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Science Lives: School choices and ‘natural tendencies’

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Science Lives: School choices and 'natural tendencies'

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An analysis of 12 semi-structured interviews with university-based scientists and non-scientists illustrates their life journeys towards, or away from, science and the strengths and impact of life occurrences leading them to choose science or non-science professions. We have adopted narrative approaches and used Mezirow's transformative learning theory framework. The areas of discussion from the result have stressed on three main categories that include 'smooth transition', 'incremental wavering transition' and 'transformative transition'. The article concludes by discussing the key influences that shaped initial attitudes and direction in these people through natural inclination, environmental inspirations and perceptions of science.

Keywords: *Scientists; Non-scientists; Narrative; Transformative learning theory; Attitude*

> I am often asked whether my African childhood led me to become a biologist. I'd like to answer yes, but I'm not confident. How can we know if the course of life would have changed by some alteration in its early history? I had a trained botanist for a father and a mother who knew the name of every wildflower you could normally expect to see—and both of them were always eager to satisfy a child's curiosity about the real world. Was that important in my life? Yes, it surely was. Dawkins (2013)

Introduction

Much has been written about how and why young people, particularly young women, aspire to or, more commonly, reject a career path in science. In this article, we

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consider both sides of the coin: key features that draw some people into doing science and the 'triggers' that initiate rejection. To do this we have talked to 12 men and women, 6 decisively scientific, 6 resolutely non-scientific, adopting narrative approaches to the research. Narrative research is the study of stories, and in this case they appear as short historical biographies related by people about themselves and about others as part of their everyday life choices. These are oral stories obtained through semi-formal interviews and used here to shape educational purpose.

An equal number of men and women in our sample is probably a reasonable reflection of the broad gender division in the UK, and according to the 2011 census the population of the country is around 63 million, of whom 31 million are men and 32 million women (Office for National Statistics, 2011). A 50:50 split of science and non-scientists, however, is glaringly unrepresentative; there are many more non-scientists (however classified) than there are those who have chosen a work-life within science. Research undertaken for the UK's Science Council indicates that some 5.8 million people are now employed in science-based roles, around 20% of the UK workforce (The Science Council, 2014). Our choice of equal numbers here has more to do with our sense of symmetry than sample statistics.

Narrative researchers posit that evidence, such as personal retrospective descriptions of life experiences, can serve to generate knowledge about significant areas of the human realm (Schank, 1990). This tackles a key theme that has come to characterise the development of narrative research in educational theory—the ongoing tension between stories and science. A story, rather than just being a passive rendering of events, assumes 'the double role of mimesis-mythos' (Kearney, 2002). That is, a story, unlike a chronology—a list of events in date order—is a 'creative re-description of the world such that hidden patterns and hitherto unexplored meanings can unfold' (Kearney, 2002, 12). To author a story is always a creative act (Coulter & Smith, 2009). As Lieblich, Tuval-Mashiach, and Zilber (1998) have asserted, frequently the study of narrative 'has been criticized as being more art than research' (p. 1)—though why art has less value as knowledge is more often assumed than argued.

Theoretical underpinnings for our work are derived from Mezirow's (1997) transformational learning. One hoped-for outcome of science education, both in schools and at university level, in the UK and elsewhere, is that students encounter transformational learning experiences (Cranton, 2006; MacGilchrist & Buttress, 2005), enabling periods of critical reflection whereby they undergo changes in their frame of reference. In this case, we are exploring stories of change both into, and away from, science as a career option. As we discuss in a moment, much of the existing literature on transformative learning contributes to understandings of the meaning-making process and its various phases, the significance of sociocultural contexts and the essentiality of critical reflection. Taylor's (2007) review decided that, within this literature, most research studies foster transformative learning in formal higher education settings. Our study follows a similar route, although in our interviews 12 respondents are not students but all established university academics (see Table 1).

The recent work by Jones, Taylor and Forrester (2011) explored the reflections of 37 scientists and engineers to examine early influences on their careers. This group

Table 1. Interview participants (with pseudonyms), category (scientist or non-scientist) and their academic roles

	Participant	Category	Academic roles
1	Dennis	Male scientist, Ph.D.	Senior lecturer in Computer Engineering
2	Parker	Male scientist, professor	Professor and Deputy Head of School
3	George	Male scientist, professor	Professor and principal researcher
4	Adam	Male non-scientist, Ph.D.	Senior lecturer in Education
5	Norman	Male non-scientist, Ph.D.	Senior lecturer in English Literature
6	Philip	Male non-scientist, professor	Professor of Music, Head of Music Research
7	Jane	Female scientist, Ph.D.	Lecturer in Experimental Particle Physics
8	Daisy	Female scientist, Ph.D.	Senior lecturer in Education and researcher in Experimental Particle Physics
9	Grace	Female scientist, Ph.D.	Lecturer in Mathematics Education
10	Greta	Female non-scientist, Ph.D.	Lecturer and course leader in Education
11	Nikki	Female non-scientist, professor	Associate professor in Education
12	Danielle	Female non-scientist, professor	Associate professor in Education

developed knowledge, skills, interests and independence in science through supportive and nurturing relationships with teachers and parents. The authors concluded with a series of questions including, 'How to sustain the interests of students through their school and out-of-school learning experiences?' In our view, one answer is to explore how, if at all, key experiences impact upon students and their future directions in relation to science. Our project therefore has four overarching purposes, to: (i) Discuss the most pressing influences on (young) people as they contemplate the study of science; (ii) Explore the learning experiences of our sample of people, currently established as they are in academic science or non-science life–work patterns; (iii) highlight the kinds of personal events (experiences and transitions) that prompted entry into science, or caused rejection of it and (iv) consider the educational implications of such issues for science education more generally.

The Influence on the Choices Made About—and Through—School Science

The gist of this article concerns the many, varied and complex influences that shape young people's decisions to study, or continue studying STEM subjects, both in and out of school. It is difficult to isolate key factors that would provide a full and clear picture. According to some expectancy-value theorists (e.g. Eccles-Parsons et al., 1983; Feather, 1982; Wigfield & Eccles, 1992), an individual's values for particular goals and tasks can help explain why (s)he chooses one activity over another.

However, many of these theories do not systematically address other important motivational questions: What actually makes the individual want to engage in something at all? And, equally important: What makes the individual *not* want to engage? The science education literature offers a range of mediating explanations, sometimes directed at all young people, sometimes at one gender or the other. The range of research studies encompassed in this is enormous, and an exhaustive review is beyond the immediate scope of this article. However, some of the major strands raised are (a) the subject itself, students' perceptions of self in relation to science and (b) peer, parental and teacher influences.

The Perceived Relevance of Science Subject, School Science and Self-identity

Many studies present a gloomy picture with respect to their uptake of science, especially at secondary school level. A key claim is that science education, particularly in physics and chemistry, remains unpopular among students (Hofstein, Eilks, & Bybee, 2011; Holbrook, 2008; Osborne & Dillon, 2008)—students are simply not interested in science learning (Jenkins, 2005; Osborne, Simon, & Collins, 2003). One frequently cited reason is that learners perceive school science and science more broadly as both difficult, and as 'irrelevant' both for themselves and for the society in which they live and operate (Dillon, 2009; Gilbert, 2006; Holbrook, 2008; Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013). Science teachers have worked to make education 'more relevant' in order to better interest and motivate their students (Holbrook, 2003, 2005; Newton, 1988a, 1988b); however, it remains unclear that this has had much effect. Bennett and Hogarth (2008) maintain that girls exhibit greater negative attitude towards school science and out-of-school science as compared to boys aged 12, which increases further throughout secondary schooling. One suggestion is that this reflects post-materialistic values and the 'late-modern identity' (Schreiner, 2006) of young women in developed countries, where girls tend to accentuate their femininity (Baram-Tsabari, 2009), in contrast to those in developing countries who view science as important for improving the quality of life. While girls at secondary school outperform boys, in the UK many more boys than girls choose physical sciences and engineering related at pre-university level (Department for Business Innovations and Skills, 2011). Young women see physics as a subject for boys, and becoming a physicist as a singularly male profession (People, Science & Policy, 2008).

Peer and Parental Pressure on School Direction and Achievement

The ASPIRES project (Archer et al., 2013, 2014) is unequivocal: parents and families exert a considerable influence on students' aspirations. 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). Numerous earlier studies have identified parental involvement as an important ingredient in promoting academic success (Hill & Taylor, 2004; Jeynes, 2010; Seginer, 2006). An early study by Breakwell and Beardsell (1992) surveyed almost 400 UK pupils aged 11–14. Boys were seen to have more positive attitudes to science and greater levels of participation in scientific extra-curricular activities and, as argued in the ASPIRES project, these positive attitudes were strongly positively related to having a father and mother who support science, and having scientific peers. The foremost student reason for an interest in STEM is a supportive parent/family member followed by inspiring teacher (Christensen, Knezek, Tyler-Wood, & Gibson, 2014) especially for young girls learning math and science (Fouad & Bynner, 2008).

The overall picture then is that while the relevance of content and image of science can be off-putting to some, particularly girls, the principal message from these studies is that the influence of home and family is paramount. There is no doubt that teachers play a role, too, in the interviews we discuss below, although we see something else occurring in the mix. As Archer et al. (2014) point out, those families with higher levels of science capital tend to be middle-class—although this is not always the case, and not all middle-class families possess much science capital. 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, some 'rebel'. Equally, some within a 'low science capital family' do find a route into science. The fascinating question for us is the stories behind these 'capital conformist' and non-conformist occurrences.

A Discussion of Transformational Learning

According to Jackson (1986), there are two enduring focuses in education, the *mimetic*, which deals with transmitting predetermined and measurable information to students, and the *transformative*, which deals with the transformation of qualities such as values, attitudes and perceptions. Unfortunately, the majority of our efforts for educating children have focused on transmitting knowledge rather than enriching, expanding and transforming everyday experience (Alsop, 2014; Toplis, 2014). Mezirow's transformative learning theory argues that, rather than typical academic learning, it is a person's life experiences that are the key initiators of life-changing transformations. He suggests that transformative learning incorporates the 'making of meanings', and describes this as an intense thoughtful journey of constructing meaning of oneself through life experiences. It is a 'continuous effort to negotiate contented meaning' (Mezirow, 2000, p. 3), which involves adult learners examining step-by-step their own beliefs, feelings and values. They undertake these processes with a 'critical and reflective lens to authenticate their reasons to adapt new actions' (Mezirow, 1996, p. 162). According to D'Amato and Krasny (2011), transformative learning theory highlights the process of the continuing conflicts of daily life leading to personal transformations, and then leading to self-development. O'Sullivan (2002) suggests that these transformations occur after a series of changes in an individual's life, in his or her perception and codes (dilemmas), so that the 'cognitive system searches for new codes by which novel and confusing perceptions can be made intelligible' (p. 3). Mezirow (2000, p. 22) identifies four main ways through which transformations can occur:

(1) Elaborating Existing Frames of Reference;
(2) Learning New Frames of Reference;
(3) Transforming Points of View and
(4) Transforming Habits of the Mind.

Mezirow's theory has been criticised for the strictness of these stages of transformation (Taylor, 2003); challenged as a particularly individualistic mode of analysis, with few links to social action (Welton, 1995) and seen to be limited by lack of reference to intuition, imagination and emotions (Boyd & Myers, 1988; Dirkx, 2006; Lennox, 2005). For our own purposes, we are interested in the personal and sociocultural factors that 'play an influencing role in the process of transformative learning' (Taylor, 2009, p. 11). What kinds of changes in life play induce the 'making' of a scientist? What novel or confusing perceptions, what dilemmas, trigger a person's 'exit' from science? Transformative learning offers a structure in which individuals' transitions, in this case towards or away from science, can be discussed through the intensity of experiences, social interactions and self-reflection. We are attracted by the stories, the way lives have developed and transformed in the journey through compulsory science education to becoming scientists and non-scientists. Like Facer and Manchester (2012), we are interested in four broad prompts or motives for learning amongst the participants: *personal events* (experiences and transitions that required emotional adjustment and personal development); *practicalities* (the development of skills and knowledge in pursuit of action in the world); *participation* (learning in pursuit of science engagement) and *pleasures* (learning prompted by curiosity and interest for its own sake).

A Discussion of Narrative Research

Narrative analysis originally grew out of literary theory (Zald, 1996) and, over the past two decades, has generated a 'narrative turn' in the social sciences (Atkinson & Delamont, 2006; Spector-Mersel, 2010). It is an interpretive approach that seeks to bring the reader closer to the phenomenon being studied (Bansal & Corley, 2011), allows an examination of social dynamics as process and enables understanding of human behaviour and the complex, relational quality of social interactions (Cope, 2005; Leitch, Hill, & Harrison, 2010). Narrative identity (McAdams & Mclean, 2013) is a person's internalised and evolving life story, integrating the reconstructed past and imagined future to provide life with some degree of unity and purpose. In the research we discuss here, we seek interpretative commonalities in the interview responses of participants as they relate personal events in their social (scientific) worlds. In our view, stories, even diverse and complex ones, provide the context within which intelligible action is taken: they tell where we come from so that we can understand who we are and what we might do. Schank (1990) sees such storytelling as a form of intelligence:

> People remember what happens to them, and they tell other people what they remember. People learn from what happens to them, and they guide their future actions accordingly ... Intelligence is really about understanding what has happened well enough to be able to predict when it might happen again. (p. 1)

In taking this route, we recognise that recalled experience is influenced and altered by memory and may not reflect the exact nature and sequence of events that took place (Powney & Watts, 1987)—the mere act of participating in an interview is a transactional event that can alter the recall of experiences (e.g. Roth & Middleton, 2006). Our orientation sees data analysis as a complex transaction between researcher and evidence, the ends of which are provisional and fallible. We probe the themes, hypotheses, categories and assertions that emerge from analysis to see how they stand up to the weight of evidence and counterclaims (Selvaruby, O'Sullivan, & Watts, 2008).

The Study

The individual semi-formal interviews were audio-recorded over a period of some two months, each interview taking place in the work office of the respondent and lasting between 40 and 60 min each. The questions drew broadly on Facer and Manchester's (2012) 'dynamics of living': personal events, practicalities, participation, pleasures, and came to us in the form of brief narratives: 'I decided to ... '; 'I think I needed to ... '. The respondents chose, or were given, a pseudonym and, as might be expected, they disclosed only those details with which they were comfortable, resulting in a rich and varied, often lively, interview session. The data were subjected to standard content analysis, focussing on three themes, or three 'life trajectories':

(i) 'Smooth transition', where interviewees 'always knew what they were going to do': they never questioned their ability or career direction; they were always going to do science or arts. We comment here on the role of parents, peers, home-life and the role of interests and hobbies.
(ii) 'Wavering transition', where there was some ambivalence, indecision, non-commitment and happenstance but no single major 'shaping event' one way or the other, into or out of science. Respondents could have chosen either route but 'ended up' in one.
(iii) 'Transformative transition', where respondents identify clear moments or periods in their lives, particular events or 'twists of fate' when decisions were arrived at, their choices made, they became resolute in what they were doing.

We need a note here on the UK school system: something that changes considerably regularly with each new political hue in government. At the time of these respondents, young people studied a fairly common curriculum consisting of a range of school subjects at secondary level, from ages 11 to 14. At this point they were offered a choice in

Table 2. Interview participants in terms of 'smooth', 'incremental' or 'transformative' transition into, and away from, science

	Into science	Away from science
Smooth transition	Dennis George Grace Parker	Adam Danielle Greta
Incremental 'wavering' transition	Daisy Jane	Nikki
Transformative transition		Norman Philip

preparation for their Ordinary Level (O-Level) examinations at age 16. Depending on the school, for the next two years they focused on between 7 and 10 subjects, wherein science may have been offered as a single integrated subject, or as separate biology, chemistry and physics. Taking three separate sciences would constitute some one-third of the possible curriculum time at this level, and would already indicate a positive inclination towards science in later study. Success in subjects at 16 would then herald study in the next two years of post-compulsory education to Advanced Level examinations (A-Levels), which act, amongst other routes, as preparation for university entrance. The implication here is that 'science or non-science' can be set fairly solidly within the curricular system as young as an age of 12 or 13.

Table 2 shows the allocation of the 12 interviewees to the 3 categories. The majority of our respondents described their routes as a smooth transition, two as incremental and two as transformative. We consider this distribution in the next section but first discuss some of their stories.

A 'Smooth Transition' into Science

Four of the six scientists interviewed (Dennis, George, Grace and Parker) never really considered doing anything else other than science or maths. The very suggestion that they might *not* do science seems not to have arisen. It is not at all clear in their stories quite how the initial interest and commitment arose, but it seems to have been consolidated around the early age of eight (mentioned by two). These respondents could recall 'mild' transformative moments in their childhood, but these seem confirmatory rather than transformational.

Dennis, for instance, was always interested in astronomy and space flight rather than biology or chemistry. Even as a young boy he was obsessed with space and rockets, and—if there was a (mild) transformative moment then the 1986 appearance of Halley's Comet was a 'confirmatory hinge point for getting into sciences'. Exposure to science-related topics in newspapers, science fiction magazines and an inspirational physics teacher aged from 14 to 18 made him progress easily on a science path. Another mild trigger at the age of 17 occurred when his maths teacher doubted

Dennis's ability, but he took this as a challenge and excelled in the subject. He never had to make extra effort in doing science as compared to other subjects because he was 'naturally quite good at it'. Both his parents were non-scientists; they were unaware of what Dennis wanted to study, and they were motivating but not really influential on his choices.

George found school science to be 'great fun', he was good at it and 'would not even take 20 seconds' to make the decision to study science in school and beyond. There was no particular inspiration for sciences from out-of-school experiences, and he 'purely and simply enjoyed school science experiences'. There were no trigger moments and, like other respondents in this theme, he really appreciated an inspirational maths teacher because he would 'rarely stick to the curriculum; just did what he wanted—and that was super', helping George pursue maths at Manchester University. He believes that 'nothing in this world can make him move from sciences at all'. His involvement in sciences and related fields has helped him to 'understand a complex organisation and how they change and how they won't change'. Now, after 25 years, he has become the head of research and 'you can't do better than that'.

Parker, too, was 'always destined' to work in the sciences. Again this was a smooth transition, and he found all the physics, chemistry and maths teachers inspiring and fairly influential throughout A-level study. He 'grew up in the era of space age; moon landings, computer advancements etcetera', and public interest towards these innovations were very high and built his interest. His (mild) transformative moment came in rejecting medical sciences in favour of the physical sciences: he was put off medical sciences because 'both parents were in medicine'. He 'never wanted to work with patients' and so 'crossed off medicine as an option'. Does he still retain his enthusiasm for science? Working on fundamental science on current long-term projects and working towards achieving 'grand goals' has kept his interest alive. Then he added, 'It's always been my job and therefore, by definition, it's my interest'. Parker perceives that as a scientist his awareness towards everyday science makes him better informed 'so you will be a little more-informed spectator'. He also believes that his full journey in sciences from the age of 15 to 50 was highly positive which has helped him to choose a career and stated, 'I am extremely fortunate. I couldn't have wish for a better outcome'.

Grace's father was a mathematician who ran maths clubs for her and her friends after school, her step-father an engineer, who helped her with physics. When she turned 16 she chose maths because it was 'easy' and a 'lighter subject' as compared to the arts. She studied English at A-level but did not continue with this because she was 'not much good at it as compared to maths'. Grace was clearly influenced by both parents and peers in her decision towards maths studies even though it was 'quite abnormal to be a girl who really likes maths' and mentioned that there were very few girls in her A-level maths lessons. She cannot imagine moving away from maths, and believes that the single most important factor to motivate more young people into maths and sciences will be incorporating relevance from daily life which will make more students to take up science in future.

Smooth Transition not into Science

Similarly, there are three non-scientists who never really contemplated doing science, and their interest always lays elsewhere (e.g. in literature). Adam began to think about subject choices aged 13–14. He was required at school to choose at least two of the sciences, so decided to opt for biology and physics but not chemistry, because he 'hated chemistry'. He stopped studying sciences at the age 16 because he particularly loved English literature and history, much more so than any of the sciences, or anything else for that matter. Why had he hated chemistry so much? The immediate reply was 'MOLES!' and he declared that mole calculations 'completely switched me off from Chemistry'. He was good at maths, continued to pre-university level but, as far as he could see, mole calculations had no conceivable benefit, were utterly and completely pointless: 'Case closed'.

Danielle's home environment was very philosophical not least because her father had studied theology and philosophy and had numerous philosophy books in his study that created a love for arts, music and drama at a very early age, 'so this is where my heart is, I suppose'. Her parents, siblings, nephews and nieces are all artists, and she stated that 'there is obviously no hope for any of us' where the sciences are concerned.

Similarly, Greta, a non-scientist, was not 'naturally inclined towards sciences and didn't achieve high grades in it'. Rather she was fully inclined towards English and Arts. There is no single trigger that turned her away from sciences to take up English, she simply had a 'feeling' at a young age that she was not good at science, she did not work well with the science teachers, progressed without difficulty with her English teacher and decided to choose humanities at A-level and university. Her parents were not influential, 'they encouraged me to do whatever I wanted to do'. So, she was never pushed to study sciences, had no particular guidance as to what to choose and so continued with the subjects in which her interests were stronger. Greta's grumble was that secondary school science entailed a 'huge emphasis on subject knowledge', and any focus on practical activities in the class diminished rapidly in secondary school as compared to primary school teaching and learning. Simply 'not for her'.

Incremental 'Wavering' Transition

The transformative moments for this group seem more marked, more significant but fall short in our sense of being sharply transformative. For example, Daisy had always performed much better in physics and maths than other subjects. Even early in school, she thought she would take a degree in sciences. While her teachers were good, the subject itself was not particularly inspiring: 'I think school science was just school science nothing particularly stands out'. One problem was that she enjoyed music and wanted to combine this with physics, perhaps taking a degree in 'music technology or sound engineering or something like that'. Unfortunately there was no such university degree available at the time. Her (mild) transformative moment came to 'close' her wavering when her teacher organised work experience during her A-level course, planning satellite observations in Oxford for two weeks. The experience was so positive, and she completed the two weeks even though her classmate decided not to continue after the first day. She made up her mind to opt for astrophysics and now Daisy is part of the High Energy Particle Physics experiment, Compact Muon Solenoid (CMS), at the Large Hadron Collider (LHC) at CERN, Geneva: one of two general purpose detectors at the LHC, which has been optimised to search for the predicted Higgs Boson.

Similarly, Jane was always able to do science. Even now she is never bored of it, 'It still gets me up from the bed in the morning'. She completed her doctorate whilst at Imperial College London working on the ZEUS experiment at Deutsches Elektronen-Synchrotron (DESY, the German Electron Synchrotron) in Hamburg, Germany. Like Daisy, she too is an active experimental particle physicist, for 7 years a member of the CMS experiment on the Large Hadron Collider at CERN. Her story, however, demonstrates a sense of puzzlement during the time she was making choices for A-level at age 16. She had chosen three subjects, 'chemistry, because my father was a chemist; physics because physics goes along with chemistry, and maths' (here she gave a shoulder-shrug, no reason given). She declared, 'I didn't like biology even before I was 14. It didn't float my boat (laugh), I was really not interested!' However, she found herself 'sitting on crossroads' at decision time between science and languages, and she was equally good at both. She was sure, though, that she liked sciences more than languages and opted for these at A-level. She soon found she was very good at maths, preferred physics to chemistry and opted to take double maths in the second year of the programme. As a result, she began to look forward to a career in maths. But, then a small twist: the physics teacher pressurised her to enter a 'special examination', Physics S-level and a higher level examination above A-level. She hesitated and there followed an intense argument with the teacher, she was afraid she was not capable of tackling a physics exam at this exalted level. In the event, she relented, sat the special paper and passed. That decided her future to become a physicist. She said, 'After passing the exam my confidence level was boosted up'.

Nikki took physics at A-level due simply to school pressure. She 'hated physics teachers and the physics book' and she opted for maths at university but struggled in the first year of undergraduate studies because of the physics components in the course. Later, she struggled with maths so, when taking a masters' course, and stayed with algebra. She did not find the experience 'worthy enough for undertaking a PhD and so I did a PhD in Maths Education'. These days she enjoys the cooperative, vast and unlimited structure of the working environment in maths education rather than in mathematics itself, and views herself to be moving progressively away from even this contact with mathematics as she becomes increasingly sociological in our outlook.

Transformative Transition

Norman had not questioned his route into science, and he simply took sciences at school and continued to the age of 20, enrolled in a Marine Biology degree. At this point his life took a 'U-turn' because he failed a second-year Marine Zoology examination. He was 'confronted by failure', began to wonder and asked himself the question: 'What do I really want to do? Have I really chosen this wisely?' He was very interested in the history of science, reading popular science works such as those by Steven J Gould, and always enjoyed science fiction. He did not, though, enjoy laboratory work and disliked the idea of working in labs for hours and hours as a scientist. At school his 'sciences friends' were quite influential whereas, at university he made friends with English students. He took 'time out and, after 3 or 4 years of self-examination' he began a degree in English Literature and Philosophy. At present, he lectures in English using science fiction in his own writing. He is not, he says, 'completely science illiterate but my limits are to read and write science fiction and understand the issues published in newspapers'.

Philip was 'just expected to do science', reflecting his subject choices at the age of 14 and 16: maths, physics and chemistry. He was never very sure, always in a state of 'continuous nervousness' but with a 'sort of underlying pressure from my father to do sciences'. He attended a technical school where there was more direction towards science subjects, and a prevailing sense that only the 'weaker' students opted for Art subjects. He wanted to be with the 'trendy and clever people but struggled to the limit', failed physics and chemistry exams at 17 and, at the same time, discovered his love for music through a beautiful piano at school. Without any formal piano training he would play the school piano in his free time. After his failure in science exams, the deputy principal of the school asked him 'What was it Philip? Too much music? I said Yes and he said, right you can do music this next year. Brilliant! He saved my life'. As a result, he relinquished chemistry, took up music in the second year of the programme. 'Unbelievably, I got B in maths and B in music even after studying only one year of Music.' He continued with maths in his first year of university (B is a good grade), but had 'escaped the sciences'. School science was taught in a very 'old-fashioned way … it was certainly not a question of nurturing talent'.

In this category of transformative transition, Norman did not directly point to teachers as a main factor for transformation, but Philip did. Both indicated the involvement of peers as quite influential in their lives: Philip perceived it as peer pressure, Norman as peer support. Neither sets of parents went to university but wanted their children to study further and were influential in directing their sons in choosing career—Norman's father being quite demanding.

Discussion and Outcomes

Narrative functions to shed light not only on the importance of choices and occurrences in a person's life, but also in tracing their orientations to their source and understanding how they developed. According to MacIntyre (2007, p. 216):

> Man is in his actions and practice, as well as in his fictions, essentially a story-telling animal …. [however] the key question for men is not about their own authorship; I can only answer the question 'What am I to do?' if I can answer the prior question 'Of what story or stories do I find myself a part?'

Our stories provide the context within which we take intelligible action; they tell us where we come from so that we can understand who we are and where we might go. We have been struck by this small collection of stories, not least by non-scientists' perceptions of science. As Wolpert and Richards (1988), Freeman (1991), Latour (1999), Loehle (2010) and Dawkins (2013) each points out, there are many forms of science and many ways to think of 'being scientific', of science 'lives' or careers. An interest in genetics could take a student into agriculture, biomedical work or the pharmaceutical industries; applied sciences are evident in forestry, mining geology and veterinary science. In various fields, in various roles, scientists need skills and dispositions towards working out-doors, in industrial complexes, as part of a large team, in solitary conditions, being abundantly unorthodox and/or creative or methodical and organised, being highly mathematical, computer literate and/or communicative orally and in writing. While it is true that some of the families involved had 'science capital', or 'non-science capital' (Archer et al., 2014), this is not so in all the stories and there seems to have been a mix of parental influences, from tight, close interest to 'do as you please'.

The three 'wavering transition' participants in our study showed fluctuating choice patterns at age 16, the 'pre-university crossroads', and made decisions on science/non-science directions by carefully judging pros and cons in terms of employability and likely success. The two 'transformational transition' participants showed similar patterns until early university, and both of these then moved out of and away from science. For 7 of our 12 respondents, however, the science/non-science die seems to have been cast at a very early age and seemed largely unaffected by circumstances and events after that point. The natural inclinations, the inherent preferences, of these majority of 'smooth transition' participants seem to have been abundantly convincing at an early age—eight was an age quoted.

At one level there is an understandable wish to see people making life and career choices entirely through rational and reasoned means. It is also fully understandable that they do not. Bettman, Luce, and Payne (2008) and Simonson (2008) discuss Behavioural Decision Theory (Colman, 2009) and accept that people's preferences are actually constructed at the point when decisions need to be made, rather than retrieved from a personal master list of likes and dislikes stored in memory. That is, preferences are said to be created during the process of making choices, and stable 'natural' or inherent values often play only a very limited role. We can see some elements of this re-construction in the responses made by our 12 in terms of life satisfaction, peer values, parental influence, schools and teachers, academic success, self-efficacy, among many others. However, by far the majority of our respondents make it clear that their natural inclinations, their inherent preferences, were *not* determined by immediate contextual factors—but derived from a long-standing persistent drive that resided within them (Berridge, 2003; Simonson, 2008). Lichtenstein and Slovic (2006) see this as self-evident that people commonly have pre-existing preferences, likes, dislikes, ways of behaving, acting that are (largely) independent of context.

Some preferences in life may seem superficial, such as choosing light-weight laptops and reliable cars over alternatives, or disliking liquorice without ever having tasted it.

From our small-scale study, we call attention to the fact that people do exhibit sturdy non-superficial, ingrained, preferences for or against things they have not yet experienced: being a dentist, undertaking lab analysis, or making a career in horticulture. Not that it is clear exactly what does initially trigger an inherent interest. Often tacit, quite intuitive, it is likely to be affective: strong feelings that direct future action, such as liking or disliking science (Alsop & Watts, 2003). As Loehle (2010, p. 13) notes, it can be wholly irrational, 'some individuals find themselves fascinated with ants or fossils or birds from an early age. Why? I have never seen an explanation for this early attraction to scientific subject. For me, at the age of 7, it was trees'.

Our future research and interventions lie in two main directions. First, there is a sense that, if the die is really cast at age 7 or 8 for the majority of people, then science education after that age is largely fruitless in terms of persuading people into science lives: this is simply not going to happen regardless of what takes place at home or school. There is need then to explore the pervasiveness and, where possible, the roots of these natural inclinations, inherent preferences over a much larger population and in different cultural contexts, since this will give force (or not) to the notion that being 'sciency' is bred in the bone. Second, science education could profitably be directed at the 'wavering transitionals', ensuring that all doors are kept securely open to allow migration from being non-sciency into science—in its many guises. Again, research and intervention need to focus on the many ways in which we can retain open-mindedness in these floating voters.

This research is limited by the nature of autobiographical reconstruction, and we are aware that peoples' accounts of events may smooth out perturbations that may have been present at the time but are lost in the re-telling—what Piaget (1929) said of young children, that they are prone to 'romancing' their answers. The age of eight may simply be as far back as people can remember. This problem of legitimation of representation, whether researchers can directly and faithfully capture lived experience, is not one to be answered here. Our direction now lies in exploring the transformative issues with a much wider sample and, where possible, tracing back to 'early orientations' what might have been those key influences that shaped initial attitudes and direction.

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