A survey of psychological, motivational, family and perceptions of physics education factors that explain 15 year-old students' aspirations to study post-compulsory physics in English schools

Tamjid Mujtaba[1] and Michael J. Reiss[2]

Institute of Education, University of London, London, England

ABSTRACT. This paper investigates the factors that influence 15 year-old students' intentions to study physics post-16, when it is no longer compulsory. The analysis is based on the year 10 (age 15 years) responses of 5034 students from 137 England schools as learners of physics during the academic year 2008-09. Factor analyses uncovered a range of physics-specific constructs, seven of which were statistically significantly associated with intention to study physics post-16 in our final multi-level model; in descending order of effect size these are extrinsic material gain motivation, intrinsic value of physics, home support for achievement in physics, emotional response to physics lessons, perceptions of physics lessons, physics self-concept and advice-pressure to study physics. A further analysis using individual items from the survey rather than constructs (aggregates of items) supported the finding that extrinsic motivation in physics was the most important factor associated with intended participation. In addition, this item-level analysis indicated that within the advice-pressure to study physics construct the encouragement individual students receive from their teachers is the key factor that encourages them to intend to continue with physics post-16.

KEYWORDS: ***Physics; Motivation; Attitudes; Science; Gender; Methodology***

THEORETICAL BACKGROUND

This paper is based on a study which was undertaken because there is a concern amongst policy makers and practitioners at the comparatively low levels of students participating in mathematics and physics in post-compulsory education – a concern which mirrors that in a number of other industrialised nations. A large body of international research points to similar issues to those faced by England, namely that as students progress through the compulsory education system there is a continual decline in interest in science. Work within Europe and the USA indicates that there are substantial problems with student engagement in science and mathematics (e.g. European Commission, 2004; National Academy of Sciences, 2007) and work within Europe suggests that interest in the sciences has declined in recent years (e.g. Haas, 2005; Bøe *et al*, 2011). Additionally, there is global evidence to indicate that there is a negative association between student interest in science and the prosperity of the country (e.g. Sjoberg & Schreiner, 2005). Science all too often fails to engage students and how aspirations and engagement with sciences decreases with age (e.g. Lyons, 2006; Lyons & Quinn, 2010). England's concern with low levels of science participation is indicated by the measures successive governments have put into place in attempts to recruit students to the sciences. It is a clear ambition of the UK to ensure that it becomes a world leader in scientific and technological discovery, largely so that it can compete within an increasingly competitive global economy (Department for Business, Innovation and Skills, 2009). The government's agenda is linked to the UK economy having an increasingly greater requirement for people

1 Email: tamjidmujtaba@googlemail.com
2 Email: m.reiss@ioe.ac.uk

who are proficient in science so as to meet economic, environmental and technological challenges. Such ambitions contrast with the low levels of students choosing to pursue the study of physics after the age of 16.

At the age of 16, students in England's secondary schools take examinations in the General Certificate of Secondary Education (GCSE). Students begin GCSE courses in year 10 (at the age of 14), with limited choice in what they study; the National Curriculum requires all students to study the sciences (in some form, either as separate or combined sciences), mathematics and English at GCSE level. After these examinations, post-16 courses allow students to exercise a great deal of choice over what it is they want to study and no subjects are compulsory. In order to choose physics at A-Level, students in England are expected to get a high grade (A*, A or B) in GCSE science or physics. At GCSE, girls attain slightly higher grades than do boys. In the 2011 GCSE science results, 3.0% of girls achieved the highest grade, A*, compared to 2.1% of boys and 10.1% of girls obtained a grade A compared to 8.0% of boys. Similarly, for physics GCSE results, 21.7% of girls and 20.8% of boys obtained an A*, while 27.1% of girls and 27.4% of boys obtained an A (JCQ, 2011a). With respect to the number of entries, 51% of these science GCSE entries and 46% of these physics GCSE entries were by girls, indicating that there are few if any difference between boys and girls in their ability at physics. In contrast to the pre-16 findings, there are substantially fewer girls who choose to do physics post-16 and the gender gap is wider in physics than in any other science subject (JCQ, 2011b). Approximately 80% of the physics A-Level entries for each of the last ten years have been boys.

This paper and the research from which it is drawn investigate the affective as well as the cognitive domain, largely because previous research indicates that the affective domain (e.g. interests, attitudes and motivation) can be as important for students as their cognitive ability (Alsop, 2005). A substantial body of research suggests that positive attitudes towards science are linked with enrolment (e.g. Osborne *et al*., 2003). Here, we take a fine-grained look into what factors influence intended choice in 15 year-old students. We also contribute to the development of affective constructs that differentiate between different attitudes towards science education (including self-concept, perceptions of lessons, motivation) and we relate these constructs to intended choice.

Bandura's work on the self-efficacy theory of motivation (1986) demonstrates a link between students' future goal intentions and their interpretations of past performances and modelling of gender-role behaviours. In addition, social cognitive theory suggests that students with high levels of academic efficacy demonstrate higher levels of intrinsic interest in their learning and performance as well as more persistence and effort in achieving their academic goals (Schunk, 1989). A common conceptualisation of students who are self-regulated learners is that they are motivationally and behaviourally active in their own learning (Zimmerman & Martinez-Pons, 1986). However, such theories of learning do not differentiate between different types of motivation that create subject interest such as dispositional differences (e.g. for intrinsic reasons such as enjoyment) or extrinsic reasons (such as career prospects, being motivated in a subject simply because students are good at it or to appease significant others) and there are also subject matter differences (e.g. reasons for wanting to do well or continue within a subject may be different for physics compared to another science and reasons may be even further removed for subjects such as art). Occupational and subject choice has been associated with the value students place on subjects in their future lives (Eccles *et al*., 1994) and the value of subjects grows or diminishes based on experiences encountered within the school environment. Within science education, Reiss' (2004) five year qualitative longitudinal study of secondary science students in England found that teacher influence was crucial in enhancing students' engagement with and liking of science; however, this research also found that over time there was a reduction in enthusiasm for science among almost all the participating students, in part because many of the students failed to see the connection between school science and their daily lives.

Student background factors influencing subject choice
Research highlights the relationship between higher aspirations and higher self-regulation / motivation amongst students from minority ethnic backgrounds, such as Indian, Pakistani, Bangladeshi and Black African students, compared to White British students (Sammons *et al*., 2008b; Strand & Winston, 2008), with some students from minority ethnic backgrounds reporting higher academic self-concepts than students of White British heritage (Strand & Winston, 2008). Students of Asian heritage have higher levels of aspirations to become scientists, higher self-concepts and are more likely to want a career in the sciences that are White British students (DeWitt *et al*., 2011). Students of Indian and Chinese heritage do substantially better (with respect to progression and attainment) than White British students, while, in contrast, students of Black Caribbean, Bangladeshi and Pakistani heritage are the most under attaining groups (Archer, 2003; Department for Children, Schools and Families, 2008) and this is true within the sciences too (Jones & Elias, 2005). Certainly, there is evidence to suggest that structural inequalities that exist within institutions and racism collectively disadvantage many minority ethnic students (Greenfield, 1996; Archer & Francis, 2007). There is also evidence to suggest that females from minority ethnic backgrounds are less likely to pursue science careers because of the way society portrays what a scientist looks like and because of general stereotyping of people (Ong, 2005).

A great deal of work has been undertaken to unearth why girls are less likely to continue with physics than are boys. Research suggests that science experiences in early life (Bhanot, 2009), the lack of connection of science to girls' personal lives (Barton, 1998), the way in which girls associate most STEM careers with males (Lee, 1998) and girls' lower confidence levels all contribute to lack of aspirations and choice in girls (Martin *et al*., 2008) and to the lower levels of interest girls typically have in physics (Reid, 2003). There is also a documented lack of encouragement and support in continuing with physics post-16 both in and out of school for most girls despite a core group of girls having similar aspirations as boys in continuing with physics post-16, whilst also experiencing aspects of the classroom environment differently than boys (Mujtaba & Reiss, in press a).

METHODS

This paper draws on the quantitative findings from a longitudinal mixed methods project, Understanding Participation rates in post-16 Mathematics And Physics (UPMAP); the detailed methodology behind the study can be found in Reiss *et al*. (2011). Prior to the commencement of the main study, our surveys went through five rounds of detailed piloting; the pilot work consisted of running reliability tests, examining the distribution of items and constructs and examining the statistical associations with our dependent variable after having collected data from three pilot schools. At this pilot stage we also undertook focus group discussions with year 7 and year 9 students after they completed one of the pilot surveys. The discussions explored whether there were items within the survey that students found difficult or intrusive, whether they understood what the items were actually measuring and whether they found taking part in the survey of use, The student discussions and analysis of survey data from the three pilot schools led to refinements in the instruments. We found that some students had difficulty in answering questions about their teachers and in completing certain psychological items. However, the great majority of students said they were comfortable in answering the great majority of our questions including ones about choosing physics in the future. Our main survey responses also mirrored these pilot findings; in particular, over 98%

of students answered the question that was our key dependent variable, namely their intention to continue with physics after GCSE.

In addition, findings from the pilot led to discussions within the team about whether the use of a dichotomous dependent variable rather than a Likert-type item would be preferable. A dichotomous choice would not allow for degrees of opinion whereas our class discussions during the pilot phase revealed that most students were unsure about their subject choices rather than able to give a definitive statement about whether they were intending to study either mathematics or physics post-16. A 6-point rather than a 5-point Likert scale was piloted and subsequently used in the main survey to allow for a greater range of opinions and to prevent respondents selecting an 'easy' middle option. We appreciated that some respondents might treat data from a 6-point Likert scale as ordinal data. To minimise this possibility, items were accompanied by both a numerically linear scale (1 - 6) and a visual analogue scale, where equal spacing of response levels was clearly indicated for each item. We therefore conclude that it is more appropriate to treat the data as interval than ordinal. There is much debate in the literature about whether to treating Likert type data as interval or not and there is support for conducting analyses as we have chosen (e.g. Labovitz, 1967; Marcus-Roberts & Roberts, 1987; Knapp, 1990, 1993).

This paper utilises findings from our national physics year 10 survey which was distributed to schools in England to address the research question 'Which factors are most important in influencing students intentions to choose physics once it is no longer compulsory?'. Within our project, equivalent mathematics surveys were distributed to year 10 students and both the mathematics and physics surveys were also distributed to year 8 students (the findings of which will be reported elsewhere). The physics surveys were distributed to students within their physics/science classes; all teachers were given a standard survey protocol to read to students which confirmed the purpose of the study, that the survey answers were confidential and that students could decline to take part at all or to answer particular questions they did not wish to.

This paper focuses on students' attitudes, perceptions and the encouragement they received within their physics education. UPMAP's quantitative strand aims to identify through a range of factors (individual, school and out-of-school, including home) and their interactions with one another, the factors that influence participation in mathematics and physics in England and to assess their relative importance among different student populations. In total we surveyed 5034 year 10 students who completed our surveys as learners of physics between October 2008 and January 2009, derived from 137 secondary schools (out of approximately 3446) in England. The project sought to obtain data from schools the majority of which were above average in either or both of mathematics and physics attainment and post-16 participation whilst also focusing on students who were thought by their teachers to be on target to get grades A*-D in General Certificate of Secondary Education in mathematics and physics/science. We also made use of England's National Student Database (NPD) and Student Level Annual School Census (PLASC). The PLASC and NPD datasets hold information on students' attainment records at ages 7 and 11, as well as various background details on students such as gender, eligibility for free school meals (a measure of socio-economic status), ethnicity and neighbourhood composition.

Students' lower levels of interest in continuing with physics in post-compulsory education are likely to be attributable to several factors, though much of the research conducted to date tries to explain engagement and participation by focusing on one particular factor; our work takes a more holistic approach, exploring a range of student-specific factors (personality, intentions, motivations, attitudes, perceptions and support). Science education research often researches *physics* issues by subsuming measurements into research on *science* issues – which is not a precise method to explore physics issues given the differences between the various sciences (e.g. in England girls are more likely than boys to study biology post-16 yet less likely than boys to study physics post-16). UPMAP is able to overcome this problem via the design of the physics year 10 survey which contained around 130 physics-specific items rather than more general items relating to science overall as is the case in most studies.

Data analysis procedures prior to main analysis

We began exploring the underlying dimensions of the physics 10 surveys using factor analysis to affirm the underlying dimensions of the physics constructs – and identified seven physics-specific constructs that were related to perceptions of learning and their physics education: home support for achievement in physics; perceptions of physics teachers; emotional response to physics lessons; perceptions of physics lessons; physics self-concept; advice-pressure to study physics and social support in physics learning. In addition, we looked at two physics-specific constructs related to motivation and values: 'intrinsic value' and 'extrinsic material gain motivation'. Within our project extrinsic material gain motivation measures the belief that obtaining a post-16 qualification in physics would be useful for some quantifiable reward, e.g. for access into higher education or future employment prospects. All of the items within each construct were scored so that a high score represents strong agreement (items were on a 6-point Likert scale), with scores above three indicating positive responses / high agreements with statements. The survey also revealed four underlying personality dimensions: competitiveness (a measure of how competitive in life students are), self-direction (whether students report they can change fate), emotional stability (whether students report they are generally happy or upset) and extroversion. The relationships between the items were then substantiated with reliability analyses via Cronbach's alpha (using standardised items) and all constructs were found to have fair to high reliability (.6-.9). Our survey also measured students' conceptual understanding via conceptual tasks (understanding of forces and electricity) from which an overall composite score was created. Other than those constructs for which we created quartiles in order to maximise numbers (as discussed in the results section), the processes around the creation of the remainder of the constructs/composite scores used listwise deletion – any cases with missing data on one or more of the items were eliminated from the analyses. The UPMAP surveys can be downloaded from http://www.ioe.ac.uk/study/departments/cpat/4814.html.

RESULTS

The focus of this paper was prompted by some of our early analyses, which suggested there is more of a gender imbalance in perceptions, attitudes and motivations in physics than in mathematics (Mujtaba *et al.*, 2010). That analysis also showed that boys were more positive about their mathematics and physics education than were girls. We begin our analysis section in this paper by discussing our construct-based quantitative findings via a series of multi-level models.

Multi-level findings: intention to participate in physics post-16

The dependent variable used within our multi-level analyses was a 6-point Likert item that asked students whether they were intending to continue with physics post-16. The coding is such that a high score represents strong stated intention to participate. The percentage response to each category is shown in Table 1 to show the distribution of student responses. Clearly these data depart somewhat from strict assumptions of normality. This means that findings close to the limit of statistical significance (conventionally $p < 0.05$) should be treated with caution; findings of $p < 0.02$ will be more robust. One advantage of making an assumption of normality when departures from normality are not too great is that it allows standard effect sizes (the Z-score of a normal distribution) to be calculated. Effect sizes are increasing used in meta-analyses (e.g. Hattie, 2008) to compare the relative importance of factors within and between studies. For the sake of brevity, 'intention to participate' in this paper refers to expressed intention to take part in a physics course at post-compulsory (i.e. post-16) education.

We used multi-level modelling (MLM) procedures to establish which combinations of factors were best able to explain the variation in students' intentions to study physics post-16. They are appropriate for the sort of data we analyse in this paper given that they recognise the hierarchical nature of student responses which are likely to be influenced by factors operating at a number of levels, principally at the individual student level and the school level. In MLM the variance is partitioned out between different levels. The standard errors are smaller than those obtained using traditional regression techniques and so MLM procedures are less likely to have type 1 errors.

The procedure began by fitting a variance components model for the dependent variable 'intention to study physics post-16'. This model gave the variance at the school level (level 2) and student level (level 1). The intra-school correlation indicates that around 7% of the variation in students' intention to study physics post-16 is attributable to differences between secondary schools with the rest of the variation reflecting differences between students. A low intra-school correlation required us to create an approach that focused more on the within-school component. We began the analyses by fitting basic models and building on them by removing or adding variables. Our final models are therefore 'nested'; we used the chi-square likelihood ratio test to establish whether more complex models provided better fits than simpler models as well as examining the deviance statistic and seeing whether individual predictors were statistically significant. There was a significant influence of ethnicity, as the paper will demonstrate, and although the effect sizes for these are reasonable, we are cautious about the findings and note that they change depending on the controls used in the models; we are also aware that the larger than expected effect sizes are based on very small numbers of students. All of the findings reported in this paper are significant at a minimum of $p < 0.05$.

Multi-level analyses using UPMAP's constructs

We built up our final multi-level model through a five stage process – for reasons of space, only the last model is presented in detail, though the other stages are discussed below. Student data on prior attainment scores, current conceptual knowledge, intrinsic value of physics and advice-pressure to study physics were divided into quartiles. This allowed us to maximise the number of students within the models as we kept students with missing scores as a valid category whilst we were also able to explore differences between those within the bottom 25th and top 25th percentiles. Student background characteristics were entered first given the known influence of prior attainment, gender and ethnicity on actual participation (as discussed in the 'Theoretical background' section above). Physics-specific measures were entered after controlling for non-physics-specific constructs in order to see if a particular focus on physics constructs that tap into students' motivation to continue with physics and / or support they receive from others in learning / continuing with physics had more of an influence on intended participation than simply students being self-motivated or encouraged by adults to do well at school subjects in general.

Stage 1 (student background characteristics)

Model 1 controlled for students' background characteristics. The analyses indicated that there was no influence of free school meal status. Students within the bottom 25th percentile of age 11 science prior attainment scores were least likely to express intentions to participate (compared to those in the top 25th percentile). Students' current conceptual abilities (measured via questions on electricity and forces) produced findings that correlated tightly with the findings on prior attainment. As expected, girls were less likely to express intentions to continue with physics post-16. Compared to students of White heritage, those of Black heritage were less likely to express intentions to continue with physics post-16 (just failed significance); students of Asian heritage were more likely to express intentions to continue with physics post-16 (due to small numbers within this group we were unable to differentiate between students of Indian, Pakistani and Bangladeshi heritage).

Stage 2 (personality traits)
In model 2 we added students' data on their underlying personality traits and removed free school meal status (given it was non-significant in model 1). Competitive personalities, extroversion and having high levels of 'self-direction' were related to increased post-16 intentions to study physics. There was no influence of emotional stability and students who expressed positive relationships with parents had positive intentions with respect to post-16 physics. The influence of prior attainment, current conceptual ability and gender remained significant. The findings in relation to ethnicity remained important, and we found that after controlling for personality traits being of Black heritage became significant.

Stage 3 (general motivation and home support for general learning)
In model 3 we introduced measures around achievement in learning, 'home support for achievement in general' (the encouragement each student received from their home environment to learn in general), alongside students' 'general motivations and aspirations towards learning'. Both of these measures had a significant positive influence on intended participation in physics. These findings indicate that having a home learning environment that encourages learning is positively associated with students wanting to do physics post-16. Students' high levels of motivation towards general learning were associated with raised intentions to study physics. The influence of the personality trait 'competitiveness' became non-significant (so was removed from subsequent models) as did the influence of Asian heritage (though ethnicity was kept in models).

Physics-specific constructs
Physics-specific constructs were added in the final two stages. In order to substantiate the impact of classroom and learning environment experiences on intended physics participation, measures that explored students' perceptions of their physics education were included prior to the inclusion of constructs that tapped into students' attitudes towards physics-specific issues (e.g. motivation and self-concept).

Stage 4 (physics teachers, physics lessons)
In model 4 we added 'perceptions of physics teachers', 'emotional response to physics lessons' and 'perceptions of physics lessons'; all of these constructs were significantly associated with intended participation – though the influence of 'relationship with parents' lost significance.

Stage 5 (support and encouragement in physics)
Finally, physics-specific constructs that tapped into the support and encouragement students received in learning physics as well as continuing with it in post-compulsory education were added for model 5. The following two constructs were now not found to be significantly associated with post-16 intentions: 'social support in physics learning' and 'extrinsic social-gain motivation'. However, the following five constructs were found to be significantly associated with post-16 intentions: 'advice-pressure to study physics post-16', 'home support for achievement in physics', students' 'intrinsic value' of physics, 'extrinsic material-gain motivation' and 'physics self-concept'. At this stage of the analysis, 'general motivations and aspirations towards learning', 'self-direction', 'perceptions of teachers' and current

conceptual knowledge in physics lost significance (so these were removed before running the final model as displayed in Table 2).

This final model indicated that the highest effect size (ES) out of all of the measures we tested within our models (and whilst controlling for the influence of other measures) was for 'extrinsic material gain motivation' (ES=.982). There were also effects of having high levels of 'advice-pressure to study physics' (ES=.616), 'physics self-concept' (ES=.245), positive 'emotional response to physics lessons' (ES=.167), 'intrinsic value of physics' (ES=.115) , 'perceptions of physics lessons' (ES=.108) and 'home support for achievement in physics' (ES=.102). With respect to non-physics-specific measures, extroversion was associated with lower levels of intended participation (ES=.135). The influence of prior attainment lost significance (though was retained in the final model); the influence of ethnicity remained significant with students of Black heritage less likely to express intentions to study physics post-16 (ES=.431). The constructs 'advice-pressure to study physics' and 'intrinsic value of physics' indicated that there were significant differences between the students in the upper-middle quartile and the ones in the top quartile. As expected, girls were less likely to express intentions to participate than boys, though the effect size for this (.202) was not as strong as for some of the survey constructs; the finding is important as it indicates that within our sample, of all the student background characteristics, this was one that remained throughout the various stages of analysis.

The findings suggest that a student's perceptions of their 'home support for achievement in physics' is a better predictor of intended physics uptake than the construct 'home support for achievement in general' (which lost significance once physics-specific measures were introduced). Similarly, general measures of students' motivation for learning or personality-based measures of general motivation in life, such as 'competitiveness', are not significant predictors of post-16 physics intentions; the physics-specific measure of extrinsic motivation is more precisely related to intention to study physics post-16. Without having physics-specific measures, we would not have been able to come to such conclusions. Encouragement outside of the home to study physics post-16 (partly measured by the 'advice and pressure to study physics' construct) had a stronger influence on intended participation than the construct that measured 'home support for physics learning'.

The importance of looking beyond what the immediate findings suggest

The results from the initial construct-based multi-level models appear to suggest that 'perception of physics lessons', 'emotional response to physics lessons' and 'perception of physics teachers' are not as strongly associated with intended physics participation as is 'extrinsic material gain motivation'. We hypothesised that though constructs that measured the influence of teachers and lessons were not as strong / effective predictors of intended physics participation (after the introduction of extrinsic material gain motivation) in the construct-based multi-level analyses, there might be individual items within these constructs that have a strong effect on intended participation in physics (even after accounting for extrinsic material gain motivation). We presumed there was a possibility that the importance of specific individual items might have been lost, once these were combined with other measures. On-going synthesis of our construct-based analysis with our emerging qualitative findings, e.g. Rodd *et al.* (2010), indicated that in some instances there was a mismatch between findings in our quantitative and our qualitative work. Some of the quantitative findings were counterintuitive (e.g., perceptions of physics lessons and physics teachers had no influence on intended participation in the final model); however, findings from the qualitative work identified the importance of physics teachers and the intrinsic value of physics / physics lessons. This indicates that our construct-based multi-level analyses failed to reveal certain important points surrounding perceptions of physics, physics lessons and the students' teachers.

Given the mismatch between the quantitative and qualitative findings we decided to conduct an item level analysis. We used bi-variate analysis to explore what it is exactly about perceptions of physics teachers, lessons and physics itself that is most important in explaining differences between girls and boys. We also used correlation analysis to explore which items (within each of these particular constructs) were most closely correlated with intention to participate in physics post-16 (Mujtaba & Reiss, in press b). We found that, despite girls and boys having similar perceptions of their physics teachers with respect to homework issues, liking their teachers, the teachers' fairness and emphasis on learning, there is still a significant gender difference with boys being more likely than girls to report that they are encouraged to continue with physics post-16. This finding is important given that the item-based correlation analysis indicated that teachers' encouragement of individual students to continue with physics post-16 was the item that associated most strongly with intended participation. These correlation analyses also indicated that students' intrinsic valuation of lessons and how relevant physics lessons were to their lives was more strongly associated with intended participation than factors to do with discussing ideas, doing experiments and knowing how well they are doing in physics.

Multi-level re-analyses to explore the importance of students' perceptions on intended post-16 physics participation (using items from the survey rather than constructs)

We conducted some further analyses of the survey data; this time we use items within constructs rather than constructs themselves, given the finding in Mujtaba and Reiss (in press b) that there were particular items within each construct which had stronger associations with intentions to continue with physics post-16. The multi-level analysis below adds another layer of findings to the original construct-based multi-level analyses we conducted (see Table 1). These models were run in a series of stages which had particular conceptual relevance (driven by the analysis described above) which included findings from the qualitative work. Our construct-based multi-level analyses indicated there was no significant influence of teachers though our qualitative work and item-level bi-variate analyses did point to the influence of teachers. We only present the final, best fit model in order to elucidate issues around how extrinsic material gain motivation (i.e. students' intention to continue with physics because of the benefits they envisage for such things as job satisfaction and salary) is important in explaining intended participation (even whilst using an item-level analysis) and also bringing to the fore what it is about students' perceptions of their lessons and teachers that are also important in explaining intended participation (which our construct level analyses missed). Items looking into perceptions of physics (which included extrinsic material gain motivation) were added towards the end of the model steps primarily because it was predicted (given earlier findings) that these items would wipe away the significant influence of teachers and lessons. It is very possible that there is a strong link between 'extrinsic material gain motivation' and students' perceptions of their teachers – though multi-level modelling will not be able to test an indirect relationship between intended participation and perceptions of teachers (via extrinsic material gain motivation).

Given that our original construct-based multi-level analyses indicated that underlying personality traits lost significance once more fine-grained measures of physics-specific measures were introduced in the models, we omitted this step as well as omitting any non-physics-specific items that measured general attitudes/perceptions of learning, support and encouragement (given they all lost significance in later models once we controlled for physics-specific factors). The only alteration we made was to one of the variables 'my teacher thinks that I should continue with physics beyond my GCSEs'; almost half of the students did not respond to this question so in order to maximise the sample size this particular variable was treated as an ordinal variable, with missing students categorised as a 'zero' (though this is not displayed within the table) and the data for which we had the students' responses were put into quartiles.

In the final model of the item-based re-analysis we introduced items that were a part of the original physics self-concept construct and within these items we found that 'I am good at physics' and 'I don't need help with physics' remained significant. In this final model students classified as 'any other group' were more likely to express intentions to study physics post-16 than students of White heritage. The influences of Black heritage and Asian heritage were just below the 5% significance level though the trends were in the direction we would expect and have talked about within our construct-based multi-level analyses (students of Asian background more likely to express positive intentions and those of Black heritage less likely). Table 3 shows that two of the items that were associated with intended participation are those to do with the original 'extrinsic material gain motivation' construct (ES=.413 and ES=1.376), two of them are from the original 'physics self-concept' construct (ES=.149 and ES=.083), one is from the original 'physics intrinsic value' construct (ES=.361), one is from the original 'emotional response to physics lessons' construct (ES=.255) and one is a teacher-related item which we had originally placed within the 'advice-pressure to study physics post-16' construct (ES=.425 of those in the top 25^{th} percentile versus bottom 25^{th} percentile of receiving advice-pressure to continue with physics post-16 from their physics/science teachers). Although teachers' encouragement of students to continue with physics post-16 was an important predictor, as were items to do with self-concept and enjoyment of lessons, the influence of such measures was still not as strong as items that measure 'extrinsic material gain motivation'. This indicates that while other factors are also important in shaping students' intentions to participate in physics post-16, physics extrinsic material gain motivation is the most important.

DISCUSSION

In this survey, students who say that their families did not encourage them in their physics learning are less likely to intend to study physics once it is no longer compulsory. Externally assigned goals (by teachers and parents) appear to be associated with an intention to continue with physics post-16 – our construct analyses indicated that 'advice-pressure to study physics post-16' was a predictor of intended choice in the final construct-based multi-level analysis. This construct measured the advice/encouragement students received from a range of people in and out of school. These findings have implications for policy and school leaders as it suggests that to boost post-16 physics participation (including from underrepresented groups) a particular focus may need to be placed on boosting students' extrinsic material gain motivation by creating an awareness of the material gain of having post-16 physics qualification. In addition, our findings indicate that personal relationships with teachers are important in encouraging students' future physics aspirations; teachers could enhance students' aspirations by actively creating a more meaningful one-to-one relational dimension within their teaching.

The use of physics-specific measures proved vital in helping this research discover more about what factors shape intended post-16 participation in physics. The physics-specific measure of extrinsic motivation is more tightly related to intention to study physics post-16 than any of the other measures used within our models. The multi-level re-analysis using UPMAP physics-specific items (as opposed to constructs) found support for the role of 'extrinsic material gain motivation' in students' intended participation in post-16 physics (as found in the original construct-based analyses). Teachers' encouragement of individual students to continue with physics post-16 was the most strongly associated item with intended participation (amongst the items that explored teachers influences on students). This item was a significant predictor in the final multi-level model even after controlling for items that measure physics 'extrinsic material gain motivation'. It is clear within the item-based multi-level analysis that the influence of teachers was very important for students' intentions to continue with physics post-16; the use of an overall construct (in the original analyses) that combined encouragement from teachers with encouragement from others masked this finding.

Other items within the 'perceptions of teachers' cluster that were somewhat important for intended participation were teachers being good at explaining physics and teachers taking an interest in students as people (for both boys and girls). These were statistically significant in earlier model steps though lost significance in later models once these models accounted for students' perceptions of physics. The multi-level findings indicate that enjoyment of physics lessons, seeing the relevance of physics and students feeling they do well in physics lessons are related to intended participation (prior to the inclusion of physics items that measure intrinsic value, extrinsic material gain motivation and self-concept); the items within the physics lessons cluster fail to reach significance in the final model.

The final model supports findings from the construct-based analyses that highlight the importance of 'extrinsic material gain motivation'. There is a strong influence of gender on intended physics participation and the gender gap in perceptions of teachers, lessons and physics remains despite controlling for a wide range of cognitive and affective measures – a finding which was not demonstrated with other measures of student background characteristics (e.g. prior attainment and ethnicity). Within the 'perceptions of teacher' items, the data highlight that the item 'my teacher thinks that I should continue with physics post-16' is the most highly correlated with intention to participate in physics post-16 as it remained as a significant predictor in the final model. There is evidence to suggest that teaching students to set themselves goals enhances their academic achievement, cognitive efficacy and their intrinsic interest in the subject concerned (Bandura & Schunk, 1981; Skunk, 1989). Miller *et al.* (2006) found that female high school students preferred courses which were people-orientated and that their choice of science courses were more to do with getting access to their chosen careers in health (e.g. pharmacy, medicine) than because of an interest in science. These students were less likely to choose science careers that were not perceived to be people-orientated (e.g. engineering, physics). Females also found lifestyles associated with careers in the sciences to be unattractive, perceiving scientists to be isolated with little time for a social life with the work of a scientist having little relevance for social problems. As our findings indicate, differences in attitudes towards physics between male and female students cannot be solely (if at all) attributable to their biological sex but to the differential treatment they receive. Farenga and Joyce (1999) found that stereotypes expressed by both genders about the sciences being more appropriate for boys develop many years prior to students being exposed to any science courses. Given that our work also indicates that girls are less likely to be encouraged to continue with physics post-16, our research points toward recommendations to continue to promote and fund interventions, initiatives and practices that take into account and attempt to reduce gender differences in physics uptake.

In this paper we have not explored differences among girls and among boys, though elsewhere our work (Mujtaba & Reiss, in press a) has shown that there is a core group of girls who have similar intentions to boys in continuing with physics post-16 and similar perceptions about aspects of their physics education. These findings mirror those of Greenfield (1996) who found, contrary to what was generally supposed at the time, that girls' attitudes to science were often similar to boys. Greenfield suggested that such findings might be due to girl-dominated science classes, exposure to female science teachers and being a part of a higher achieving class cohort. Greenfield also suggests that ethnicity has an effect on students' attitudes. We did not find ethnicity to be as important for students' intentions as gender or the other factors discussed above – though it is possible that the influence of ethnicity is masked or already accounted for by attitudes and perceptions we controlled for within our models. Further research to explore possible issues around ethnicity could use more parsimonious models (such as structure equation modelling) or use bi-variate rather than multi-variate analyses (e.g., as in Dewitt *et al*., 2011) to help bring any ethnicity issues to the fore. The analyses we performed did result in findings already known from other studies: students of Asian heritage are more likely to express intentions to continue with physics post-16 and those of Black heritage are less likely to express such intentions (compared to those of White heritage).

Although our research began by taking on board criticisms about the lack of clarity in science education research (e.g. Gardner, 1996) with respect to differentiating between different aspects of attitudes (e.g. differentiating as we did between attitudes to teachers and attitudes to lessons), as well as using physics-specific measures (rather than general science ones) to explore physics attitudes, we also found that even when using physics-specific constructs that differentiated between teachers, lessons and self-concept, there is further differentiation when using individual items that we found to be valuable in explaining intended participation amongst 15 year-old students. We present evidence that the use of a construct, as opposed to a single item, is not always essential for physics education research, particularly when an item can very precisely measure what it is one intends to measure. Indeed, overreliance on constructs can lead to methodological problems. So, for instance, our construct 'advice-pressure to study physics', though originally intended to measure the encouragement students received to study physics post-16 from a range of people within their lives, masked the influence of encouragement from their science/physics teachers (an item we found to be important within our final multi-level model). In addition, our original construct of 'perceptions of teachers' was later found to be characterised by a number of distinct sub-constructs. For example, the way students reported that their teacher related to them on a personal level had different associations with intended participation when compared to the items that tapped into how fair teachers were seen to be in the way they engaged with all students – the former was more important in influencing intended participation. The use of an overall construct that measured perceptions of teachers obscured such important distinctions in the original construct-based analyses. The use of an overall construct did not indicate anything useful about what it was about teachers that was related to intended participation by their students in physics post-16. The tradition of psychology (e.g. Ajzen, 2001) indicates that attitudes towards various attributes collectively create an attitude towards an overarching theme; it is clear from our research that research questions ought to guide and help conceptualise a measure whilst taking into account how students may differentiate between items within a construct.

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TABLE 1
Intention to participate in physics post-16 for year 10 students in England

Percentage responses	*Strongly disagree*	*Disagree*	*Slightly disagree*	*Slightly agree*	*Agree*	*Strongly agree*
Overall results for England sample	21.4	23.7	13.1	18.9	14.0	8.8
Boys	17.7	18.1	12.7	19.5	18.7	13.3
Girls	24.9	28.7	13.6	18.4	9.9	4.5

TABLE 2

Model 5 estimates of fixed effects on year 10 (age 15) England students' intentions to study physics post-16

Parameter	*Estimate*	*Std error*	*df*	*t*	*Sig.*	*Effect size*
Intercept	1.393	0.204	3997.623	6.838	0.000	n/a
Gender	-0.202	0.040	2155.011	-5.083	0.000	0.202
Physics self-concept	0.131	0.023	4246.252	5.659	0.000	0.245
Extrinsic material gain motivation	0.541	0.027	4257.859	20.312	0.000	0.982
Home support for achievement in physics	0.045	0.016	4257.545	2.728	0.006	0.102
Perception of physics lessons	0.057	0.026	4186.885	2.193	0.028	0.108
Emotional response to physics lessons	0.093	0.020	4248.236	4.656	0.000	0.167
Extroversion	-0.079	0.018	4244.314	-4.297	0.000	0.135
Science KS2 age 11 score (comparison group: top quartile)						
(bottom quartile)	0.099	0.061	3873.841	1.612	n/s	n/s
(lower middle quartile)	-0.050	0.057	4237.743	-0.881	n/s	n/s
(upper middle quartile)	-0.086	0.057	4240.486	-1.514	n/s	n/s
Ethnic group (comparison group: White British)						
European White	0.021	0.125	4256.829	0.171	n/s	n/s
Any other ethnic group	0.174	0.241	4248.705	0.721	n/s	n/s
Asian	0.073	0.089	1861.861	0.819	n/s	n/s
Black	-0.431	0.143	3670.607	-3.019	0.003	0.431
Chinese	0.181	0.266	4257.715	0.680	n/s	n/s
Mixed	0.003	0.124	4254.428	0.026	n/s	n/s
Unclassified	0.043	0.164	2872.828	0.261	n/s	n/s
Advice-pressure to study physics (comparison group: top quartile)						
(bottom quartile)	-1.500	0.064	4241.686	-23.482	0.000	1.357
(lower middle quartile)	-1.208	0.057	4258.999	-21.288	0.000	1.092
(upper middle quartile)	-0.681	0.051	4247.994	-13.229	0.000	0.616
Intrinsic value of physics (comparison group: top quartile)						
(bottom quartile)	0.114	0.071	4254.915	1.608	n/s	n/s
(lower middle quartile)	-0.093	0.056	4253.784	-1.651	n/s	n/s
(upper middle quartile)	-0.128	0.056	4244.451	-2.307	0.021	0.115

Random-effects parameters

Variance (Level 2)	0.034	0.009
Variance (Level 1)	1.221	0.026
Deviance (-2 x Log restricted-likelihood)	13180.943	

TABLE 3
Final model Estimates of fixed effects on year 10 (age 15) England students' intentions to study physics post-16 using items from the survey and original constructs

Parameter	*Estimate*	*Std Error*	*df*	*t*	*Sig.*	*Effect size*
Intercept	0.319	0.130	3134.670	2.448	0.014	n/a
Gender	-0.143	0.039	2158.329	-3.694	0.000	0.133
Item is a part of the original 'advice-pressure to study physics' construct: my teacher thinks that I should continue with physics beyond my GCSEs (comparison group: top quartile)						
(bottom quartile)	-0.455	0.075	4108.431	-6.099	0.000	0.425
(lower middle quartile)	-0.194	0.073	4183.841	-2.653	0.008	0.181
(upper middle quartile)	-0.074	0.066	4204.838	-1.131	n/s	n/s
Item is a part of the original 'extrinsic material gain motivation' construct: Physics is a useful subject.	0.154	0.019	4188.246	7.929	0.000	0.413
Item is a part of the original 'intrinsic value' construct: Physics is an interesting subject.	0.133	0.018	4204.326	7.191	0.000	0.361
Item is a part of the original 'extrinsic material gain motivation' construct: Physics will help me in the job I want to do in the future.	0.462	0.013	4201.490	35.555	0.000	1.376
Item is a part of the original 'self-concept' construct: I am good at physics.	0.061	0.018	4203.682	3.416	0.001	0.149
Item is a part of the original 'self-concept' construct: I need help with physics.	0.029	0.012	4203.576	2.319	0.020	0.083
Item is a part of the original 'emotional response to physics lessons' construct: I enjoy my physics lessons.	0.093	0.016	4182.515	5.947	0.000	0.255
Ethnic group (comparison group: White British)						
European White	0.052	0.040	3723.123	1.296	n/s	n/s
Any other ethnic group	0.451	0.223	4198.858	2.022	0.043	0.422
Asian	0.150	0.087	1924.548	1.712	n/s	n/s
Black	-0.265	0.140	3672.830	-1.884	n/s	n/s
Chinese	0.069	0.256	4202.853	0.271	n/s	n/s
Mixed	0.044	0.120	4198.077	0.364	n/s	n/s
Unclassified	-0.041	0.159	2600.897	-0.253	n/s	n/s

Random-effects parameters

Variance (Level 2)	0.033	0.009
Variance (Level 1)	1.144	0.025
Deviance (-2 x log restricted-likelihood)	12701.065	