GENDER DIFFERENCES IN 15 YEAR-OLDS' PERCEPTIONS OF PHYSICS, PHYSICS LESSONS AND PHYSICS TEACHERS.

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Abstract: This paper is based on quantitative survey findings of year 10 (15 year-old) students in 140 schools drawn from a longitudinal mixed methods project: Understanding Participation rates in post-16 Mathematics and Physics (UPMAP). The low number of students continuing with physics after compulsory education is a key concern amongst UK policy makers; the likelihood of girls going on to do physics post-16 is substantially less than that for boys despite there being no inherent gender difference in aptitude for physics. A literature review in conjunction with the team's expertise informed the development of a survey to explore students' attitudes towards various physics-related issues, support they received in physics learning as well as intentions to continue with physics post-16. Confirmatory factor analysis supported the various components of the survey, with some minor modifications. Analysis of the students' responses indicated the importance of teachers' encouragement in post-16 studies and further cemented our ideas about the importance of physics material gain motivation in inspiring students to continue on with physics after compulsory education.
Keywords: physics, gender, motivation, perceptions, teachers

INTRODUCTION

There are concerns around the gender gap in the uptake of post-16 physics in the UK as in a number of other countries in Europe and elsewhere; in addition, the gender gap is a continuous and established problem at secondary school, further education and higher education levels. Post-16 academic courses mostly take the form of Advanced Level (A-Level) in about two to four subjects with a great deal of student choice with examinations taken at age 18. In order to do physics at A-Level, students in the UK are typically required to get a high grade (A*, A or B) in the science or physics examinations they take at age 15 or 16. Attainment levels of boys and girls in physics/science at age 16 are quite similar with, if anything, girls doing slightly better (JCQ, 2011a). This demonstrates there is little if any inherent difference between boys and girls in their ability at physics.

In 2010, 51% of science General Certificate of Secondary Examination (GCSE) entries and 46% of these physics GCSE entries at age 16 were by girls. In contrast to this, the odds of girls going on to do physics post-16 are substantially less than that for boys, even after controlling for entry requirements into A-level, with the gender gap being wider for physics than for mathematics or any other science subject (JCQ, 2011b). The concerns with female participation rates in STEM (science, technology, engineering, mathematics) courses are also very much related to the high attrition rates of women at each post-16 stage as well as females in STEM careers (Blickenstaff, 2005). In the UK, there have been a number of national initiatives put in place to raise girls' engagement with physics by exposing them to educational activities that promote female-inclusive education such as 'Girls into Science and Technology' and 'Women into Science and Engineering'. These campaigns received much enthusiasm from schools (Smail et al., 1982; WISE, 2007). However, despite these initiatives, physics remains highly gendered. In response to this, the Institute of Physics commissioned a review with the hope that knowing what to do to boost girls' participation in physics A-Level would help resolve the problem with female recruitment into physics (Murphy and Whitelegg, 2006). However, the review was unable to come to firm conclusions about how to boost girls' participation in physics in post-compulsory education. Reasons put forward for the low participation of girls has ranged from: the low confidence and low science self-concept of girls, (Green et al. 2007); teacher influence and seeing the relevance of science (Reiss, 2004); lower levels of physics enjoyment and interest (Reid, 2003); and girls feeling STEM careers are for males (Lindsey et al., 1997).

CONTEXT AND METHODS

This paper is derived from the mixed methods longitudianal study Understanding Participation rates in post-16 Mathematics And Physics (UPMAP) study (2008-2011) which aims to identify factors that relate to students' intended choices with respect to physics and mathematics. This paper focuses on physics. We designed student questionnaires to include items from established psychological constructs alongside validated physics conceptual tasks. In total we had 5642 year 10 students who completed our surveys as learners of physics between October 2008 and April 2009. We also matched on data from the government such as prior attainment at age 11, gender, eligibility for free school meals (FSMs) and ethnicity.

The psychometric validity of our instruments were established via confirmatory factor analysis. Cronbach's alphas were used to assess the internal consistency of all constructs and these were found to have fair to high reliability (.6-.9). 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 indicate positive responses/agreements with statements. In this paper we explore students' perceptions, attitudes and motivations regarding physics lessons, physics teachers and physics itself. For such purposes we do not use the overall constructs but explore the importance of individual items within constructs. This focus was prompted by other UPMAP findings presented elsewhere suggesting there is more of a gender imbalance in perceptions, attitudes and motivations in physics than there is for mathematics. Previous work concluded that students' physics extrinsic motivation (i.e. students' intention to continue with physics because of the benefits they envisage for such things as job satisfaction and salary) was particularly important in encouraging year 10 students to continue with physics post-16 and the statistical significance of perceptions of teachers and lessons lost significance when controlling for students' physics extrinsic motivation.

RESULTS

For this paper the use of t-tests helped to gain an insight into the sorts of areas (perceptions of teachers, lessons and physics itself) that would be important for our work and inform the multi-level model analysis. The relationship between intention to participate and gender is consistent with general patterns of participation as reported in many studies. We found 13.3% of boys strongly agreed to continue with physics post-16 compared to 4.5% of girls while 17.7% of boys strongly disagreed to continue with physics compared to 24.9% of girls.

There were three areas that explored issues with teachers: encouragement, relationships and competence. Students on the whole had positive perceptions of their teacherse. Table 1 shows students were most positive about their teachers really wanting students to understand physics (mean of 4.93), followed by teachers believing that all students can learn physics (mean of 4.90). Students were least positive about teachers being interested in them as people (3.32) and physics teachers liking all students (mean 3.79). All of the items are summarised in Table 1 which includes the breakdown by gender and whether differences were statistically significant.

Table 1: Year 10 students' perceptions of physics teachers

Overall perceptions of physics teachers	All students	Boys	Girls

Item	N	M	SD	N	M	SD	N	M	SD
**My teacher thinks that I should continue with physics post-16	2607	4.06	1.6	1253	4.33	1.49	1343	3.79	1.65
**I like my physics teacher	4878	4.02	1.54	2234	4.07	1.54	2625	3.99	1.51
**My teacher has high expectations of what students can learn	4448	4.82	1.07	2037	4.90	1.07	2395	4.76	1.06
My teacher believes that all students can learn physics	4423	4.90	1.03	2032	4.91	1.05	2373	4.89	1.01
My teacher wants us to really understand physics	4555	4.93	1.02	2088	4.96	1.04	2451	4.90	1.01
My physics teacher sets us homework	4715	4.79	1.24	2146	4.80	1.25	2552	4.77	1.23
My teacher believes that mistakes are OK when learning	4420	4.59	1.24	2048	4.57	1.27	2356	4.61	1.25
**My teacher is interested in me as a person	3704	3.32	1.56	1698	3.41	1.58	1990	3.23	1.53
My teacher seems to like all the students	4319	3.79	1.57	1969	3.79	1.59	2336	3.79	1.55
My teacher is interested in what students think	4434	4.26	1.36	2021	4.30	1.37	2396	4.23	1.34
My teacher only cares about students who get good marks	4347	4.38	1.44	1968	4.35	1.5	2363	4.41	1.4
My teacher lets us get away with not doing homework	4526	4.56	1.39	2061	4.56	1.44	2447	4.56	1.35
My teacher treats all students the same regardless of their ability	4439	4.36	1.39	2041	4.37	1.41	2382	4.35	1.37
**My teacher is good at explaining physics	4630	4.28	1.41	2119	4.47	1.36	2494	4.12	1.43
*My teacher marks and returns homework quickly	4346	4.05	1.47	1984	4.12	1.45	2344	3.99	1.49

Notes: ** significant at .001; * significant at .01; N (number); M (mean); SD (standard deviation); comparisons between girls and boys.

Teachers' encouragement: Boys were more likely to give positive responses about feeling their teachers: encouraged them to continue with physics post-16 ($t=8.085$, $p<.001$); had high expectations of what students can learn ($t=4.353$, $p<.001$).
Personal relationships with physics teachers: Boys were more likely to report their physics teachers were in interested in them as people ($t=3.426$, $p<.001$).
Competence of physics teachers: Boys were more likely to report that their physics teachers: were good at explaining physics ($t=8.328$, $p<.001$); marked and returned homework quickly ($t=2.918$, $p<.01$).

Students' perceptions of physics lessons

There were four areas that explored issues with physics lessons: laboratory and practical work; learning physics concepts; enjoyment of physics lessons; self concept in physics as impacted by physics lessons. All of the items are summarised in Table 2 which includes the breakdown by gender and whether differences were statistically significant.

Table 2: Year 10 students' perceptions of physics lessons

	All students			Boys			Girls		
Item	N	M	SD	N	M	SD	N	M	SD
**I look forward to physics classes	4964	3.13	1.44	2276	3.39	1.46	2669	2.90	1.38
**My teacher explains how a physics idea can be applied to a number of different situations	4893	3.82	1.39	2248	4.03	1.37	2627	3.65	1.37
**I have the opportunity to discuss ideas about physics	4921	3.87	1.41	2260	4.03	1.39	2643	3.74	1.40
**I do well in physics tests	4926	3.82	1.34	2263	4.15	1.28	2645	3.53	1.32
**I enjoy my physics lessons	4945	3.43	1.47	2267	3.72	1.45	2661	3.18	1.43
**I can see the relevance of physics lessons	4903	3.94	1.39	2246	4.17	1.35	2640	3.74	1.38
**When I am doing physics, I always know what I am doing	4958	3.19	1.31	2270	3.57	1.30	2669	2.87	1.23
When I am doing physics, I am learning new skills	4944	4.00	1.25	2266	4.16	1.25	2660	3.85	1.23
*When I am doing physics, I am not bored	4940	3.18	1.53	2260	3.42	1.56	2661	2.98	1.48
*When I am doing physics, I pay attention	4959	3.82	1.31	2270	4.00	1.31	2672	3.67	1.29
When I am doing physics, I don't get upset	4927	5.02	1.38	2254	5.07	1.45	2655	4.98	1.32
**When I am doing physics, I don't daydream	4940	3.26	1.59	2262	3.49	1.65	2659	3.07	1.50
**In my lessons, we do investigations to test our own ideas	4553	3.46	1.48	2081	3.52	1.50	2456	3.41	1.46
**I look forward to spending time in the lab to do practical	4585	4.11	1.59	2093	4.44	1.50	2475	3.82	1.61

investigations									
**Thinking about your physics lessons, how do you feel you compare with the others in your group?	4867	3.32	1.09	2233	3.63	1.08	2616	3.05	1.03

Notes: ** significant at .001; * significant at .01; N (number); M (mean); SD (standard deviation); comparisons between girls and boys.

Descriptive statistics indicated that students on the whole had positive perceptions of their physics lessons but with some areas of concern. Students were most positive about not being upset when doing physics (mean of 5.02), followed by looking forward to spending time in the laboratory doing experiments (mean of 4.11). Students were least positive about looking forward to physics classes (3.13) and not being bored when doing physics (mean 3.18), an indication that students were showing signs of being bored, closely followed by students reporting that they always knew what they were doing when doing physics (3.19). For some of the items in Table 2 there were statistically significant differences in responses between boys and girls, with boys reporting more positively about questions around physics lessons. The largest significant difference in responses between boys and girls was ‘When I am doing physics I always know what I am doing’ (.69 mean difference), followed by ‘I do well in physics tests’ with a mean difference of .62.

Laboratory and practical work: Boys were more positive about: looking forward to spending time in the laboratory doing practical investigations (t=13.236, p<.001); having the opportunities to do investigations to test out their own ideas (t=2.435, p<.001).
Learning physics concepts: Boys were: more likely to report that their teacher explained how physics ideas can be applied to a number of different situations (t=9.630, p<.001); more positive about having the opportunity to discuss their ideas about physics (t=7.110, p<.001); more likely to report seeing the relevance of physics lessons (t=11.050, p<.001).
Enjoyment of physics lessons: Boys were more likely to report: looking forward to their physics classes (t=12.334, p<.001); enjoying their physics lessons (t=13.154, p<.001).
Self concept in physics as impacted by physics lessons: Boys were: more positive about doing well in their physics tests (t=16.670, p<.001); more likely to report doing better in their physics lessons than their peers (t=19.102, p<.001).

Students’ perceptions of physics

There were six areas that explored perceptions of physics: laboratory and practical work; usefulness of physics; self concept in physics; liking of physics; physics and social skills; and doing physics. Descriptive statistics (Table 3) indicated that students’ responses about physics were generally positive though there were some aspects of physics that students were not positive about / did not agree with. Students were most positive about / in agreement with ‘To be good at physics, you need to work hard’ (mean 4.66) and least positive about ‘Being good at physics makes you popular’ (mean 1.95).

Table 3: Year 10 students’ perceptions of physics

Perceptions of lessons	**All students**			**Boys**			**Girls**		
Item	**N**	**M**	**SD**	**N**	**M**	**SD**	**N**	**M**	**SD**
**I think physics is a useful subject	4988	4.24	1.24	2292	4.43	1.24	2676	4.08	1.21
**I think physics is an interesting subject	4904	3.67	1.45	2246	3.99	1.45	2641	3.40	1.40
**I think physics will help me in the job I want to do in the future	4868	3.05	1.59	2235	3.35	1.65	2615	2.80	1.50
**I am good at physics	4880	3.84	1.31	2254	4.23	1.21	2606	3.49	1.28
**People who are good at physics get well-paid jobs	3820	4.17	1.18	1776	4.28	1.1	2028	4.07	1.17
Being good at physics impresses people	4187	3.36	1.41	1889	3.40	1.44	2287	3.33	1.38
**Physics teaches you to think logically	4400	4.05	1.25	2020	4.15	1.29	2364	3.96	1.21
**Physics helps you in solving everyday problems	4484	3.33	1.30	2062	3.47	1.37	2409	3.21	1.28

Physics improves your social skills	4361	2.20	1.21	1965	2.27	1.30	2382	2.13	1.12
**To be good at physics, you need to be creative	4397	2.57	1.31	1987	2.84	1.41	2398	2.35	1.17
To be good at physics, you need to work hard	4712	4.66	1.22	2138	4.69	1.22	2560	4.64	1.22
**Being good at physics makes you popular	4225	1.95	1.17	1909	2.08	1.23	2305	1.84	1.06
**Physics is interesting	4920	3.60	1.53	2251	3.92	1.53	2653	3.32	1.48
**Physics is important in making new discoveries	4576	4.57	1.22	2110	4.67	1.21	2450	4.48	1.23
**Those who are good at physics are clever	4435	4.06	1.40	2023	4.14	1.38	2398	4.00	1.41
**These days, everybody needs to know some physics	4498	3.95	1.27	2062	3.99	1.31	2422	3.91	1.23
**It's interesting to find out about the laws that explain different phenomena	3719	3.90	1.45	1777	4.12	1.41	1934	3.70	1.46
**There is only one right way to solve any physics problem	3489	4.23	1.38	1655	4.17	1.46	1824	4.28	1.29
**I don't need help with physics	4900	3.37	1.52	2243	3.82	1.53	2639	2.99	1.40

Notes: ** significant at .001; * significant at .01; N (number); M (mean); SD (standard deviation) ; comparisons between girls and boys.

For some of the items in Table 3 there were statistically significant differences in responses between boys and girls, with boys reporting more positively about questions around physics. *Usefulness of physics:* Boys were more likely to report that: physics is a useful subject (t=10.021, p<.001); physics is more likely to to help them get into jobs they want to do in the future (t=12.196, p<.001); physics teaches individuals to think logically (t=5.270, p<.001); physics helps individuals to solve everyday problems (t=6.697, p<.001); physics is important in making new discoveries (t=5.243, p<.001); people who are good at physics get well paid jobs, (t=5.655, p<.001).
Self concept in physics: Boys were more likely to report that they: are good at physics (t=20.625, p<.001); do not need help with physics, (t=19.821, p<.001).
Liking of physics: Boys were more likely to report that: physics was an interesting subject (t=14.372, p<.001); they found physics interesting (t=13.753, p<.001); these days everyone needs to know some physics (t=2.102, p<.05); it is interesting to find out about the laws of physics that explain different phenomena (t=8.915, p<.001); physics is a useful subject (t=10.021, p<.001).
Physics and social skills: Boys were more likely to report that physics: improves individuals social skills (t=3.682, p<.001); makes individuals popular (t=6.671, p<.001).
Doing physics: Boys were more likely to report that: to be good at physics individuals need to be creative (t=12.508, p<.001); those who were good at physics were those who were clever, (t=3.379, p<.001). Interestingly, girls were more likely to report that there is only one right way to solve any physics problem (t= -2.275, p<.01), which if read carefully is in line with many of the findings around physics. Girls, as a group, feel disengaged with physics and this may be related to the way it is taught, with girls not feeling there are a range of ways to learn physics.

Multi-level models that explore the importance of students' perceptions in intended post-16 physics participation

Multi-level models were run in a series of stages which had particular theoretical relevance and in this paper we will present the final, best fit model (model 6) rather than models run prior to this (Table 4), though will mention in passing results emanating from earlier models that became redundant, 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.

We first established a variance components model, which indicated that 6% of the variance in intention to participate scores was attributable to differences between schools whereas the vast majority of the variance in scores was attributable to differences between students. In model 1 we differentiated between students' year groups, so that we could compare the impact of gender (when introduced in model 2). The younger students (year 8, aged 12-13) were statistically significantly more likely to express an intention to continue with physics in post-compulsory education. Model 2 showed that the gender gap between girls and boys in their intentions to continue with physics post-16 were larger for year 10 students than for year 8 students. Such differences continued after adjusting for students' age 11 (key stage 2) prior attainment scores and current conceptual ability in physics (in model 3), suggesting that even after controlling for students' attainment levels, boys were more likely than girls to express an intention to continue with physics post-16.

In model 4, we introduced items that explored students' perceptions of their physics teachers and found that even after adjusting for prior attainment, age and gender the following items were significant: 'my teacher thinks I should continue to study physics after the age of sixteen', 'my physics teacher is good at explaining physics' and 'my physics teacher is interested in me as a person'. However, in the final model it was only the last of these items that remained significant after controlling for physics extrinsic material gain motivation. In model 5, we introduced items that tapped into perceptions of physics lessons. Enjoyment of physics lessons was the only item that had a significant influence on intended participation in the final model. Though we saw the influence of prior attainment lose significance, we note that the influence of gender remained important in the final model and that this influence was stronger in the year 10 cohort than in the year 8 cohort.

In model 6 (our final model) we explored the influence of the items that measured students' perceptions of physics and within this grouping the following items were found to have a significant influence on intended participation: 'I think physics is a useful subject'; 'I think physics is an interesting subject'; 'I think physics will help me in the job I want to do in the future'; 'I am good at physics'; and 'I don't need help with physics'. Table 4 shows that the majority of the items that explain intended participation are those to do with perceptions of physics rather than ones to do with perceptions of teachers or of lessons (because at this point the great majority of items that were significant in previous models lost significance or had a weaker influence). Although teachers' encouragement of students continuing 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 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.

Table 4: Factors that shape intended participation amongst year 8 and year 10 students

Fixed effects	Coefficient	Standard error
Intercept	3.514	0.03278
Year 8 or 10	-0.28	0.03
Gender (female)	-0.13	0.00
My teacher thinks that I should continue with physics beyond my GCSEs.	0.11	0.01
I enjoy my physics lessons.	0.09	0.01
I think physics is a useful subject.	0.20	0.02
I think physics is an interesting subject.	0.14	0.02
I think physics will help me in the job I want to do in the future.	0.40	0.01
I am good at physics.	0.08	0.02
I need help with physics.	0.02	0.01
Random effects variance	0.269	0.056

CONCLUSIONS AND IMPLICATIONS

An item analysis rather than a construct analysis found support for the importance of extrinsic material gain motivation on intended participation in physics. In addition the analysis showed that amongst the perception of teachers items, teachers' belief in individual students continuing with physics post-16 is the most strongly associated item with intended participation. This item was a significant predictor in the final multi-level model even after controlling for physics extrinsic motivation. Other items within the 'perceptions of teachers' cluster that were somewhat important in intended participation were teachers being good at explaining physics and teachers taking an interest in students as people (for both boys and girls). The multi-level findings indicate that enjoyment of physics lessons (intrinsic value), seeing the relevance of physics (extrinsic value) and students feeling they do well in physics are related to intended participation. There is a strong influence of gender on intended physics participation and the gender gap in perceptions of teachers, lessons and physics increases as students get older. These findings point toward recommendations to continue to promote and fund interventions, initiatives and practices that take into account of and attempt to reduce gender differences.

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