal associations among undergraduates' research experience, self-efficacy, and identity. *Journal of Research in Science Teaching*. *52*(6), pp.847-867.

Rodogno, R. (2012). Personal Identity Online. *Philosophy and Technology*. 25(3),pp. 309–328.

Rodrigues, S. (2014). Language and communication in the science classroom. In D.M. Watts.ed. *Debates in Science Education*, London: Routledge.

Ransome, P. (2010). *Social theory for beginners*. UK: Policy Press.

Reay, D., Crozier, G., & Clayton, J. (2010). ‘‘Fitting in’’ or ‘‘standing out’’: Workingclass students in UK higher education. *British Educational Research Journal*. 36(1), 107–124.

Reay, D. (2004) Education and Cultural capital: The implications of changing trends in education policies. *Cultural Trends*, 13(2), pp. 73-86.

Roth, W., & Middleton, D. (2006). Knowing what you tell, telling what you know: Uncertainty and asymmetries of meaning in interpreting graphical data. *Cultural Studies of Science Education*. 1 (1), pp.11–81.

Salehjee, S. (2017). *Making scientists: Developing a model of science identity*. Un-published PhD thesis.

Salehjee, S., Ludhra, G. & Watts, D. M. (2018) (in press) Young South-Asian women and science identity. *Cultural Studies of Science Education*

Salehjee, S. & Watts, D.M. (2015). Science lives: school choices and ‘natural tendencies’. *International Journal of Science Education*. 37(4), pp. 727-743.

Seginer, R. (2006). Parents’ educational involvement: A developmental ecological perspective. *Parenting: Science and Practice*.6 (1), pp.1–48.

Spillane, M. (2000). *Branding yourself: How to look, sound and behave your way to success*. Pan: London: Sidgwick & Jackson.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R. & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*. 49(1), pp. 1-34.

Stinson, D., & Bullock, E. (2012). Critical postmodern theory in mathematics education research: A praxis of uncertainty. Educational Studies in Mathematics, 80, 41–55. doi:10.1007/s10649-012-9386-x

Sullivan, A. (2002). Bourdieu and Education: How Useful is Bourdieu's Theory for Researchers? *The Netherlands Journal of Social Sciences*. 38(2), pp.144- 166.

*Corresponding Authors address

Email: saima.salehjee@strath.ac.uk

Tao, V.Y., 2016. Understanding Chinese Students' Achievement Patterns: Perspectives from Social-Oriented Achievement Motivation. In *The Psychology of Asian Learners*. Springer Singapore, (pp. 621-634).

Taylor, C. (2009) *A Good School for Every Child: How to Improve Our Schools*. UK: Routledge. [Online]. [Accessed 10/09/16]. Available from:http://books.google.com/books?id=6ZWRgVl454MC&pg=PA73&dq=science+specialist+teachers&hl=en&ei=rYtSTOCTDIfb4Ab5jN3_Ag&sa=X&oi=book_result&ct=result&resnum=5&ved=0CEMQ6AEwBA#v=onepage&q=walter&f=false

Tissenbaum, M., Lui, M. & Slotta, J.D. (2012). Co-Designing Collaborative Smart Classroom Curriculum for Secondary School Science. *J. UCS.18*(3),pp.327-352.

Wang, M.T., Eccles, J.S. & Kenny, S. (2013). Not lack of ability but more choice individual and gender differences in choice of careers in science, technology, engineering, and mathematics. *Psychological Science*. 24(5), pp.770-775.

Wood, R. & Ashfield, J. (2008). The use of the interactive whiteboard for creative teaching and learning in literacy and mathematics: a case study. *British journal of educational technology*, *39*(1), pp.84-96.

Welton, M. R. (1995). *In defence of the lifeworld, critical perspectives on adult learning*. Albany, NY:SUNY Press.

Yeager, D.S. & Walton, G.M. (2011). Social-psychological interventions in education They're not magic. *Review of educational Research*. 81(2), pp.267-301.