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# Undergraduates talk about their choice to study physics at university: what was key to their participation?

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# Undergraduates talk about their choice to study physics at university: what was key to their participation?

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***Background:*** The research on which this article is based was commissioned because of concerns about perceived shortages of willing and able young people choosing to study physics at university.

***Purpose:*** This article reports on first year physics undergraduates' narratives of why they are studying physics and uses these narratives to identify reasons for their choice.

***Design and method:*** Narrative-style interviewing with a purposive sample of first year undergraduates yielded data that revealed complexities around decision making, including choice of university course. Analysis of the texts was informed by psychoanalytical notions rooted in the work of Sigmund Freud. These psychoanalytical notions were used both in generating the interview data – the undergraduate volunteer interviewees were conceptualised as 'defended subjects' – and in analysing these interviews in order to conjecture how unconscious forces might figure in young people's decision making.

***Results:*** After analysing the interviews with physics undergraduates, with respect to the question 'why are they reading physics?', the claim is that identification with a key adult is an important element in an individual's participation. On the other hand, we discerned no evidence that experience of the sorts of innovation typically designed to increase physics uptake – for example 'fun projects' or competitions – had been key with respect to a desire to read physics.

***Conclusion:*** Attempts to recruit more students to university to study physics should note that a young person who identifies with a significant adult associated with physics, typically a teacher or family member, is in a good position to believe that physics is a subject that is worth studying.

**Keywords:** physics; participation; higher education

## Introduction

> First, the instinct of mimesis (imitation/representation/identification) is implanted in man from childhood, one difference between him and other animals being that he is the most imitative of living creatures, and through mimesis learns his earliest lessons; and no less universal is the pleasure felt in things imitated.
> (Aristotle: Poetics, Part IV, translated by S. H. Butcher http://classics.mit.edu/Aristotle/poetics.mb.txt)

> I don't know if it's relevant cos it's not to do with education as such but my Grandpa, he helped a lot because when I went to visit him in Spain we went for a walk and he was telling me about the stars and about the earth rotating and it's all these new

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> things, it was like, wow… I didn't see him often because he's lived in Spain since I was about that age [10 years old]. It was just a couple of one offs put together… he is a very practical man, very logical and I don't know what he did before he retired, but he obviously has an interest in it [physics]. I don't know if it's as big as mine now, but he definitely enjoyed teaching it to me for no reason whatsoever, he just decided to teach me.
> (Benjamin, University A, reading physics with theoretical physics)

> The unconscious is attraction. Its qualities, pressures, aims and objects, associated with gratification at all costs, inevitably exchange the problem of judgement for the interdictions of its own authority.
> (Deborah Britzman 2011, 127)

### *Reasons for relevance*

In 2007 the Economic and Social Research Council (ESRC) in the UK commissioned research in science and mathematics education (ESRC 2006) in order to supply evidence for policy proposals that would provide a technically proficient new generation. This interest in finding out what would attract well-qualified young people to study mathematics and physics came from economic modelling (HM Treasury 2004) that predicted that current post-16 participation rates in these subjects were not sufficient to sustain desired economic growth. At the same time, the question as to what would attract young people to study mathematics and physics is of interest in many other countries (OECD 2009).

One of the projects commissioned at this time was 'Understanding Participation rates in Mathematics And Physics' (UPMAP). This project collected data over a three-year period, 2008–11, within three 'strands'. Strand 1 collected approximately 30,000 student questionnaires from schools throughout the UK; Strand 2 collected interview and observational data from 12 schools from three different regions in England; Strand 3 collected narrative interview data with 51 first year undergraduates from four UK universities who were qualified to read physics or mathematics.

The focus of this article is on the seven Strand 3 physics undergraduates interviewed. We aim to answer the question 'Why are they studying physics?' through analysis of their interviews and to offer some principles based on this analysis relevant for policymaking. The quotation from Benjamin above indicates something of the type of data that the interviews provided: the narrator goes off on a tangent from what he believes is being requested ('education') and reveals a source of inspiration. Attention to evidence in the narratives of the subliminal, that is, of material that is below the threshold of conscious awareness, is central to our analysis, as is being alert to interpretations of that which might not be said directly in order to get a picture of why these young people opted to study physics.

The purpose of the research reported here was to find evidence for reasons for participating in physics from those who had actually made the commitment to study physics at university. We invited first year undergraduates to come for an interview, in part because we conjectured that they might have a fresher take on how their decision had taken place compared with those further along in a course of study.

This article contributes new knowledge to the research field in two respects, one to do with methodology and the other to do with our findings. Methodologically, we demonstrate that an approach, in terms of both data collection and analysis, that is sensitive to unconscious forces has much of value to contribute to studies about participation in physics (and probably other subjects too). In making this claim, we therefore build on work that has already been undertaken in mathematics using such approaches (notably Black, Mendick, and Solomon 2009; Bibby 2011). Our main finding from analysis of the interviews is that *identification with people* rather than *engagement in physics projects* played a key role in students continuing with physics, once the subject was no longer compulsory, through into higher education.

### *Literature review of research on 'participation' in studying physics*

An academically successful, university-bound, young person being educated in the UK has choice points at age 15 or 16 when they choose their specialist subjects to study for university entrance, and again at around age 17 or 18 when they actually choose a subject to do at university. The focus in this article is on the second of these choice points. However, one cannot choose to study physics at university without having studied physics up to the age of 17/18. In 2012 the number of students taking physics at A level[1] was 34,509 which was 4.0% of the total number of A levels that year (JCQ 2012). Despite the 2012 figure being a rise from a local minimum of 3.4% in 2006 (JCQ 2006), it is still lower than typical figures in the 1980s (Sainsbury of Turville 2007).

To combat this low rate of participation, both in-school and out-of-school projects and strategies have been implemented by government, companies and educational charities. Examples of in-school initiatives include: producing more engaging A-level curricula (e.g. Advancing Physics and Salters Horners Advanced Physics); making the subject more attractive to girls, as girls only account for about a fifth of A-level entries; improving school laboratories; and increasing the supply of specialist physics teachers (e.g. through Subject Knowledge Enhancement courses, Teaching Agency 2012), as approximately one in four 11–16 state schools in England has no specialist physics teacher (Moor et al. 2006). Out-of-school initiatives attempting to increase post-16 participation in physics include visits by students to places where physics is used (Parvin and Stephenson 2004; Swinbank and Lunn 2004) and competitions (e.g. The British Physics Olympiad, F1 in Schools). When such initiatives designed to increase the numbers of post-16 students of physics do evaluate their projects, the usual method of evaluation is to ask students to complete a survey – typically with prompts about enjoyment – rather than to engage with them personally or to track their participation in physics over some years (Johnson, Riazi-Farzad and Reiss 2009).

Furthermore, an extensive review of the literature on attempts to increase female participation in physics undertaken by Murphy and Whitelegg (2006) concluded that there are no 'quick fixes'. For both genders, Angell et al. (2004) showed that 17–19 year-old students in Norway find physics interesting but difficult, hard work and formalistic in nature. Duit, Niedderer, and Schecker (2007) concluded that physics learning 'includes difficulties that are due to the particular nature of physics' (2007, 599), such as a high degree of abstraction and mathematical modelling and the fact that physics is often seen as counterintuitive (Lyons 2006). They noted the importance of these findings given that 'emotional factors play an essential role

in learning science' (Duit, Niedderer, and Schecker 2007, 607). An earlier German study showed a considerable discrepancy between students' interest in physics and the kind of physics instruction practised in the physics classroom (Häussler and Hoffmann 2000; cf. Krogh and Thomsen 2005). Hazari et al. (2010), in a study of US colleges and universities, found that students' 'physics identity' strongly predicted their intended choice of a physics career. Physics identity was found to correlate positively with a desire for an intrinsically fulfilling career and was positively predicted by several high-school physics characteristics or experiences, such as a focus on conceptual understanding, real-world or contextual connections, students answering questions or making comments, teaching classmates and having an encouraging teacher. Furthermore, there is increasing evidence that such interest in science in general or physics in particular starts early in life (Maltese and Tai 2010; Archer et al. 2012) and may require a 'significant person', such as a teacher or parent, to be successfully fostered (Sjaastad 2012).

In short, post-compulsory participation rates in physics are low and are seen to be low from the perspectives both of many governments and of many students who find that their school physics fails to connect adequately with their interest in the subject. Despite many engaging projects with positive evaluations, there has not been sufficient increase in physics participation. The lack of success of the investments is puzzling, which is why we analysed the subset of our Strand 3 UPMAP interviews with undergraduates who had made a commitment to studying physics as their degree subject, in order to gain a sense of what had informed their choice.

### *Theoretical framework*

On questionnaires or in structured/semi-structured interviews, standard 'reasons' presented by students for their choice of subject of study include 'I'm good at it', 'I enjoy it' and 'it will help me get a good job'. Strand 3 of the UPMAP project aimed to complement such readily available responses in typical student discourse with narrative interview data. Following Hollway and Jefferson (2000), the interviewee was theorised as a 'defended subject' who may:

- hear a prompt or question in a way not intended by the interviewer
- protect themselves by 'investing' in ways of talking
- not understand why they feel things they do
- unconsciously disguise some feelings (adapted from Hollway and Jefferson 2000, 26).

This conceptualisation of interviewees as 'defended subjects' relies on a theoretical foundation due to Sigmund Freud, who posited the existence of unconscious forces that operate beneath conscious awareness (Freud 1911/2005). While there are many acknowledged manifestations of the unconscious (Frosh 2002), 'defence mechanisms' (e.g. 'denial': 'it's not me!'; or 'projection': 'it's you!'), are related to the conceptualisation of 'defended subjects' associated with this type of data, i.e. narrative interviews. Although there is a sense of negativity that surrounds the word 'defence' in everyday language, this is not the case in psychoanalytical contexts, including the discussion here. Melanie Klein's development of Freud's theory of defence mechanisms, based on her work with very young children, showed that defence mechanisms are a central part of mental development; mind comes into

being from infancy onwards by employing defence mechanisms and coping with consequences of such defence of the self (Waddell 1998).

Within the UPMAP project, part of the data analysis included locating useful psychoanalytical notions related to the 'defended subject' methodology to help answer the specific question being asked of a given cluster of data. In the cluster of data that consists in all our interviews with physics undergraduates, where the question to be answered was 'why did these young people choose to study physics at university?', the notions we have found to be useful were 'identification' and 'projective identification' – these will be introduced presently – whereas, for example, in Rodd, Reiss and Mujtaba (in press), we employed the notions of 'good enough' and of 'splitting' and in Rodd and Silverman (2011) the central psychoanalytical term used was that of 'states of mind'. The theoretical framework based on conceptualising our interviewees as 'defended subjects' provides many psychoanalytically informed constructs that may be used to answer our research questions.

### *Identification and projective identification*

The theoretical notions of 'identification' and 'projective identification' are associated with Kleinian object-relations psychoanalysis (Waddell 1998) and have somewhat different interpretations in post-Kleinian thought (e.g. Young 1992), discussion of which is beyond the scope of this article. The term 'identification', initially understood as in ordinary language, indicates that the individual maps him- or herself on to a significant other, for example, mother, father or teacher. Identifications develop from infancy and an individual may not be aware that unconsciously he or she is identifying with another but, clearly, some identification with other people is a part of every person's normal psychological development. 'Projective identification' is also a normal psychological function, but unlike 'identification', necessarily has its roots in unconscious mechanisms of communication. One of the standard defence mechanisms is to 'project' that which cannot be coped with into another, so that that other person experiences emotions to do with the uncomfortable feelings of the first person. For example, the angry child shouting at their parent might distress the parent. The parent will deal with the child's projected anger in some way – shouting back, soothing, ignoring. 'Projective identification' occurs when that other person, in this case the parent, processes the projected feeling that, for the original person, in this case the child, is uncontainable, such that the child feels as the parent feels, that is, identifies with the parent into which they have projected. Good or bad, welcome or unwelcome, projective identification goes on beneath conscious awareness. In Robert Young's review of the concept, he notes that projective identification underpins both empathy and narcissism 'it is part of an epochal change in how we think about knowledge and about nature, human nature and human relations' (Young 1992).

The next section of the article, 'Methods', includes a presentation of methods used to collect data in the form of narrative interviews and methods used to analyse these, and continues to explain identification and projective identification through illustrations of our analysis of interview data. The Methods section also includes discussion and exemplification of our analysis of those narratives. Following this, in the Results section, the claim is developed that a identification with a key person representing physics is important to all our undergraduate physicists. Discussion and implications conclude the article.

## Methods

Undergraduates were invited (through e-communication from their university) to come for a conversational interview to talk about their choice of subject of study. We interviewed selected individuals on a single occasion in order to obtain a relatively fresh and uninhibited take on how they got to be studying their subject at university. In order to facilitate their talking freely, we interviewed within a safe space (a comfortable room, conveniently located at or near the undergraduate's university) and maintained a positive atmosphere of interest in the interviewee consonant with a 'narrative' approach to interviewing (for more details see Rodd, Mujtaba and Reiss 2010, Reiss et al. 2011). The interviewer facilitated a very open-ended interview, encouraging the interviewee to talk about their subject choice and how they related to their subject. The data generated from this encounter were an audio file (later transcribed as a text file) and brief field notes about the undergraduate's demeanour. Each interviewee was given a £20 book token and was invited to give feedback on the experience of the interview; all who gave feedback were positive, the most frequent type of response was that talking to someone helped them to understand themselves better, which they appreciated.

Interviews were analysed by a team (the three authors and a graduate student). We studied the transcripts, initially individually and later in discussion between us. For this particular subset of interviews we held in mind the research question 'why did these undergraduates opt for physics?' and marked indicators of attraction to physics within their narratives. The aim of the narrative interview method is to 'encourage' unconscious forces to leave their trace in language, for, in Freud's words, 'How are we to acquire knowledge about the unconscious? We know it of course only after it has been transformed or translated into something conscious' (1911/2005, 49). These language traces then permit us to analyse the transcripts; this means that, in common with standard psychotherapeutic and psychoanalytical methodologies, we focused particularly on apparent contradictions, on passages where the interviewee seemed to feel deeply about something, on hesitations, on slips of the tongue and so forth. Such instances are signs for an analyst (used both in the psychoanalytical and social science research senses) that there may be something here that is worth attending to and might be developed into a theme or conjecture. For example, consider the following extracts from Zac's narrative:

> (1) Physics started to interest me because it made sense, we had a good teacher that would tell us about, he'd tell us that he wasn't telling us the full truth. And then he'd go into it after class sometimes and he got me interested in physics. He'd write stuff down but then he'd sort of throw in quietly situations where it doesn't work … he definitely taught us that there was a lot of interest and stuff once you got into it. So that's how it started. It's definitely why I did physics …
>
> (2) It's just because he's your dad, isn't it? You kind of want to do what he did. Never thought about it properly.
> (Zac, University A, reading physics and mathematics).

In extract (1), at face value, Zac gives a reason for doing physics from educational discourse: 'it made sense', 'there was a lot of interest', but there is more that can be discerned with a psychoanalytical lens: the teacher transgresses his role ('after

class', not 'the full truth', 'where it doesn't work'). In extract (2), hitherto unconscious feelings are revealed in that Zac relates that his father 'did' physics but (from later in the interview we find) he was mostly absent during Zac's adolescence; the man who was the physics teacher was present, playful and intellectually stimulating. When Zac talks about physics making 'sense ... [because he] had a good teacher' he is telling us that his cognitive competence when it comes to studying physics is due to the teacher with whom Zac is identifying and thinking alike (Waddell 1998, 213–217). Zac's narrative indicates the centrality of his teacher and is one example that gave rise to the conjecture that *a young person's participation seems to be linked with their identification with a key adult who represents the potential field of study.*

Location of evidence of unconscious forces in texts is a contentious methodological issue. If one analyser points to a selection of text that he or she reads as evidence of unconscious forces leaving their trace in language, it does not follow that the next analyser or another reader will agree. The process of seeing in text the remnant of another's psychic processes cannot be an entirely objective process reducible to codes or categories; it is interpretive, so interpretations are results' intermediaries. The following two extracts from the interview with Gita exemplify how small the language traces can be that the research team, both individually and collectively in this case, did interpret as evidence of unconscious forces:

> (1) I wanted to do something that, I wanted a degree that, if later on in the, if when I'm older and stuff and something was to go wrong, I've got a good degree to fall back on if anything was to happen. I thought physics, em, I went to my careers advisor and I read a lot on the internet and it said that physics, it opens a lot of, it opens a lot of em, opportunities and stuff.

These reasons (the esteem value of a physics degree and the opportunities a physics degree provides), though rather uncomfortably voiced, are both rational and standard. However, later on in her interview, Gita repeats the little phrase 'back on' ('...' indicates that text has been cut):

> (2) My mum got married when she was 19, … my mum was like, now she does regret that she didn't do anything cos she thought to herself, you know, I'm not that stupid I could have done something so then she wanted to part, she wanted us [Gita and her brother, one year older than her] to do something for our future cos when we were young, when my parents came here [from India as newlyweds, Gita was born in the UK] and we were really poor and we didn't have much, so Mum's like, I don't want you to be the same when you're older, I want you to have some sort of foundation that you can go back on if you've got an education you've got everything in this world. Well, not everything but.
>
> (Gita, University D, reading physics)

The phrase 'fall/go back on' belongs to Gita's mother and Gita uses it as her own. The interpretation is that Gita's mother's projection into her daughter is carried unconsciously by Gita, who projectively identifies with her mother and, when prompted to talk about coming to read physics at university, Gita's mother's desire for her (only) daughter is what emerges from Gita's narrative. Thus, we have a different angle to support the conjecture *that a young person's participation seems to be linked with their identification with a key adult who represents the potential*

*field of study.* In Gita's case, her mother's representation is through the mother's desire 'to have done something' rather than actually being a teacher or physicist and, as will be presented below, Gita also had a significant physics teacher.

## Results: participation in physics is supported through identification with key adults

With respect to the question 'why did this young person choose to study physics?', all of the seven physics undergraduates' interviews indicated the hitherto unexpected centrality of the importance of a significant adult representing physics. This interpretation came not only because of what the interviewees said – although each referred to physics being personified in some sense – but also because of what they did not say: none of the physics undergraduates suggested that an intervention,[2] such as a project, was key to their participation. To further communicate the claim that *a young person's participation seems to be linked with their identification with a key adult who represents* physics, we present the case of Eleanor in more detail.

### *The case of Eleanor*

Eleanor is the older of two sisters and was brought up in southern England. Her father was originally from Scotland and had been in the army before working in a bank; her mother had worked in a bank and was now in public relations. Eleanor went to a maintained selective school after having moved primary schools in order to better her chances of success at the 11+ examination. Eleanor took physics, mathematics and English at A level, achieving grade A in all three, and German AS level. She studied mathematics A level in a 'further maths' class, although did not take the further maths examination. At the time of her interview she had completed her first two terms of studying for a four-year Master's level degree in physics at University C.

The following extracts from the transcript of Eleanor's interview constitute about a fifth of the text, narrated chronologically. These sections have been chosen because they illustrate aspects of her relationships with her father, her GCSE[3] physics teacher and her A-level physics teacher, as well as indicating the high-achievement and wide-choice culture in which she was raised. The rest of the interview included more biographical information that did not strike us as particularly significant with respect to her subject choice.

> E: I [went to] a grammar school so I have always had to do sciences and languages. I chose to do history, art and German as well as French at GCSE on top of the ones we had to do… I was going to do English literature, German, history and physics [A level] but then I always thought I was going to do English literature at university.

> E: I always found [physics] fascinating from an early stage, space and particle physics, and I read books about it for a long time because my dad was interested in it so there was books around the house and that helped me to develop my interest.

> 4. Is your dad doing anything with physics?

> E: No he isn't, I mean he left school at eighteen, never went to university, worked at a bank but he has always had a casual interest in it. He has got all the Stephen Hawking books and it was always a well-respected thing in the house, so I took that

> purely out of interest and then my parents persuaded me if I am going to do physics you may as well do maths and you have got the option of taking it somewhere because if I didn't have maths A level I couldn't do anything with it but doing maths and physics and also having German and English would give me the choice to go either way and so I did that. I am not that interested in maths but it was doable and then as I went through the AS levels I started thinking about my university choices and then I started to move away from the English idea and partly because of job prospects, it was always going to be easier to find a job with a physics degree than a degree in English literature so that was a factor and I thought it would be more interesting a girl taking physics than a girl taking English literature because so many people do it and I thought it would be more interesting so in the end I dropped German and kept maths and physics and did English out of interest so I kind of switched over.

In this extract, Eleanor weaves the 'rational choices' discourse in with her unself-conscious communication of the centrality of her father to her. His interest becomes her subject. His lack of physics education is repaired by her choice of university course. She permits herself to be positioned through her choices (maths rather than history A level) both to be him and to surpass him. In discourses available to young women like Eleanor, not only is 'job prospects' available but also the 'specialness of being female'. Nevertheless, Eleanor 'knows' that the appropriate reason for 'choice' in her society is 'interest'; so, while English remains 'of interest', physics – or, perhaps with unconscious conflation, her being a 'girl' in physics – is positioned as 'more interesting', and thus 'sensible/rational' to choose:

> I: So what do you think of your future now?

> E: I am not to sure to be honest, I still like writing and that sort of thing so there was always a possibility at the back of my mind about writing about science … I feel like I have a lot of options with it. I don't see myself going further into research. I am doing a master's course for the fourth year in physics and I can't see myself taking it any further.

That Eleanor 'can't see' continuing with physics beyond her degree is an important issue with respect to the education of future scientists. In particular, given the recent increases in A-level physics participation outlined above, it behoves policymakers to attend to the stories of young women like Eleanor who, while studying physics at university, do not anticipate taking it further as a career. In the next extract, we read of Eleanor's GCSE physics teacher who, together with her father, was key to her studying undergraduate physics. This raises the hypothesis about the imagination of future identities: father and school teacher, representing home and school, were sufficient to get to undergraduate level, but, at the time of our interview with her, Eleanor had not found a relationship with someone who represented professional physics practice and it seemed to her that that mattered:

> I: Going back, you said you had a very good teacher at GCSE, what was good about him or her?

> E: She was very good at making it interesting, she made the lessons fun and I suppose I got on with her on a personal level so that helped and she was very encouraging, she wouldn't tell you stuff directly, she would hint until you managed to work it out yourself, which I found I enjoyed learning like that and I found it worked well for me and she was fairly strict but fair, she encouraged people a lot and made it very

> interesting. I suppose she did encourage me to take it further, she was always quite supportive.
>
> … but she wasn't my A level teacher but I saw her a lot during my A levels because my A-level teacher was pretty bad.
>
> I: Why was he or she bad?
>
> E: He was bad because he didn't know my name for maybe nine months and he didn't pay any attention… it got to a point where I wouldn't go to the lessons sometimes and would teach myself from the books, to some extent I taught myself … I got my old teacher to write my references, he was just useless but I was able to keep up an interest regardless.
>
> I: So personal contact is important for you, isn't it?
>
> E: Yes I think so, I suppose to some degree I am motivated if I want to impress someone so if there is someone around who cares how well you do then yes it means a lot.
>
> … It's one of the things which I find about university difficult is that no one really cares and I really have to motivate myself but I had to do that [at] A level anyway, yes I did find that very helpful and she expected me to do very well so tried my best to do very well.
>
> I: What about your family?
>
> E: … When I was going to do English they were happy with that and willing to support me, I think my dad is very pleased I have changed my mind because he has always loved science and he is very interested in what I am doing now and he finds it all fascinating which is nice because when I come back I tell him I am doing this, this and this and he would say 'Amazing' because he never really got the chance to study it as he came from a very deprived background and left school at eighteen and joined the army so he never really had the chance to pursue it further and he said if he could go back he would and he is very happy with what I have done and at the same time if I had done something else that would be fine.

In this part, which starts off with discussion of school and teachers before returning to the father, what is notable is her story of the A-level teacher who never becomes a significant figure for her. It seems that the GCSE teacher, who is both role model and friend, as well as instructor, is sufficient for Eleanor to sustain her imagination for a physics degree, but not career.

While it is not possible to observe 'unconscious forces', it is possible to track the traces in language that they can leave. And it is important to note that multiple explanations of participation can be offered for any given student's story. As we said in the Methods section, young people readily explain their choices through standard discourses of achievement, motivation, utility, etc. For example, the explanation of Eleanor's participation given above is in no way incompatible with the 'face-value' interpretation that she had sufficient intrinsic interest herself to keep her motivation up, despite having a bad teacher. These are both valid conclusions. What we are offering is a further dimension on reasons for participation, not a denial that students having good motivation are well positioned for participation, for, after all, where does motivation come from?

***Summary from results with another extract from each of Zac and Gita***

In every case we have of an undergraduate reading physics, their narrative tells that an adult has been significant in their becoming a physics undergraduate. Not peers, not enrichments, interventions or events, but some adult person or people. And the route is not predictable. For example, Zac's narrative reveals the interplay of projective identification between teacher and student: the teacher that 'over-gave' is characterised as 'good' but not followed. And the teacher who made him do things 'he didn't like' was appreciated after the teaching was taken in:

> Zac: I didn't like chemistry at all. She was a good teacher. She spoon fed everything to us like they do in school and my physics teacher wanted to get us into university so he didn't give us everything he made us go and look for it, which was worse. I didn't like that cos I like having everything there so you can just read it sort of thing, but he did sort of make you and look. You needed it cos you had to get used to university like I'm glad I did it now. I'm glad he made us do it now. But at the time I would have preferred it given to us.

The extract from Gita's narrative, below, illustrates projective identification: Gita projects the 'bad' 'he didn't think girls could do physics' back to her physics teacher and together with his subsequent attention to her, Gita identifies with the 'brilliant' part of him, supporting her continuing to study physics at university:

> Gita: When we first met him I thought he was really arrogant and I used to think he didn't think girls could do physics. I thought that. I think that was one of the reasons for thinking, I'm going to show you one day, I'm going to do a physics degree … he obviously did a degree in physics and he did it at Royal Holloway but he's doing a PhD at Cambridge, so everyone was like, wow and he was like the smartest teacher in the school. So, everyone, I, everyone liked him, everyone did look up to him and you could talk to him about anything and he was really, really intelligent. He knew stuff about economics, everything. You ask him a question, he was like your walking talking encyclopaedia. So, he was really brilliant, he gave me help with em, your UCAS and personal statement. What to write, what to say in your interviews and stuff.

This teacher is an 'emotional figure; he stands in for the parental and cultural authority' (Brtizman 2011, 127) that possibly Gita's 'really poor' and recently emigrated parents did not have. This teacherliness is not achieved by every instructor a young person faces. Eleanor's A-level physics teacher was not an 'emotional figure' for her.

The undergraduates' imaginations (conceptions) as to the nature of physics are internalised from these other, more mature, adults. And these relationships can be varied and interconnected, as we have indicated. For Zac, Gita, Eleanor and Benjamin a key person that was central for their relationship with physics was, respectively, his (male) physics teacher and his father, her mother and (male) physics teacher, her father and his grandfather. Of the remaining three physics undergraduates interviewed, Jack (University A), Samira (University C) and Nasrine (University D), analysis of their interviews revealed their key people were his father, her sister and her (male) physics teacher, respectively.

An open query is whether such a key person need not be known personally (like father, teacher or older sister) but the identification can still exist in the imagination. For example, television science presenters (e.g. the 'Brian Cox effect'), just like film stars or popular musicians, can excite adolescent fantasies and become 'emotional figures'.

## Discussion

Projects and other interventions that promote engagement in physics are important in getting young people over the threshold into a physics degree course and helping them to have confidence in their abilities. Some of our interviewees who were not studying physics at university, despite having the requisite qualifications to do so, gave examples of physics-relevant projects (e.g. flying with the RAF, contributing to product design in industry, going to the Olympic site) that did not facilitate their participation in physics. Did the enthusiasm generated by the fun of the project wither in these cases because a human-based identification had not been established?

Many, perhaps nearly all, young people in UK schools are positioned to choose and thereby consume educational products. This contrasts with practices in cultures where children are specifically inducted early in life into their role. In such cultures, choices are few. For example, in Mali, musical families have been producing musicians for many generations. In contrast, while in the UK and other modern societies (Schreiner 2006) musical families do produce musical offspring, opportunities for a career rarely depend on music alone; music is a cultural artefact and only a very few – deemed quite exceptionally talented (and needing to be particularly dedicated) – earn their living through music. In terms of livelihoods within UK contexts, farming still has something of a traditional family connection. However, where once a modest farm would have supported an extended family in work, within the last 50 years family farms support only one farmer, with other adult members needing to work elsewhere. This can cause tension for those for whom farming 'is in their heaf': there may be a family responsibility or commitment to having an adult role on the family farm but many children of farmers are uprooted whether they choose to be or not.

Projects such as UPMAP are part of society's defence against the loss of old relationships with the arts, with crafts or with the land. Current discourse assumes that human beings' adaptability can be exploited so that people never experience a connection with music or land over generations, but that from early childhood choices are presented so that flexibility is a virtue, multi-tasking is a skill. How can young people be turned into physicists, mathematicians or engineers when there is no identification? Given the discourse of life-designing in economic-driven societies, can we reckon on children following in their parents' footsteps? Even the nature of the work of scientifically technical people is such that it is done away from a child's eyes. So science is double damned: more scientists are 'needed', yet the children of scientists are not generally drawn into practices through 'legitimate peripheral participation' (Lave and Wenger 1991). The new generation of participants has to be taken from elsewhere. Facilitating traditions is not a significant part of UK education policies, although – because many professional parents do position their offspring for professions such as law or medicine – policy discourse does address widening participation in these fields. The issue of the design and implementation of a curriculum that is flexible enough to support traditional livelihoods, while not unduly privileging insiders and while retaining a young person's entitlement to compete in an international field, is a challenge to be addressed. However, there is a paradox at the heart of current discussion around choice and participation: as a young person, one 'should choose' what is one's 'interest', given at least a modest skill, but as policy, those who are scientifically capable 'should choose'

science, technology, engineering and mathematics (STEM), if national or collective interests are to be met. So while scientifically capable young people should choose STEM because it is in the collective good, at the point of choice – as current discourse and policy do not include collective responsibility – they must believe that it is to their individual advantage.

## Conclusion

The principal finding that emerges from our analysis of these physics undergraduates' narratives is that a young person comes to be studying physics because of his or her identifications with key people. Is this different from those reading humanities subjects, say English or history? A conjecture is that there may indeed be a difference; in humanities, such as English or history, a deep involvement in the subject is likely to include favourite characters from literature or the past. A relationship is made with these characters. They become someone to think through within the imagination; the mind of the other is taken in and used as part of mental, even spiritual, growth. This process of taking in another's mind may relate to social aspects of learning in situations where there is a group attraction to characters – whether particular teachers at school or media celebrities; the group reinforces and helps to construct the process. In what sense can this character-creation happen in mathematics or the sciences? When do Fermat's Last Theorem or black holes become character-like? The strength of Andrew Wiles's emotional connection to Fermat's Last Theorem is evident in the BBC's 1996 *Horizon* documentary that followed his relationship with the Theorem; however, this exquisitely personal relationship with a theorem is unusual. More unusual than, say, personifying Heathcliff or Elizabeth I and taking these literary or historical characters into oneself as people to think through, meaning that in some sense their minds are introjected in imagination and through their feelings being felt, something of their approach to the world is taken on, as we claim our undergraduate physics students have done with their key people. In Britzman's words, 'Identifications are the earliest form of emotional ties. It is how the world is taken inside' (2011, 110). Our claim is that the 'physics world' – as a place to journey – is typically taken inside through such identifications with key people.

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## Notes

1. The 'A level' is the standard examination used for university entrance in England, Wales and Northern Ireland.
2. Although physics-based interventions were not raised by the physics undergraduates as key to their decision to study physics, various interventions were cited by a few of the 51 interviewees overall: for instance, Geraldine (University A, electrical engineering) mentioned SENTINUS, Robin (University A, history with economics) talked about the Engineering Education Scheme and Joe (University B, mechanical engineering) described his experiences with the Smallpiece Trust. But even with these examples, the role of adults, as 'elders', is evident. Geraldine, while acknowledging the 'push to get girls into engineering', comes from a family that includes engineers (father and older

brother). Joe also comes from an engineering background and was introduced to the Smallpiece Trust's courses by a family member. Robin got involved in the Education Engineering Scheme through his history teacher at school and although he did go to university to read Engineering, he dropped that course and enrolled on a history with economics degree.

3. GCSE (General Certificate of Secondary Education) examinations are taken at age 16 in England, Northern Ireland and Wales.

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