Why should women take a chance on physics?

A case study of Access to Medicine students' views on the issue at a College of Further Education in England

Abstract

Girls opt out of studying physics post 16 more than boys because, as a minority, they need to overcome the barrier of entering a male dominated discipline.

Through adolescence, for young women the challenges which all learners of the subject encounter through the school curriculum intertwine with the need to construct a feminine identity, which is in conflict with the male dominated discipline.

The lack of co-ordinated career guidance from schools and colleges is compounded by the lack of career guidance and encouragement from the personally influential (such as family members) which prevents this cycle from being broken.

Primary research question

Why are girls in particular opting out of Physics post 16?

The use of the word girls and women in the research title and question are both used deliberately to emphasise that upon leaving compulsory education, school girls may chose not to study physics post 16 whilst they are simultaneously becoming young women.

The use of the words *girls* and *women* are thus synonymous with *female*, the biological sex at birth.

However in order to attempt to answer such a question one must also have an understanding of gender, which "is conceptualised not as a trait of the individual but as something that is created and negotiated by the individual in response to a specific social setting. The aim of such a post-structural analysis is, as argued by Davies and Gannon, 'not to document differences between men and women, but to multiply possibilities, to demassify (sic) ways of thinking about "male" and "female"' (2005, 319)." (Danielsson, pp3 – 4, 2011)

Hence like Danielsson (2011) "Inspired by a post-structural understanding of gender I am in this article aiming to portray the nuances in the students'doing of gender." (pp3 - 4)

Purpose and justification of the research

Through my involvement in the Stimulating Physics project from the Institute of Physics (IoP) it became apparent to me that not only is physics a shortage subject, but if there were as many girls studying it post 16 as boys there would not be this shortage. However, "We still do not have research based understanding of why gender has such a profound impact on the choice of physics post 16 in England." (pV, Murphy and Whitelegg, 2006) Although it has been suggested that social stereotyping is influential. (Measor, p17,1983). "There is little information available about girls' experiences of science and physics in schools in England and how this informs their attitudes and future aspirations." (pVI, Murphy and Whitelegg, 2006). Extending this issue to Sweden Brandell and Staberg (2008) put it "Opting out from mathematics at upper secondary level can even become an obstacle for later study choices and success in advanced level studies. Knowledge of women's reasons for choosing or not choosing mathematics is important if we are interested in recruiting more women to mathematics, science, technology and other mathematics intensive domains." (pp495 - 496)

Having surveyed adults on the 'Access to Medicine' course at a College of Further Education in England I aim to shed light on why students, who have come back to physics study, were turned away from it earlier on in life.

In these times of high student and national debt it makes economic and educational sense to recruit more students for physics, a shortage subject, to develop the knowledge and skills base required by employers to grow Britain out of near recession.

My position

As there are fewer women studying physics than men it makes sense to encourage more women to study it and to increase the overall numbers of physics students, whilst also transforming a masculine physics society into a more feminine one. *Masculine as opposed to feminine cultures* "strive for maximal distinction between what men are expected to do and what women are expected to do". (Hofstede, G., p75 -89, 1983). I advocate a more gender neutral society that is equally represented by the preferences of both sexes, not a society built on the preferences of women over those of men.

Fundamentally I advocate an egalitarian society on the grounds of morality, whilst realising that more women in physics means more people in physics, which has the potential to grow physics as a subject within the post-compulsory education sector and subsequentially provide more graduates for industry that can grow the country economically.

So although my view as a *pragmatist* is primarily to allow a physics society to emerge that is balanced on the grounds of sex and hence increase the total number of people involved in it, I also argue that a *feminist* approach to transforming British physics society from masculine to feminine is advantageous for society at large.

Like Schacht, (2000) I would describe myself as a *male heterosexual feminist* by which I mean that I favour women being held equally high in society as men; not women becoming dominant over men.

However although it is necessary to define myself in terms of the definitions used by other writers in order to lead to a common understanding, I must admit that the labelling of the *equal society* as *feminine* and myself as a *male heterosexual feminist* makes me feel uncomfortable for the reasons that follow. By being male Schacht (2000) would argue that I was born into the role of the *oppressor* as opposed to the *oppressed*. My claiming to be a *feminist* may therefore be opposed by some *female feminists* on the grounds that I cannot ever know what it is like to be a woman who is oppressed and therefore cannot further a cause to bring women out of such oppression. However although I agree that I like other men cannot ever know what it is like to be a woman, my choice to affirm my *heterosexuality* in such a definition of myself demonstrates the inherent fear I have of other men, as I can be more comfortable without the fear of *homophobic persecution* through misinterpretation. By recognising that more men may misinterpret my claiming to be feminist as selling out men to the dominance of women I further demonstrate my fear of the *oppressor*. Furthermore, by being male, I am able to challenge the prejudices of other males because I may well be listened to precisely because I am not a woman, attempt to limit or reduce oppressive behaviours and potentially begin to convert some men to feminism. Like Schacht (2000, pp9) "I believe both the oppressed and the oppressor must form alliances across difference to create an egalitarian future (Bystydzienski and Schacht in press)."

Moreover the discomfort I experience in negotiating a *male feminist* identity in middle age emphasizes to me that identity is constructed and even continuously evolves, as by looking back on the discomforts of my own adolescence, be that as a male, allows me to acknowledge that those females choosing to be or not to be physicists may well find the process difficult, even though I will never know how it actually feels.

The case

Written statements from 17/ 22 students on the Access to Medicine Level 3 diploma 2011 - 2012 at a College of Further Education in England form the basis of the qualitative data used in this research. However pre-existing quantitative data is also drawn upon in the introduction from AS and A2 physics students at a school 6th form and first year physics and chemistry undergraduates at a university in another county in England 2007 - 2008. Qualitative statements from Sally, an A2 student at the 6th form are also used. This allows for students views to be represented across time and educational sectors, but also enables a critique of the methodology using quantitative and qualitative data when attempting to answer such a research question.

The approach

The qualitative statements from the students on the Access to Medicine level 3 diploma course 2011 - 2012 form the basis of the enquiry as this is where true insight into individuals views are found and allows the issue to be explored.

However as the quantitative data from 2007- 2008 was already available it made sense to analyse this in advance so as to first check if any findings suggested questioning in an area not already considered, or so as to clarify any ambiguous findings.

For this reason although quantitative and qualitative data are both used in this research I avoid using the term 'mixed methods' (Bird, 1992) as the approach in methodology is fundamentally qualitative in nature as it attempts to explore meaning rather than measure it.

Therefore it is suggested that findings from the qualitative data should be given most attention in the reading of this article, and that the quantitative data is used at the start as it was obtained earlier and analysed prior to the writing of the qualitative survey so as to be able to inform it before issuing it to students.

Methods, How I got the data.

Both the quantitative and qualitative data were obtained through issuing questionnaires to students in their usual classroom sessions. This allowed for maximum return and completion whilst also allowing me to clarify questions. The qualitative questionnaire was made up of several open ended questions that would enable students to write their views at length. Being in the classroom meant that I could listen to discussions between the students and encourage them to elaborate on their responses as required.

Quantitative

With no research question clearly defined, I set out in 2007 -2008 to acquire quantitative data to enhance the cause of the national Stimulating Physics project, to encourage more learners to pursue physics at A-level and degree level.

A quantitative questionnaire was prepared (Appendix 1) modelled on those used by Reid (2006) to investigate why students are attracted to and also drop Physics post 16.

The questionnaire was issued to 1st year undergraduate Physics students, 1st year undergraduate Chemistry students at the university & Year 12 &13 A-Level Physics students at the school.

The initial intention had been to categorise on subject presently being studied, year of study and gender to identify patterns of responses between subject-year-gender categories. The limited number of respondents 37 males and 20 females meant that looking for patterns between genders alone would be unable to determine statistical significance and therefore it was certainly inappropriate to look for patterns also across educational sectors and year groups.

For this reason responses from individuals in different year groups at the school and different degree courses at the university have been combined so as to only compare and contrast different responses from each sex, as this also attempts to answer the re-defined research question.

Quantitative data was entered into spreadsheets in Microsoft excel to produce bar charts.

Limitations in the findings from the quantitative data meant that I learnt the lesson of needing to use a type of data that fits the research question.

Findings from the quantitative questionnaire to give food for thought for further enquiry

Question 9

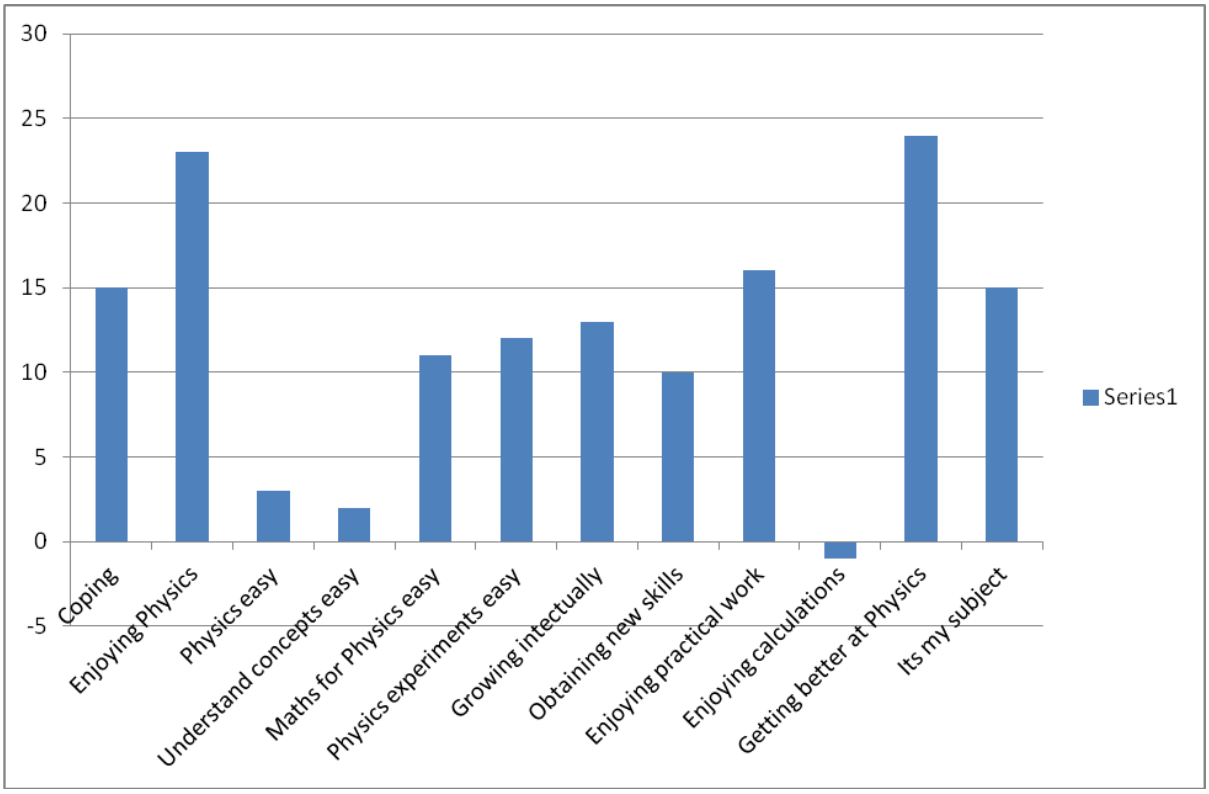
What were your opinions about the Physics you studied prior to your present course (Consider the most advanced course if you studied it beyond GCSE otherwise consider GCSE)?

Place a tick in one box between opposite phrases to indicate where your opinion used to lie.

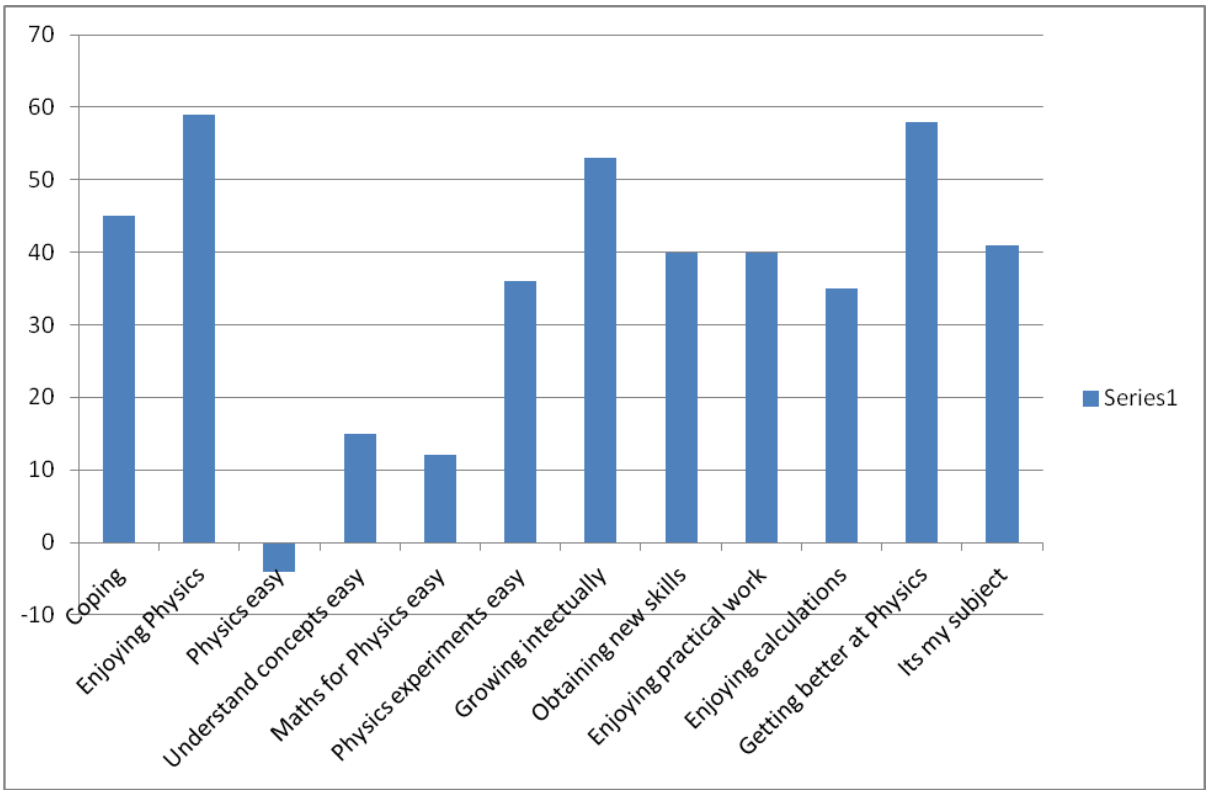
I felt I coped well							I felt I did not cope well
I did not enjoy the subject							I enjoyed the subject
I found the subject easy							I found the subject hard
The concepts in physics were difficult to understand							The concepts in physics were easy to understand
The maths for Physics was easy							The maths for Physics was difficult
The experiments in Physics were difficult							The experiments in Physics were easy
I grew intellectually							I did not grow intellectually
I did not obtain new skills							I obtained new skills
I enjoyed practical work							I did not enjoy practical work
I enjoyed calculations							I did not enjoy calculations
I got worse at the subject							I got better at the subject
It was definitely my subject							I was wasting my time in this subject

Each item on the *Osgood* scale as used by Reid (2006) was scaled -3,-2, -1, +1,+2, or +3. Zero was not an option, to ensure that respondents did not choose the central scale point on each item i.e. this aimed to force a decision, as opposed to avoiding one. Positive and negative statements were randomly alternated between the left and the right of the grid so as to force respondents to read the item and select a choice, again in an attempt to avoid the temptation to tick repeatedly down one column, to arguably summarize their views for faster completion. This meant that on some items the far left box corresponded to +3, whereas on another item the far left box corresponded to -3. The positive statements were put into the spreadsheet with numbers then applied so that +3 meant 'most positive agreement' and -3 meant 'most negative disagreement'. The frequency of response to each part of the discrete scale was then multiplied by the scale value and then all of these products were added together to indicate the overall collective response of each gender to the item. The overall collective response is what is plotted on the vertical axes of the following bar charts.

Female responses



Male responses



Findings from question 9

Generally there is little difference between male and female responses to each item.

Both genders suggest, “Maths for Physics easy”, though with about half as many females as males in the sample the comparable ‘overall collective responses’ of about 12 suggest that females arguably find the “Maths for Physics”, twice as easy as their male counterparts.

In contrast males appear to “enjoy calculations” whereas females slightly don’t “enjoy calculations”.

Perhaps this suggests that females feel confident in their abilities to do the “Maths for Physics” which they don’t particularly enjoy, whilst the males may be less confident in their mathematical abilities but are more likely to take the risk of doing physics because they enjoy doing calculations.

However what may be more striking from this research is that we cannot really ever ascertain truthful meaning of such subjective concepts as “confidence”, “ease” and “enjoyment” from an objective questionnaire. That said, it made me think about questions to probe in a more qualitative approach.

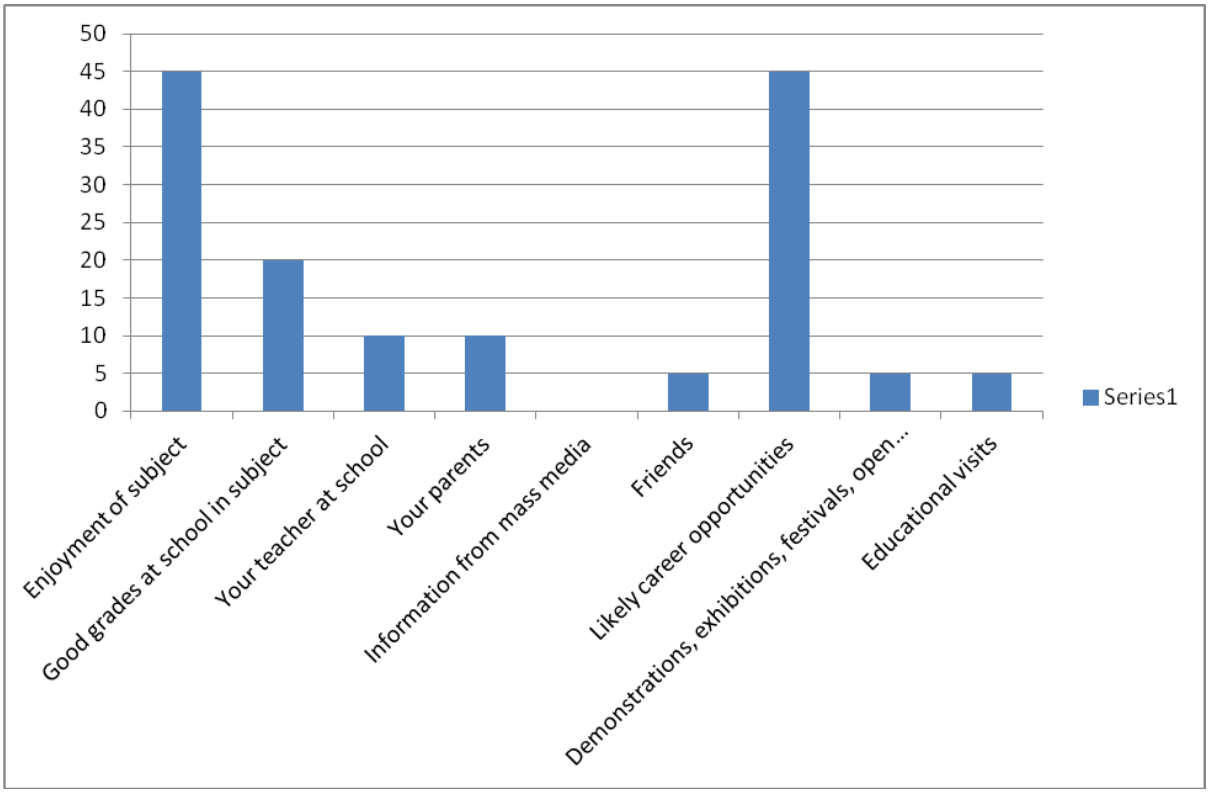
Question 7

Which factor(s) influenced your choice of subject(s) that you presently study?
Tick as many as you wish.

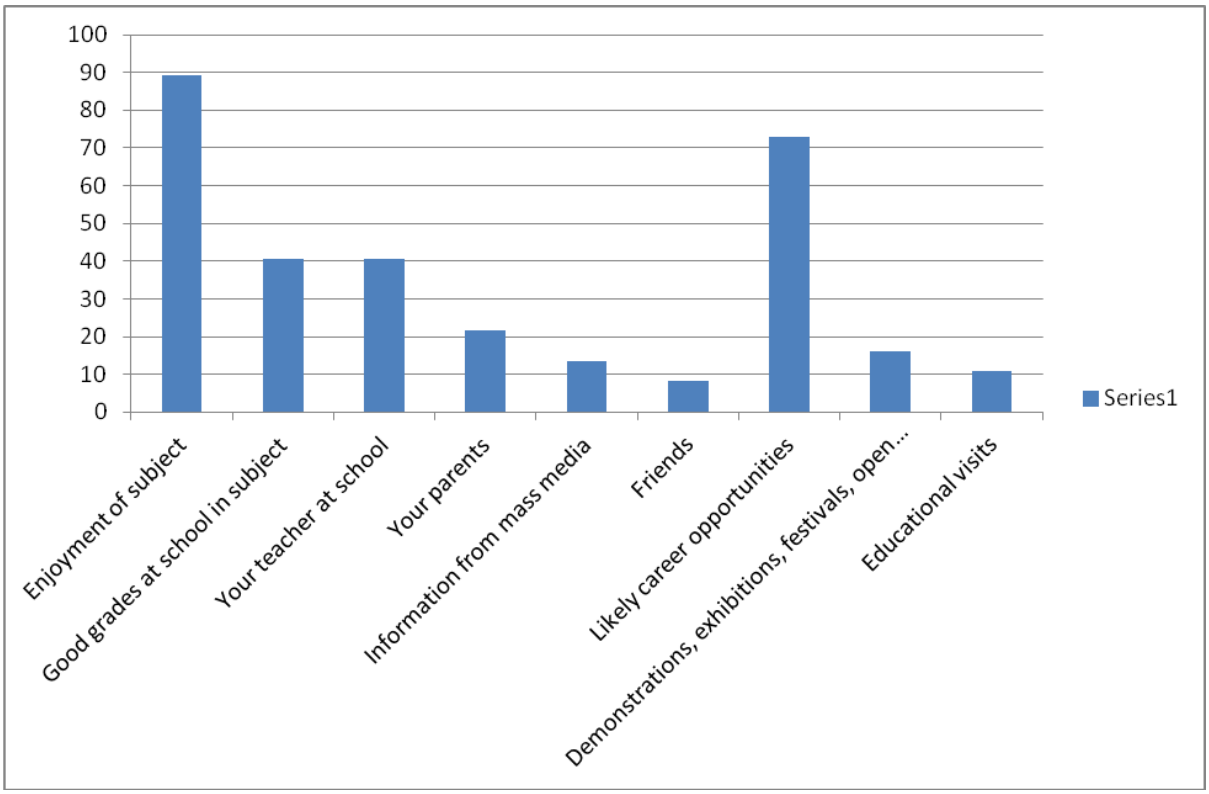
- Enjoyment of subject
- Good grades at school in subject
- Your teacher at school
- Your parents
- Information from mass media
- Friends
- Likely career opportunities
- Demonstrations, exhibitions, festivals, open evenings
- Educational visits
- Any other factors (please list).

The vertical axes on the following bar charts show the percentage of respondents which selected each statement.

Female responses



Male responses



Findings from question 7

Generally there is little difference between males and females.

The main reason for choosing a subject for both genders was “enjoyment of the subject” and “career opportunities”.

Both factors were equal for females, “career opportunities” 45%; “enjoyment of the subject” 45%.

For males “enjoyment of the subject” at 88% may cautiously (without statistical significance) be more influential than “career opportunities” on 73%.

Males’ selection of factors influencing their choices of subject appear more polarised than those selected by females, i.e. females select a wider spread of different factors.

Parents and teachers appear to be more influential on males’ choices of subject than those for females. Is this due to there being more male role models? Is it due to females choosing most categories so as that there no obvious factor which stands out for them, whereas males limited their selection?

The influence of friends appears comparable for the genders but also minimal.

These findings in relation to friends’, teachers’ and parents’ influences contradict those from the qualitative data which follows, for which I would attribute greater trustworthiness.

“Good grades” was selected by 40% of males and 20 % of females, but who defines “good”? Could a greater disparity of grades for males give a more obvious better and worse?

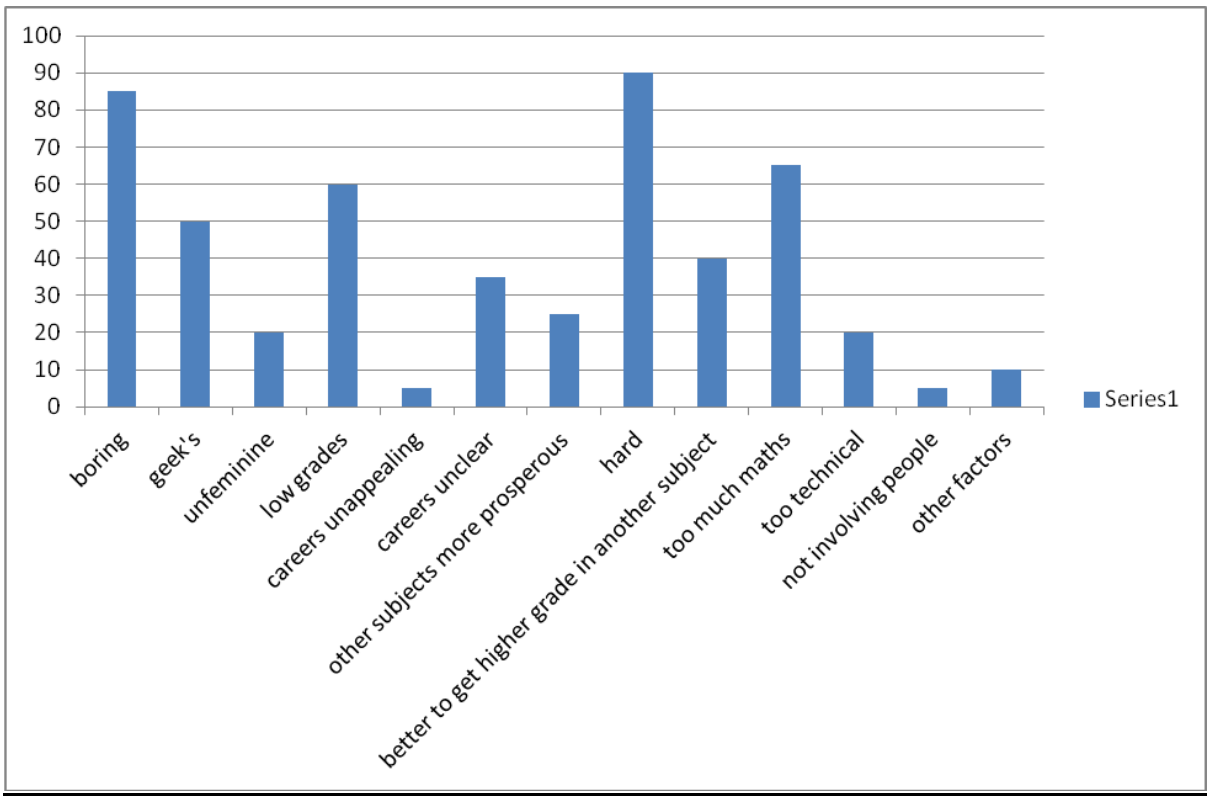
Media, exhibitions and visits appear to have little influence (particularly for females).

Question 13

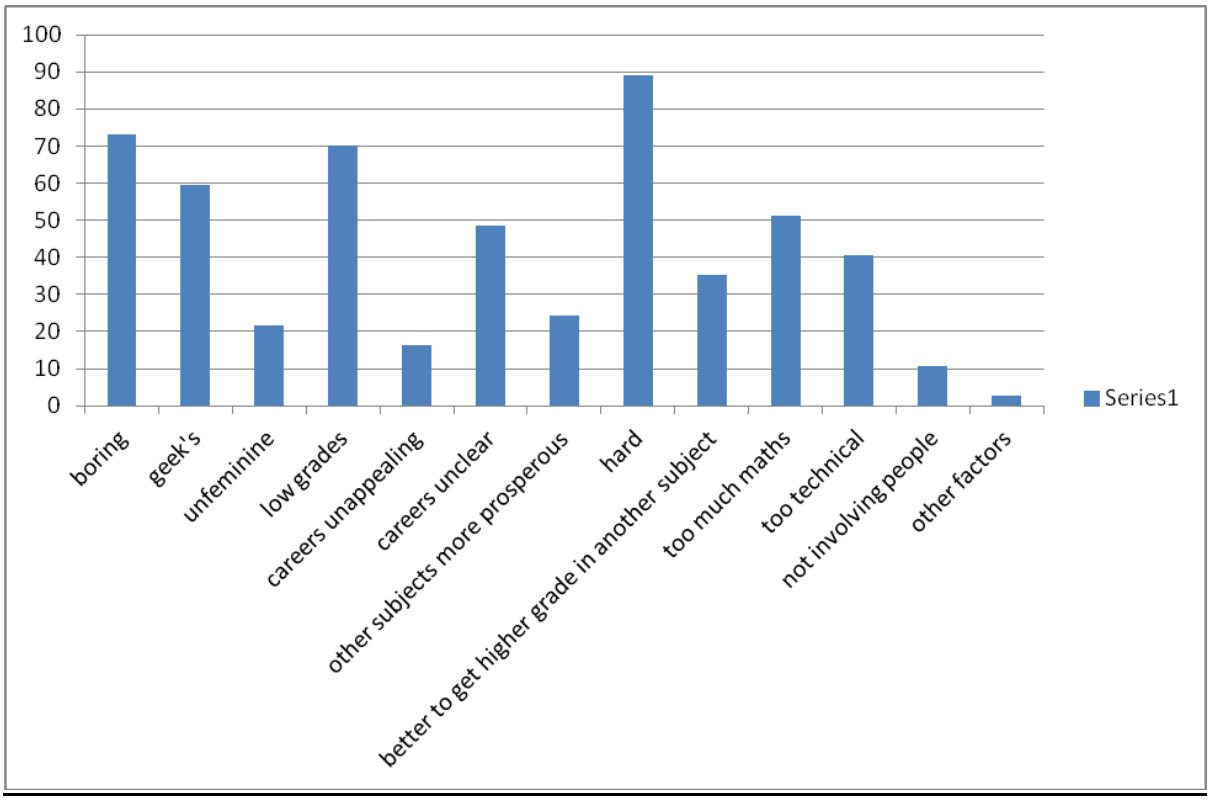
Which factor(s) do you think influence people to choose not to study Physics?
Tick as many as you wish.

- Perceived as a boring subject
- Perceived as a geek’s subject
- Perceived as an unfeminine subject
- Got low grades at school in the subject
- Career opportunities unappealing
- Career opportunities unclear
- Other subjects offer more prosperous career paths
- Perceived to be too hard
- Its considered better to get a higher grade in another subject than a lower grade in physics for the same effort
- Perceived to require too much Maths
- Perceived to be too technical
- Perceived to not involve people
- Any other factors (please list)

Female responses



Male responses



Findings from question 13 Virtually no difference between genders.

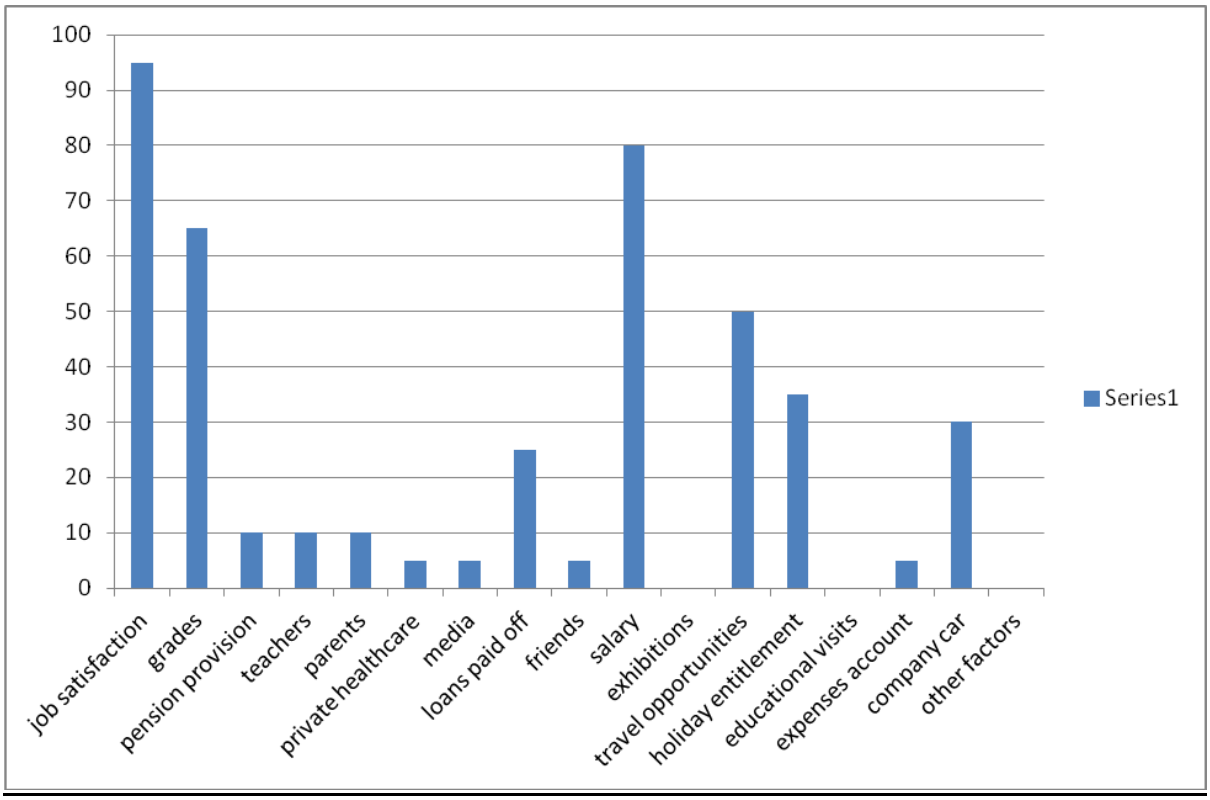
Question 18

Which factor(s) will influence your choice of career?

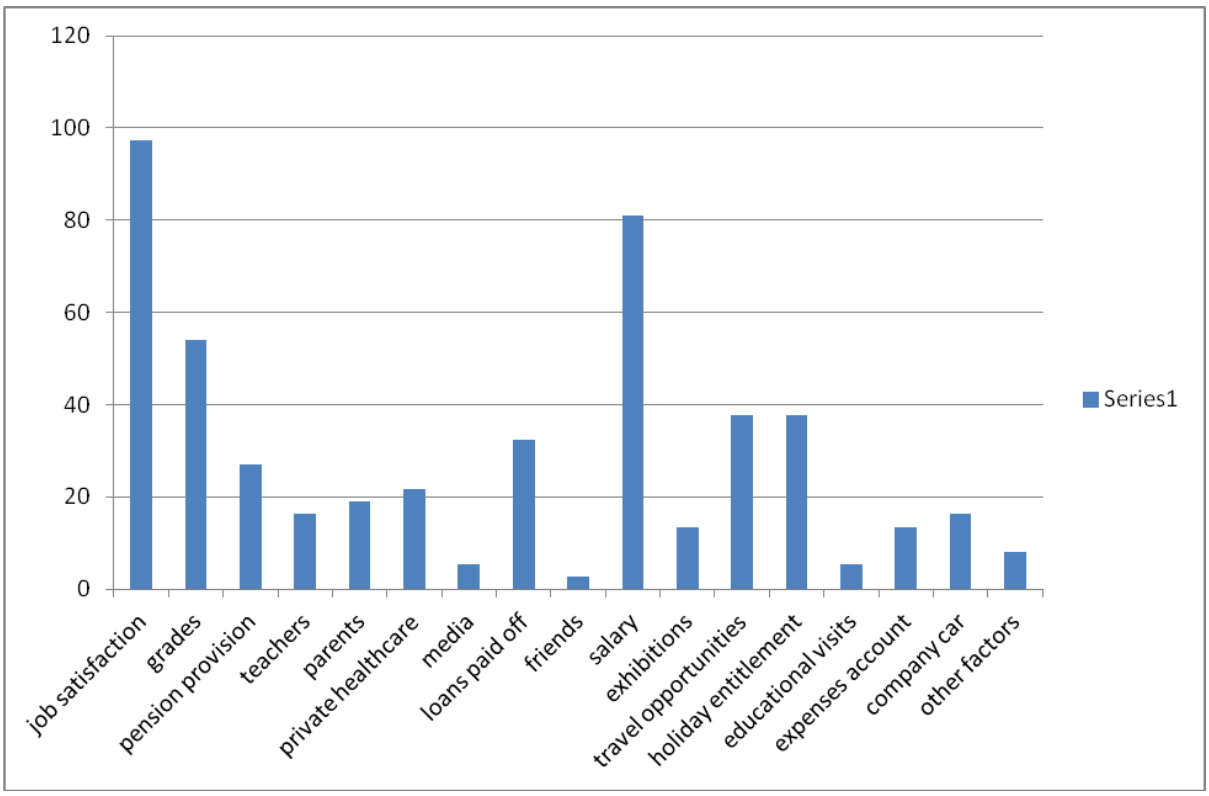
Tick as many as you wish.

- Job satisfaction
- Grades at school and/ or university
- Pension provision
- Your teachers/ lecturers
- Your parents
- Private healthcare scheme
- Information from mass media
- Student loans being paid off in full by company or government
- Friends
- Salary
- Demonstrations, exhibitions, festivals, open evenings
- Opportunities to travel
- Holiday entitlement
- Educational visits
- Expenses account
- Company car
- Any other factors (please list)

Female responses



Male responses



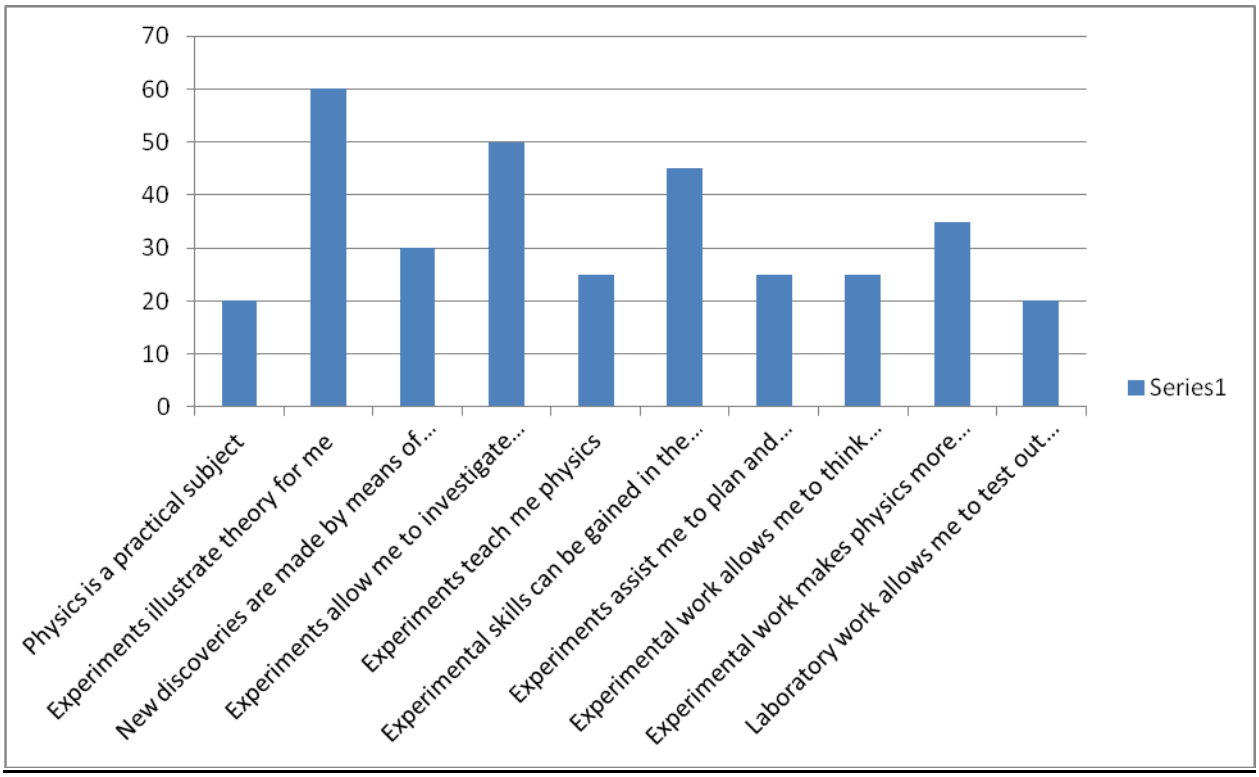
Findings from question 18 Virtually no difference between genders.

Question 24

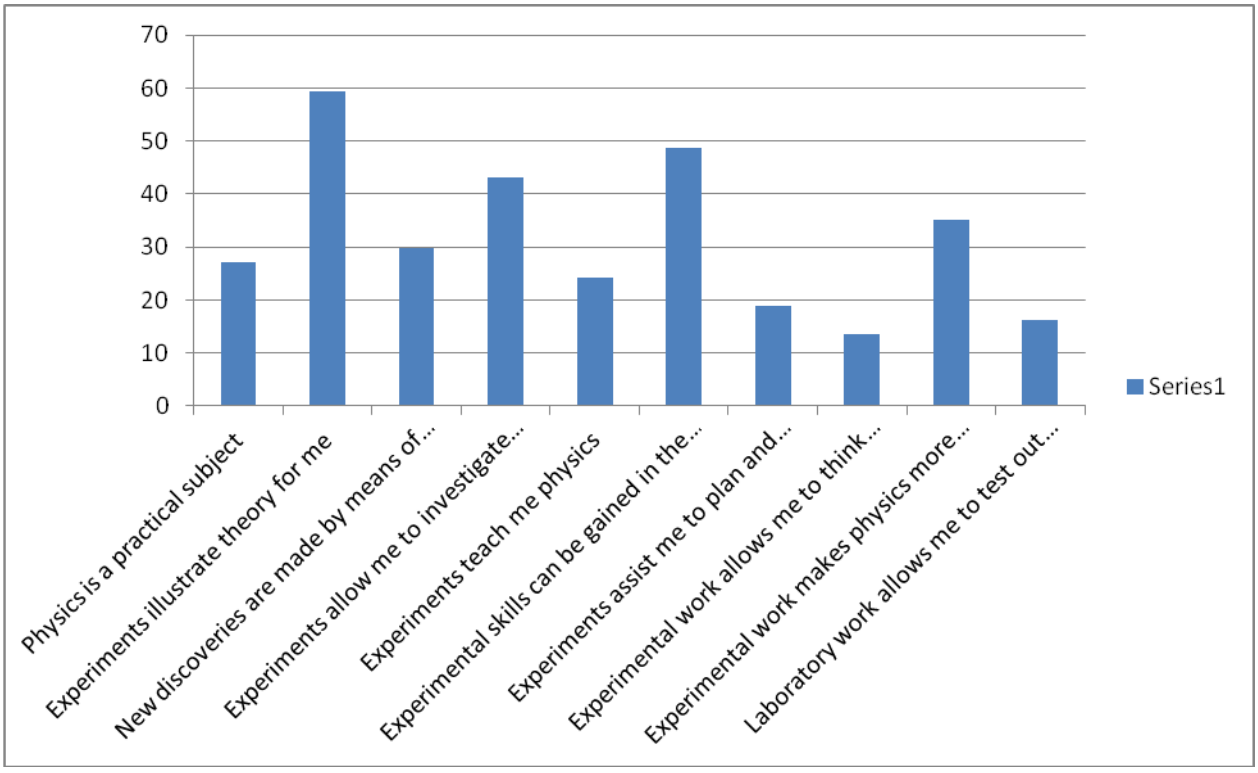
Here are several reasons why experiments are carried out in the laboratory for courses including physics. Place a tick against the THREE reasons which YOU think are most important.

- Physics is a practical subject
- Experiments illustrate theory for me
- New discoveries are made by means of experiments
- Experiments allow me to investigate physical laws
- Experiments teach me physics
- Experimental skills can be gained in the laboratory
- Experiments assist me to plan and organise
- Experimental work allows me to think about physics
- Experimental work makes physics more enjoyable for me
- Laboratory work allows me to test out ideas

Female responses



Male responses



Findings from question 24 Virtually no difference between genders.

Qualitative - The responses

The open ended qualitative questionnaire (Appendix 2) was issued in the classroom meaning that 17/ 22 students from the class completed it. Others were either absent or opted out on the grounds of wanting to study for a Maths assignment. Although it was somewhat disappointing that not all students engaged with the questionnaire it was also reassuring when 4 students from the other practical group turned up having missed their own session, showing that they had made extra effort to be engaged with the research. Hence the statements can be taken to be fairly representative of the views of the class as a whole.

Pseudonyms are used to protect respondents' anonymity. They were chosen by themselves so as to avoid a name being imposed upon them by their teacher-researcher as they may not have otherwise have liked it perhaps because it might conflict with their preferred identity.

Asking students to complete the questionnaire in class also allowed me to elaborate on what the question was asking if they needed further clarification in order primarily to encourage completion and elaboration from them. One example was Cornelius , who asked, "You don't want an essay?", "Yes!", I joked. Further elaboration ensued with prompting and explaining the need for it. The students were on the whole supportive and co-operative. However in the case of Olivia, it also allowed me to re-assure her that the statements in question 8 which she didn't like because she found them stereotypical were not my views and with clarification she felt more at ease and then wrote at length.

It also allowed complimentary verbal qualitative statements to emerge which I noted in a diary. Olivia, was one to make such a statement. She expressed that, "it was more subtle than that, people influence gender stereotyping without realising they are doing it". She asked me about my own kids and how I play with them. I acknowledged that this question made me feel uncomfortable as that on the survey had made her. Openness and honesty allowed discussion to occur. I told her about how my children play and gave examples, but acknowledged that I agreed with some of her written statements.

Another verbal statement from Cornelius was that he would feel uncomfortable entering a profession that was female dominated.

Another reason for completing the questionnaire in the classroom was to encourage the students to engage in discussion before writing their responses. What surprised me (though with hindsight should not have because they are educated adults) was that initially they wrote silently and I had to hold myself back from intervening to promote discussion. The written responses were fine as they were and gradual gentle prompting was enough to encourage discussion where it would be beneficial without interrupting their trains of thought.

Another benefit of having carried out the survey in the classroom was in effect a means of piloting it for possible use in a larger research project to follow on from this study. Some feedback from the students was that Q1 and Q5 seemed to them the same. This meant I could clarify my different intention of meaning in order to solicit appropriate and complete response but also allows this to go on the record should the questions need modifying, changing or adapting in the future.

Category construction

Once the students had been surveyed, I read through all of the responses and noted down themes and categories that emerged in my research diary.

Next I got pieces of graph paper and folded them and wrote on them the name and number of the themes and categories which had emerged.

I then read through all the responses again and photocopied each page that had a statement on it that fitted the category and inserted them within the graph paper category. The specific statement for the category was also circled on the photocopy so as to extract it later for typing up.

Each graph paper that wrapped around a category was then spread out on a work bench in the laboratory, so that there was space for me to sort and look at the categories holistically to gain a view on how they appeared to be similar and different. In order for further thematic analysis to take place it was essential to then make a 'categories' diagram so as to record the category construction under themes as a fixed image so as to build structure into the report from the outset. A simple single page word document with text boxes sufficed as it made sense of it to me. The category names were then cross checked with each other in order to make sure that there wasn't any duplication of categories. It was judged that two categories were too similar to be separate categories and so were merged, all other categories remained unchanged.

There were 4 general themes which emerged, 'Masculine Society', 'Curriculum', 'Guidance', and 'Identity' each of which were subdivided into categories totalling 12.

Feminine Society

Curriculum

C1 The uninspiring National Curriculum

C2 The teacher

C3 The practical

C4 The Maths

Guidance

G1 Lack of career guidance from the state

G2 Lack of encouragement from the personally influential

Identity

I1 Identity construction through adolescence

I2 The parents – who are they to think they have influence?

I3 The nerdy geeks are doing it hard on their own!

Masculine Society

Hence my argument was born: ***Curriculum, lack of guidance and the construction of identities through adolescence re-enforce the traditional masculine society for physics as opposed to transforming it into a more feminine one.***

The themes:

MS) The foundation theme: Physics is a masculine society as it has always been historically in Britain. Subject choices are made by students in the post-compulsory education sector which assure the status quo.

This continues because of the following parallel themes:

1) **Curriculum**
2) **Guidance (or the lack of it)**
3) **Identity**

MS) Fundamentally women choose not to study physics because they have more at stake and need to take more risk than men.

This is supported by Danielsson and Linder (pp138, 2009) "we agree with Byrne (1993) in her claim that the masculine, disciplinary culture of science is likely to be the greatest barrier for those adolescent girls who want to be seen as 'feminine', to pursue a career in science."

Whilst adolescent males and females construct their identities, females who choose to enter the male dominated arena of physics are presented with conflict between their gender identity and career choice whilst males are not. Females choosing to study physics may feel they don't belong in a community of males, may feel intimidated or uncomfortable at being the minority sex and may be concerned that their image may be perceived as unfeminine by their peers. For males the opposite it true. Choosing physics allows them to be comfortable in an environment with other males, whilst confirming their masculinity as perceived by peers in society.

This is supported by Danielsson and Linder (pp133 -134, 2009) drawing "on Wenger's notion of identity for an elucidation of how an individual student's joining a learning community becomes affected by the gendering of the practice." Furthermore "Viewing gender manifestations of communities of practice allows us to consider how the students constitute physicist identities in relation to their sense of being male or female; their memberships in certain masculinities and femininities."

Put simply women must be more committed, determined or convinced to choose physics as they have more to lose in their gender-identity construction.

Each of the themes are sub-divided into the following categories:

Curriculum	Guidance	Identity
C1 The uninspiring National Curriculum	G1 Lack of career guidance from the state	I1 Identity construction through adolescence
C2 The teacher	G2 Lack of encouragement from the personally influential	I2 The parents – who are they to think they have influence?
C3 The practical		I3 The nerdy geeks are doing it hard on their own!
C4 The Maths		
Masculine Society		
MS 1 Conforming to the status quo	MS 2 Most physics icons in history are male; there are fewer females to inspire more of them.	MS 3 Boys toys

MS 1 Conforming to the status quo

13/17 of the students surveyed suggested that the reason why fewer females choose to study physics than males is that they effectively make gendered choices that support the status quo, a male dominated physics community.

Uncomfortable, intimidated, segregated, put off

Two of the students simply made reference to physics and related careers being male dominated.

Isabelle wrote, “jobs that are available after physics are stereotypically more male orientated.” Whilst Daisy put it, “Physics may be related to other typically male careers, e.g. engineering.”

This image that these young women perceive is hardly surprising as there are more men in physics and engineering hence the reason for this research project.

However others attempt to explain why.

Mary wrote, “Many careers associated with physics like electricians and engineers are traditionally male based. Females going into an all male setting may feel uncomfortable or segregated.”

Peter wrote, “Many females may feel daunted by the prospect of studying physics, only to progress to male-dominated occupations, such as engineering”.

Sasha wrote, “Physics may have the image of being studied predominantly by males (putting females off). Jobs are normally done by men after studying physics – e.g. electricians/ physicians/ physics teachers.”

Cornelius wrote, “Perhaps certain careers have a very low number of females, careers which may require maths and physics. The reasons females are underrepresented in certain careers may be varied. They could be made due to the points made above or those below, but no doubt could put off females that are able in the subject but do not foresee a career in a male dominated profession.

Jeff wrote, “Physics leads on to (traditionally) more male centred jobs – engineering etc. Past industry and trends have led to this male focussed industry often being intimidating for women who wish to enter it.”

Alex wrote, “It would be a suspicion of mine that an already male dominated subject is less appealing to females than a sex neutral subject. This has something to do with fear of intimidation or isolation within a class. Causation is result and result is causation. Culturally adopted stereotypes of social ‘roles’ between sexes are still very apparent in children.”

This suggests that the mere presence of more males than females in a subject of study such as physics and related working environments is enough for many females to be put off from such a career path for fear of feeling uncomfortable or even intimidated by men. This ensures continuing segregation.

Overall this is best summarised by Olivia, “I also think that a lot of the jobs that physics leads to (engineering, industry, even academia) are male dominated and this can further put off a female from choosing it as a subject of study at a higher level. This ‘de-selection’ of physics could be because they might not necessarily want to work in ‘laddish’ environments or/and a perception that even if they studied it at a higher level they might feel that as a woman they are unlikely to get the jobs or even feel less respected within the work environment.”

Indeed it makes sense that women attempting to construct a feminine image may not want to associated with ‘laddish’ environments. However Danielsson (pp7, 2011) refers to Ann who” describes her previous workplace as very ‘laddish’ and is letting this workplace [the physics lab] represent ‘masculinity’ in a broader sense. Thus, for Ann, the somewhat less man-dominated physics does not come across as particularly masculine, thereby demonstrating the relational nature of gender.” (pp7)

Furthermore Cecilia’s “rejection of ‘traditional femininity’ is also explicitly expressed through repeated descriptions of herself as ‘laddish’. On the one hand, this non-participation in traditional femininity serves the same purpose as for Ann; by drawing on a discontinuity between traditional femininity and physics they are able to position themselves as non-participating in one and participating in the other. But not only that; through her participation in physics Cecilia is also able to participate in a particular kind of masculinity. Thus, by her participation in physics she simultaneously constitutes her own gendered physicist identity and the community of practice as gendered.” (Danielsson , 2011, pp12) “Cecilia’s counter-identification with traditional femininity may not challenge the masculine norms of physics, but it does challenge heteronormative understandings of all men as desiring to be masculine and all women desiring to be feminine.” (Danielsson , 2011, pp13)

Vicious circle

Whereas those males and females in the section above refer to how it might feel to work in a male dominated working environment, the following males look on it from an historical perspective.

Louis wrote, “I believe, although probably stereotypically, that traditionally men pursued more technical careers where physics was an essential element of their training where as women have traditionally chosen careers in the arts. I believe this has led to male dominated jobs, which in turn has discouraged women from pursuing those careers as they may feel they can’t succeed in those

roles. I believe that despite equal opportunities this may still be a reason why less women pursue careers where the sciences are needed."

Put most concisely, William questioned, "Physics is currently male dominated, so vicious circle continuing the trend?"

Clearly struggling to speak of how it feels to be a woman making subject choices, these men support a plausible argument by suggesting that physics became a male dominated discipline in times when British society was even more masculine than it is today, when there was clearer distinction between what roles in society men and women should take. Furthermore they point out that once this situation had been established the continued sex segregation is difficult to overcome with equal opportunities legislation alone.

Real life?

There may be an issue with how people perceive physics, its relevance and what it's used for. To me it seems that Lyra's statement which follows, shows an anglicised confusion of the term engineer, which many often associate with the man that fixes things, like a car mechanic.

She writes, "Physics is greatly maths orientated and associated more with 'how things work'. Generally male interests surround this area more –for instance 'fixing things' is something males tend to enjoy. In a nuclear family it has generally been seen that men fix things around the house and car and females perhaps sew, cook and clean. Although times are changing, when considering boy and girl interests at a young age, generally males enjoy building and fixing more so than females. Therefore, when it comes to physics, they associate these things they are interested in with what they are learning in Physics, i.e. electricity, mechanics – cars to do with velocity etc."

An engineer is, "a person who designs, builds, or maintains engines, machines, or structures." (http://oxforddictionaries.com/definition/engineer?q=engineer)

Perhaps an over use of the word with reference to the maintenance of engines, machines or computers in modern English is at the expense of the origin of the word from Middle English "(denoting a designer and constructor of fortifications and weapons; formerly also as ingineer) which was in early use from Old French engigneor." (ibid)

As such the image of engineering, involving men who fix things as opposed to the people who design for a brighter future is not only distorted, and demeaning to those who have studied so hard for engineering degrees, it is also gendered and consequently may put off women in particular from considering engineering as a profession.

I would argue that in modern French society, people would associate the word engineer with the alternative definition, "a person qualified in a branch of engineering, especially as a professional: an aeronautical engineer". (ibid)

Henry suggests, "Careers based on physics are perceived as male dominated. Perhaps girls are more attracted to subjects whose subject application to daily life is clearer."

Furthermore I would advocate promoting the status of engineering in British society and perhaps one way of encouraging more women to consider engineering may be to focus on the definition of civil, "relating to ordinary citizens and their concerns, as distinct from military or ecclesiastical matters" (ibid) as in 'Civil engineering'.

Perhaps by promoting engineering as a discipline where people design homes, vehicles, infrastructure and commodities for a healthier population physics and engineering will be seen as more attractive to more people especially women.

Similarly emphasising the applications of physics in pre-natal scanning and medical physics may be a means of re-branding physics as more gender neutral.

MS 2 Most physics icons in history are male; there are fewer females to inspire more of them.

This category supports the wider theme of a male dominated physics community continuing throughout history as perhaps perceived from a British perspective. It is suggested that in the past, on the whole, science was not considered an appropriate course of study for women. Science was done by men and published by men. For this reason the historical physics idols such as Galileo, Newton, Einstein, Hawking and Cox are arguably better known than any female physicists perhaps with the exception of Marie Curie.

Equal opportunities legislations has now been passed by successive parliaments, in an attempt to promote a more egalitarian future, something which I adamantly support. However this category highlights that such legislation struggles to overcome the negative image that, *Science has and always will be done by men*.

This mirrors the findings of Hatchel (1998) who found that the girls could think of very few female scientists in history and that this reinforced science being a masculine subject, in their perceptions.

It is also worth being aware that the only two learners of the 17 in total to suggest this theme were male. Hence this theme could be cautiously described as what *some males think about females' thinking about physics*. Their accounts follow,

According to Burt, "Although I can not certain why this is the case, but physics could be perceived as a more masculine subject due to its development throughout history. Mainly male figures influenced the path of physics in a time when women were inferior."

Aaron, supports this, "Many of the pillars of physics, such as einstein, are all male. This may alienate females, they may think that they do not belong in this field."

It is my view that this point is noteworthy and that publishers and teachers should be aware of highlighting the contribution of famous female scientists throughout history. However it is my view that this should not occur to an extent by which it could distort history. By appearing to make the scientific achievements of females equal to those of males, a denial of historical inequalities could lead to the questioning of a need for latter civil rights struggles throughout history.

In short however this issue appears to influence women's choice of subject to a much lower extent than that of how the labour market and educational system in relation to physics is gendered (MS1 above).

However perhaps we should not ignore, what Staberg (1994) suggests that "the science curriculum of today is deeply rooted in boys' grammar school" and that chemistry and physics "were developed and constructed mostly by men in an environment which was and still is masculine." Furthermore, "men have the power over technology, a technology which rules our lives in many respects."(pp43). She questions, "if the differentiations and sequencing of subjects in compulsory school are better suited for boys, since boys have always been the norm for 'pupils'" whilst suggesting ""gender-sensitive education" (Martin, 1985) is more general and theoretical" and through implication may be an alternative for girls.

MS 3 Boys toys

This category supports the wider theme that physics is male dominated because of society at large. It is suggested that as a result of traditional sex roles in the work force and how boys and girls are expected to play as children, society is still re-enforcing the status quo of a male dominated physics community. As children, many of us enjoyed playing with certain toys and certain games, the further back in history our childhood was potentially the more gendered the playing was. So although many parents may well be aware that equality of play in childhood, may well be the expectation in modern society, the reality I would argue is still that boys are implicitly encouraged to play with toy cars and football and that girls are implicitly encouraged to play with dolls and go to ballet lessons. So although I would argue that parents may well less frequently explicitly tell their children how they must play, whom they must play with, what is a girl's game and what is a boy's toy, implicitly these stereotypes are still re-enforced. It may be the giving of a gift from father to son, the train set father remembers playing with his own father and would like to experience again from the other side of a comparable relationship. It could be grandmother teaching granddaughter to knit, but not thinking to offer this to grandson. In our attempts to provide our children with the childhood we so much enjoyed it is so easy to implicitly re-enforce the expectations of the bygone era. In addition if the parents of a particular child are able to always agree on how best they should bring up their children in a perfectly non-sexist way, such progressive parents cannot shelter their children from more traditional values that their children will inevitably be exposed to on television, in the playground or in society at large.

Moreover not only does the gendered notion of play and toys reinforce gender stereotypes it also arguably puts boys at an advantage when it comes to learning physics.

Denise suggests a reason fewer females chose physics than males is due to how boys choose to play through childhood, "children's inclination to play and explore (boys tend to play with Lego, trains etc, which tend to develop cognitive skills and their understanding of mechanics and engineering)."

Furthermore Henry suggests that boys' way of playing, influences not only how and what they learn, but also the informal teaching they are exposed to "Perhaps during childhood, boys ask more questions and are therefore exposed to a rudimentary level of physics as their parents attempt to explain how things work."

Alex suggests that this way of learning through childhood makes physics as a formal subject more appealing to boys "The image of physics and what it represents (mechanics, engineering, calculation) is one that appeals to boys because of their predisposed independent association with building, making and solving problems from a young age."

The following statements from Lyra and Maria link physics as a formal subject with what each woman perceives males enjoy.

Lyra states that, "Physics is greatly maths orientated and associated more with 'how things work'. Generally male interests surround this area more –for instance 'fixing things' is something males tend to enjoy. In a nuclear family it has generally been seen that men fix things around the house and car and females perhaps sew, cook and clean. Although times are changing, when considering boy and girl interests at a young age, generally males enjoy building and fixing more so than females. Therefore, when it comes to physics, they associate these things they are interested in with what they are learning in Physics, i.e. electricity, mechanics – cars to do with velocity etc."

Maria states, "I believe man enjoy much more physics and calculations, but specially practicals, I think man enjoy "playing" during practicals and the challenge, more than girls. (Maybe is due to female are more sensitive and subjective and male more pragmatic and practical). The part I enjoy the most in

physics is the theory, is reading the textbook, is understanding, discovering, I do not enjoy applying it (this is for the boy!!!)"

In these statements Lyra's "fixing" is akin to Maria's "playing"; both women expressing their perceptions of how boys prefer to learn.

A commonality amongst the statements from Lyra and Maria along with Denise, Henry and Alex is the implications that boys seem to choose to play and hence learn in a certain way that differs from that for girls.

However in contrast, Olivia implies that how children are taught and how they learn is due to, "Conditioning at a younger age → I feel that teachers and parents have a way of consciously or subconsciously enforcing the idea that physics is a boy's subject so for many girls when it is time to choose, it doesn't enter the list of subjects that they would like to choose. Even something as simple as a father playing with their children, they're more likely to show physics related games to their sons than their daughters."

Olivia thus challenges the notion of 'how and what boys choose to learn' by proposing 'what and who parents and teachers choose to teach'. Although in my opinion many parents would allow their children a freedom of choice of learning through play, perhaps as parents we should all be cautious and more frequently question and check that our offerings of toys and play are not differentiated on gender grounds through our implicit assumptions of what the boys or the girls will prefer, as this may reinforce the gender segregation of subjects in post compulsory education as adolescents construct their gender identities in parallel with choosing their career paths.

Maria's statement is important here due to her references to learning physics through practical, as she implies that she does not enjoy practical by suggesting preferring reading. I suggest that at the very raising of a questions about what each gender chooses to do in this case study physics, Maria is actually "doing gender" (Danielsson, pp2, 2011) by clearly aligning herself in the pre-determined feminine category. Later however when questioned simply about her own learning when gender is not raised as an issue her apparent contradiction in welcoming more learning of physics through practical is because in that case she is instead "doing physics" (Danielsson, pp2, 2011). This is particularly apparent to me as her teacher as it was something she also said to me at the start of the course without any prompting, having not experienced practical physics in her home country she said that she welcomed the opportunity to learn in this new way.

Furthermore, Hatchel (1998) acknowledged that although informal learning through play, has in previous studies suggested that boys are put at advantage in learning formal science, as a result of how society expects boys and girls to play, the increasing gender neutrality of play, as regards to computer games and television has been coupled with a demise in the use of boys and girls toys and that potentially this factor may be less divisive in the future.

Curriculum

Curriculum is the first of three themes (the others are guidance and identity) which provide the intertwining fibres of the thread where there may need to be change to transform the male dominated physics community into one that is gender balanced.

Marsh (pp1-3, 2009) suggests that although 'curriculum' has a Latin root meaning racecourse, western civilisation has since the 4th century has been influenced by the ancient Greek philosophers, Plato and Aristotle. So curriculum could be described as the subjects taught then, so curriculum could be interpreted as 'classics'. However through the 20th century 'curriculum' became

synonymous with 'that which is taught by the school'. This statement represents the theme. Marsh (pp4, 2009) refers to six definitions of curriculum and analyses the problems with each. The definition I run with here is that of (pp5, 2009) "Definition 1 Curriculum is the 'permanent' subjects that embody essential knowledge. e.g. the U.K. National Curriculum enacted 1988". A problem with this is that it "assumes what is studied is what is learned and does not question the change of knowledge". (ibid) "Goodson and Marsh (1996) point out that the National Curriculum in the United Kingdom is simply a reconstitution of subjects included in the secondary regulations of 1904, suggesting that historical amnesia allows curriculum reconstruction to be presented as curriculum revolution (p157)."

C1 The uninspiring National Curriculum

This category considers overarching issues of curriculum that are wider than the other more specific categories of:

- C2 The teacher
- C3 The practical
- C4 The Maths

Marsh (pp1-3, 2009) suggests that "As reported in Walker and Soltis (2004), he [Whitehead (1929) argued that "we should begin an engagement with any subject in a romantic way, feeling excitement in its presence being aroused by its attractiveness, and enjoy its company" (p44). Furthermore "Tomlinson and Germundson (2007) elaborate on the rhythm of curriculum by comparing teaching to creating jazz. The enacted curriculum for these authors is characterised by a teacher blending musical sounds 'blue notes for expressive purposes and syncopation and swing to surprise . . . to create curriculum with the soul of jazz – curriculum that gets under the skin of young learners' (p27)." (ibid)

In contrast in this category I discuss the issue of students not having felt inspired to want to do physics at A level.

Aaron writes, "My only experience of physics was at high school. I remember that we had a single teacher for all three sciences. She had a personal preference for biology, so this may have rubbed off on her students. Certain topics such as "space" were really interesting. However, I consider myself a practical learner, I like to be hands-on, this was not frequently possible in physics.

I suggest that this teacher was not alone at this time in being a non-specialist required to teach physics. It is my view that the National Curriculum amalgamated the separate science subjects of biology, chemistry and physics, blurring the distinctions between the subjects.

As the vast majority of Science teachers in secondary schools then and now are biology specialists and there were and still are fewer chemistry specialists and even fewer physics specialists the consequence of this has been that biology specialists have been required to teach physics to Key Stage 3 (KS3) and even General Certificate of Secondary Education (GCSE) where their expertise in physics may be limited, having perhaps graduated with a biological science degree and not necessarily having studied physics to GCSE themselves.

Although advocates of the National Curriculum would argue that by having all students learn all three sciences to GCSE new younger entrants to the teaching profession may now not be in that extreme position, I suggest that may have occurred in some cases past and that the present situation is there are still many non-specialists teaching physics and that this is not desirable, though with so few

people studying physics, there aren't enough graduates in physics related areas going into teaching to allow for an alternative.

As non-specialists are teaching physics they may well find it more difficult to inspire their students in it than in their own subject e.g. biology. With reference to Aaron's statement above I would argue that his limited learning through practical physics not being "frequently possible" may have been due to the non-specialist teacher not having the experience outside her specialism to organise learning in this way.

From my own experience as a physics specialist it is apparent to me that I have over the years introduced more practical activities once I have become more secure with the syllabus and discovered new and more varied ways of communicating it to students. I can also relate to being required to teach biology on occasions where I was less comfortable and would be inclined to teach from a theoretical standpoint for what was needed for the exam feeling less experienced to venture into the complexities of experiments.

Aaron's statement highlights two points in my argument. A shortage of physics specialist teachers means that the teaching of physics, a compulsory subject up to 16 in Britain is being organised by teachers that may lack either the confidence, experience, expertise or enthusiasm to teach the subject in as an inspiring way as may be desired to promote the uptake of the subject at A level. Consequentially fewer A Level students means fewer graduates in physics related areas and therefore fewer physics specialist teachers. Another is Aaron's reference to preferring to learn through practical work. Although in this paper some students refer to disliking learning through practical work and views on this issue may be gendered, I argue that some non-specialist teachers of physics may offer fewer opportunities for students to learn physics through practical work (which in my view is a key to understanding, motivating and inspiring) than specialist teachers,.

The statements from the following students surprised me in that they found it so difficult to recall experiences of school physics despite it having been compulsory for most up to GCSE since the introduction of the National Curriculum. I describe this as *amnesia of the physics classroom*.

Lyra states, "I slightly remember a few things from GCSE Science to do with electricity."

Cornelius states, "Physics seemed boring and hadn't particularly grabbed my interest prior to choosing A Levels. GCSE level study seemed very basic and laborious. Seemed quite abstract with not much relevance to everyday life. Remember electricity and bits on conduction, but little that stood out. I didn't find the school environment well suited to my learning."

Further, Olivia states, that she was "Not the greatest at GCSE level, in fact I have no recollection of it."

Whilst Henry phrases it, "I have no memory of being in a physics classroom at school".

Sasha states, "The only physics I have studied is at GCSE level 14 years ago (C grade). I remember light bulbs, balloons and not much else at this point."

Denise further supports the amnesia theory, "I can't remember much! I can't even remember my physics teacher." Whilst also supporting the memories of Aaron, "I can however remember my biology lessons."

This is also mirrored by Burt, "Physics at GCSE level was not a favourite subject and I struggle recalling any physic science. Biology was most preferred as I think I related to it more".

Although it may be expected that students wanting to pursue a career in medicine may prefer biology to physics, the experiences these students have of physics leave much to be desired. Alex sums it up.

"I remember very little of my school physics. We had a very disruptive class even at A Level (I went to a pretty rough and ready state school), and being easily distracted, I found it difficult. Despite a fairly uninspiring and unsupportive teacher (who incidentally had terrible breath) I enjoyed the course, and did quite well. It amazes me how much I have forgotten!"

C2 The teacher

A minority of students (5/17) including, Denise, suggested, "a dislike for the teacher", as a reason why fewer females might choose to study physics than males.

In support of Denise's statement, Lyra, highlights how an association of the teacher with the subject can have a negative influence, "I did not understand the teacher – found it very hard to learn from her and presumed I was not able enough. I dreaded going to her classes and therefore felt the same towards physics."

This association of the teacher with the subject however is echoed by the fortunately more positive experience of Daisy, "My physics teacher was a 'Mad-Professor' type, but a good teacher + I enjoyed the lessons." Lyra continues, suggesting that the individual student's views, can also change "I enjoy physics now and believe a lot of it is down to the teacher".

Aaron eludes to the potentially positive and negative influence of the teacher's enthusiasm for a subject, "My only experience of physics was at high school. I remember that we had a single teacher for all three sciences. She had a personal preference for biology, so this may have rubbed off on her students."

Moreover these statements suggest that human emotions are often difficult to separate from teaching and learning (if at all they should) and that the teacher's enthusiasm for a subject is an attraction for his students to take it on or otherwise, whilst the student's like or dislike for the teacher will attract or repel her from the subject.

According to Murphy and Whitelegg (p23, 2006), "in physics girls' relationships with their teachers are more significant for their learning than are boys relationships with teachers." Moreover, "By adulthood, women are purported to exhibit greater empathy than men. (e.g. Baron-Cohen 2003)." (p460, Demetriou, Wilson and Winterbottom, 2009). However it should be noted that "One of the first studies in this field looked at the relationship between students' choices of mathematics and science in general secondary education and the *gender* of the teacher (Van der Werf *et al*., 1984). It was found that girls who are taught by women do not choose these subjects more often than those taught by men. However, the *prob lem awarenes s* of the teacher did appear to be related to girls' choices of mathematics and science." (Volman 1995)

Alex's remarks on the other hand show that with interest students can overcome the repulsive teacher and that the compulsory issuing of mouthwash to teachers, may be a partial solution to the recruitment of physics students, though this may not address the lack of physics learning they retain.
"I remember very little of my school physics. We had a very disruptive class even at A Level (I went to a pretty rough and ready state school), and being easily distracted, I found it difficult. Despite a fairly uninspiring and unsupportive teacher (who incidentally had terrible breath) I enjoyed the course, and did quite well. It amazes me how much I have forgotten!"

This suggests that the teacher has some influence over students' choice of subjects which is also supported by the quantitative data, though it is not acknowledged by the majority of students surveyed. Also with quantitative data showing slightly that males may be influenced more by the teacher than females and responses in the qualitative data suggesting slightly to the contrary, it is reasonable to infer that the teacher may not affect the subject choices of one sex more than another, though the small sample sizes in both cases are too small to be conclusive. More appropriately, more research is needed in this area.

I would also advocate the use of qualitative data as the subtleties of the teacher's influence may well have an effect on students' future subject choices but may not be explicitly acknowledged when asked to respond to a closed question.

When doing so one must not lose sight of the cultural dimension in such studies as emphasised in the following example.

Paradoxically due to a double discrimination for Arab girls in Israel, their confidence in mathematics and perceived career path is greater than that for Jewish girls. As most professions high in the national social hierarchy are barred to Arabs, those educated find Arab schools and teaching their only hope, hence raising the profile and arguably the quality of teaching in Arab schools in Israel. (Mittelberg et Lav-Ari, 1999)

C3 The practical

The practical aspect to physics was cited by a few of the students in a positive light which suggests that this may be a way into wanting to study physics.

Burt wrote, "Practical sessions help a great deal giving me an aspect of physics which I have physically undertaken and experienced."

Denise mentioned, "more practical demonstrations" as one way of helping her to understand areas in which she encountered most difficulty in her learning.

Aaron's statement, also supports the desire of students to learn through practical. "My only experience of physics was at high school. I remember that we had a single teacher for all three sciences. She had a personal preference for biology, so this may have rubbed off on her students. Certain topics such as "space" were really interesting. However, I consider myself a practical learner, I like to be hands-on, this was not frequently possible in physics."

Maria's statements were of particular interest due to the frequency with which she referred to 'practical' without specific prompting, but also for her apparent contradictions which mirrors some of the findings of Danielson (2011), in relation to 'doing physics and doing gender'.

First of all she twice cites the benefits of practical work to her learning and interest in the subject.

"I only had contact with the subject in school, ten years ago, however, in [home country] we do not have practical. Now it is much more interesting because of the practical and makes me link it with my daily life."

"Having practicals before going to university it has been of a great help."

As such she suggests that practical work not only stimulated an interest in physics for her but also suggests how it improves her learning. She is grateful for the opportunity to learn through practical which was not a possibility when she was at school in her home country.

However, whilst apparently actively engaged in 'doing physics' and accepting the benefits to learning she goes on to state that, "I believe females do not enjoy practicals and calculations as males"'. Moreover perhaps by also 'doing gender' (Danielsson, pp2, 2011) she makes an apparent contradiction, "I believe man enjoy much more physics and calculations, but specially practicals, I think man enjoy "playing" during practicals and the challenge, more than girls. (Maybe is due to female are more sensitive and subjective and male more pragmatic and practical). The part I enjoy the most in physics is the theory, is reading the textbook, is understanding, discovering, I do not enjoy applying it (this is for the boy!!!)" Maria's words here parallel those of Sara found by Staberg (1994, pp40) below.

Furthermore Staberg (1994, pp41), acknowledges Maria's learning preferences suggesting that girls "need to use the language is not really taken into account. Girls' theoretical way of approaching the subjects, partly owing to their unfamiliarity with tinkering and partly to their learned diligence, is one of the reasons for their craving to understand; another is their longing for overall comprehension." (pp41)

Although practical work may (Danielsson, pp2, 2011) be an area of physics study where young women are presented with the greatest identity conflict whilst 'doing gender' and 'doing physics' simultaneously, which may influence women's subsequent choice to discontinue with physics, it is worth noting that none of the students referred to practical work as a 'put off'. It may therefore be considered as an attractive part of the subject to varying extents dependent upon the individuals' preferences, and for a very small sample it may be inconclusively put that practical work is as attractive to both sexes for their learning of physics. In a way it seems that there is somewhat of a consensus that the 'doing of practical' is an essential part of the 'doing of physics' and in order to become 'more in tune with physics' one must become more 'engaged with the practical'.

For some women this 'doing of practical' is acceptable through negotiation with gender identity. Danielsson (2011) describes Mia and Ann who, "value practical skills in the student laboratory, even though they do not see themselves as possessing such skills in the context of laboratory work. When Ann talked about how she worked in the student laboratory she expressed the following:

Ann: 'Cause most of the time I've been doing lab work with guys and then most often I've taken the female role, partly because I feel a bit slow." (pp6)

Danielsson goes on to explain how historically science and femininity "have ever since the Enlightenment been defined in opposition. Further, Ann's use of the expression 'taking the female role' shows how this particular femininity for her is something she does, rather than something she is. " (pp6)

"Ann talks about herself as different from 'normal' women and repeatedly comes back to how she is more 'comfortable among guys' than in woman-dominated environments. Thus, Ann can be understood as positioning herself as a non-participant in 'traditional femininity'; a positioning that makes a simultaneous positioning as a participant in physics possible. This kind of a positioning as a non-participant in traditional femininity is well-documented in earlier research, which has shown that women within science and technology often construct them themselves as 'one of the boys' in order to be able to position themselves as scientists/engineers (see, for example, Henwood 1998; Hughes 2001; Walker 2001). Further, Ann is also distancing herself from a particular kind of technological masculinity, focused on practical skills, represented both by the men at her earlier workplace and by certain physics coursemates. Such a technological masculinity has been argued by Wajcman (1991) and Mellström (1999) to be particularly prominent and highly valued by working-class men." (pp7)

The danger for some women however is the identity conflict this may cause in moving from engagement to marriage as by 'doing practical' they may be perceived to be 'doing masculinity' an unacceptable part of the marriage for the young woman who thrives on a feminine image.

For this reason Maria's apparent contradiction must not be seen as *two faced.* On the contrary she is well aware of the importance of image in her previous profession as a television presenter. It is just that essentially her feminine identity, is in conflict with masculine physics.

In a way her expressions demonstrate her need to re-define herself, by re-negotiating her gender upon entering masculine physics. Her case also shows how it is possible to have multiple gender identities in the different contexts of our lives and as Danielsson and Linder (pp136, 2009) put it "identity is first of all seen as a negotiated experience, not a stable category."

Furthermore "From a situated learning perspective participation in a practice is the key to 'being' and 'becoming', for example, a physicist – and what feminist post-structural theory challenges us to do is to think about gender in a similar fashion. Paechter explains: Identity can in this way be seen as being related to competent and convincing performance of a particular role; it is defined not just internally by the individual but externally by the group's inclusive or exclusive attitude to that individual … Thus, it becomes not sufficient to claim a particular identity; that identity has to be recognised by group members, which in turn reflects back on one's understanding of oneself. (2003, 74)" (Danielsson, pp3, 2011)

From this perspective it could be suggested that Maria and other women may retain their femininity so long as this continues to be recognised in an informal social setting, whilst also becoming identified as a good physicist when recognised as such by their class mates and teachers.

It is important therefore as a feminist to emphasise to young women that it's O.K. to be a physicist and to also be feminine. Indeed perhaps we should as teachers be this explicit, as what Staberg (pp42, 1994) describes as "more girls into technology' propaganda" implicitly attempts to find a solution, whilst failing to recognise the problem.

Furthermore we should encourage a feminist classroom as described by Schacht (2000, pp3) where "a shared sense of struggle should diminish the likelihood that critical classroom dialogue will lead to personal insults and student withdrawal. In sum, a feminist classroom is a context that not only rewards student participation but honors the experiential diversity of all classroom participants."

Moreover by attempting to limit or reduce oppressive behaviours there is the potential to begin to convert more men to feminism and make physics less masculine.

Furthermore teachers of masculine subjects should tackle head on any man who attempt to make a fellow course member feel inferior to them by labelling them feminine.

Maria's comments also back up the findings of Staberg (1994) who found that, whilst boys are keen to tinker with equipment in science class, girls perhaps being more advanced in reading would rather do so, viewing boys as more immature and their activities likewise.

"Girls' learning style could be characterised by *work* and boys' by *play,* which is particularly obvious in laboratory work. As an example: during a lesson on electric motors the pupils were supposed to put together a motor of some components. When the motor started to rotate the girls put it aside and started working with the questions in their books while the boys continued to play with the motor. "Boys are more interested in doing experiments and we in doing the exercises", said Sara." (Staberg, 1994, pp40)

This resonates with my own previous research into the learning of year 8 pupils in a co-educational comprehensive school in England using a CD ROM known as 'States of Matter'. Conclusions were that the boys learned more effectively using the CD ROM as opposed to a textbook whereas the opposite was the case for girls.

G1 Lack of career guidance from the state

This theme surrounds the notion that there is a lack of adequate career guidance in schools and colleges. This student view is made explicit by some of the following statements and otherwise implied by others.

With reference to what attracted her to the subjects she chose to study at A Level,

Lyra who Staberg (1994) might have described as *insecure* states, "I enjoyed them (English literature, Geography, Psychology and Spanish) the most, and wanted to learn more. I felt I could best in these subjects. I had no career path in mind though".

Further on she elaborates, "During high school I was very quiet, worried a lot and worked hard. I never realised what I really enjoyed. Going from GCSE → A Level → Degree is a very fast process. It doesn't allow you much time to think. There's immediate pressure after GCSEs to start thinking about University. I never had time to truly think/experience life and with that I just followed onto studying a subject I thought I could do and felt I could get a job from. After graduating I realised this wasn't the case. The pressure of deciding immediately after GCSEs is a lot for most young people who do not know what they want to do."

In response to the question,

Why might fewer females choose to study physics than males?

Denise states, "Lack of guidance at A Level".

Whilst in response to the same question,

Alex states, "(Perhaps) by a misguided perception that physics isn't useful in the real world".

Whereas Daisy suggests, "Can't see the relevance of physics to career opportunities".

With reference to what attracted her to the subjects she chose to study at A Level,

Isabelle's statement also suggests career misguidance, "I went to a specialised music school, with the insight to become a professional musician, so A Levels were orientated around music and I enjoy literature. (I did want to do biology but was encouraged to take music technology which I did not enjoy)."

I would argue that by having an interest in an academic subject does not necessarily imply that a student is interested in following a technology course in the related field. In fact I would argue that she may have benefit more from continuing to learn a variety of academic subjects before being guided to start applying them to a career too early. I suggest that academia was what she thrived on and that by keeping her academic interests open may well have allowed her to delay making a specific career choice that would later rely on her chosen higher education. Perhaps as an academic she may well have got more out of studying biology. I also question if physics was ever suggested to her as option whereby she could learn about wave theory and how music is made and measured. Although I would argue that her interest may well have been in playing music and performing it, I suggest it may not be wise to limit the options of the academic early in their career, as it is at least apparent that she enjoyed physics as well, as in response to the statement,

'Write about your experiences of studying physics prior to embarking on this course.' She wrote,

"I did some at high school which I enjoyed."

Others like Louis and Jeff, refer to entering paid work rather than continue with post compulsory education due to not having a career plan in mind.

Louis states, “When I left school at 16 I was offered an apprentiship in Electrical Installation. Lacking any real idea of what career I wanted to pursue I felt that it was my best option at the time."

Jeff states, “I had little interest in pursuing a particular career at 16, instead just entering unskilled paid work.”

Perhaps again without a career plan or obvious subjects which he wanted to continue with William refers to being attracted to study something different, usually not available to study pre-16 , “Business studies because I thought I would enjoy it (I was very wrong).”

Daisy appeared to have always had an interest in Science, having studied chemistry, physics and maths at A level. It would seem reasonable that with appropriate career guidance she may have found work in this area. However her case is particularly striking because she then chose two more level 3 courses in the sciences before starting the Access to Medicine course, her 4th level 3 science course. Knowing her as a very able student, I suggest she typifies the lack of career guidance, (although she would have to have picked up Biology which she had not studied at A level in order to progress to a Medicine degree).

“None of my previous science qualifications inc. level 3 BTEC or science foundation from [*a university*] were acceptable to universities. Only choice really.”

Access courses such as the one from which these students were questioned provide an opportunity for students to change career paths it is reasonable to assume that this sample is biased to towards more people with less clear careers in mind than may be the case in the wider population.

Moreover some would argue that planning a career is the responsibility of the student, as I agree in part.

“Teachers and guidance counsellors also play a role in influencing student perceptions of different subject areas, with some evidence that female students may be more reliant on advice from school personnel in making their choices than their male counterparts (Stables and Stables 1995; Stables 1996). Advice from teachers may serve to reinforce, or to challenge, the gendering of certain subject areas.” (Smyth and Darmody, 2009, pp276)

However I suggest that at the very least students should have the opportunity to discuss different career pathways with their subject teachers who on the whole through their life experience should have a better idea of the possible careers a subject may lead to than a non-specialist career adviser. It might also try to avoid what Staberg (1994, pp42) describes as “ “more girls into technology” propaganda”. This was often interpreted as “all girls should become car mechanics”. Learners should also be given a mentor to guide them through an enhanced process of career planning. This I argue would be in the interest of the learner, the government, the country and the economy if we are to attempt to get students on appropriate courses in the first place which appropriately reflect their talents and informed choices that are in their own best interest.

This recommendation I also emphasise should not become another government initiative to tack onto the already stretched role of the teacher as a superficial add on, but should be incorporated into the curriculum with hours set aside for teachers specifically for this purpose.

Sasha reinforces this point in response to the statement,

Why might fewer females choose to study physics than males?

“There is not enough promotion and awareness of physics for females to be enticed.”

“Physics is never encouraged to females.”

“Females do not bother finding out about what physics entails in F.E. therefore less likely to choose this as an option.”

Furthermore she elaborates, “Females, certainly from my culture (South Asian) are not encouraged to study physics – not for any particular reason. I just think physics is hugely underrated education promotion.”

G2 Lack of encouragement from the personally influential

In a society which is becoming increasingly reliant on an educated work force it would seem that the personally influential people in these students’ lives such as parents are not providing the encouragement and guidance in choosing subjects that link to an appropriate career.

Lyra who Staberg (1994) might have described as *insecure* states, “None of my close friends or family did Science (apart from my parents who were vets) but my parents did not affect me. They allowed me to choose. So I picked subjects I felt secure with.”

Olivia states, “I do feel that we as a society (parents, teachers, government) need to encourage these subjects to all our children and that these subjects are taught better, I feel currently that this is not the case at all whether it be with regards to teaching/ encouraging.”

For some traditional work is encouraged instead of academic studies, perhaps showcasing working class masculinity, Burt, states, “Encouragement came from the different generations of my family which all left education to work after secondary school. Instead I was encouraged into a traditional family as a joiner. That was good but didn’t fulfil my desire for academics and learning.”

It is also noteworthy that upon choosing his pseudonym Burt Coal, he joked that this was a Northern sounding name, hence allowing him to retain another dimension to his identity.

Although only 3/17 students surveyed suggested that parents either don’t encourage the uptake of particular subjects or actively encourage the taking on of traditional employment, I argue that this lack of encouragement from the personally influential people in youngsters lives is actually greater than it might seem, as when asked about experiences it may often be difficult to notice what was not experienced as opposed to what was.

I also recognise that many may not mention this so as not to attribute blame to parents as I certainly do not. It is merely that no-one is able to have an overview of every possible subject and career, so without the young people themselves having an obvious and clear subject and career plan parents find it difficult to encourage nothing. Parents are also quite rightly cautious not to dictate what their children should do, hoping that they will eventually make up their minds.

Identity

“Brickhouse (2001) also points out: ‘The idea of learning as a *transformation of identity-in-practice* provides a way of thinking about learning that is gendered, but does not regard gender as a stable, uniform, single attribute. We are not born with gender. We do gender’ (290, emphasis added).” (Danielsson, pp3, 2011)

From a feminist constructivist perspective Staberg (1994) reasons that, “The mutual construction and reconstruction of gender and of science/technology contribute to gendered choices of study programmes in upper secondary school.” (pp 35)

Key findings include,

- ✓ *Girls and boys prefer different subject areas.*
- ✓ *Boys have a practical while girls have a more theoretical approach to science.*
- ✓ *Girls seek 'connected knowledge', and even the successful girls question their understanding.*
- ✓ *Girls who take an interest in physics and chemistry often have supporting scientist fathers or at least parents with a higher education.*
- ✓ *Technology is rejected by all girls.* (Staberg,1994, pp 35)

I1 Identity construction through adolescence

“In the words of Brickhouse: Learning is not merely a matter of acquiring knowledge, it is matter of deciding what kind of person you are and want to be and engaging in those activities that make one part of the relevant communities. (2001, 286)” (Danielsson, pp2,2011)

In attempts to construct feminine identities some women find it difficult to associate themselves with masculine imagery they interpret physics as a part of.

Mary states, “Physics is often associated with manual labour and so female could be put off this as physically they are not a strong as men.” Although I would argue that physics as an academic subject has little to do with manual labour, the careers it leads to can. Heavy industry, Civil Engineering usually including building are examples. Despite such industries being highly mechanised in the modern era, it is perhaps that this image is unappealing to females and that their fears of not integrating easily into male dominated work forces, are really the issue as opposed to a conscious thought of not being strong enough.

Danielsson and Linder (pp137, 2009) “Wajcman (1991) has characterized the gendering of technology in terms of two masculinities, one practical based on physical strength and machine related skills and one based on ‘the professionalized, calculative rationality of the technical specialist’ (144).”

Identity construction through adolescence, perhaps better explains what is going on here, summarised so well by, Alex. “Unfortunately, scientific subjects (like other academic subjects) are deemed ‘not cool’ at a young age. Without foresight, it seems to most that social inclusion and acceptance within the defined hierarchy of the school system is more important than a scientific education. Young people, especially young women, seem to be very concerned with image. Subjects that may enhance their image as an attractive atypical female (though which subjects these are is a matter of debate) may well seem more appealing at the time.”

Moreover, I would argue that some women may find what Danielsson (pp2, 2011) describes as ‘doing physics’ incompatible with ‘doing gender’, through fear of potentially being misinterpreted as unfeminine or even homosexual.

Sasha, states “I think if a female were to choose physics at A level and degree level she may be frowned upon and classed as ‘masculine’ or maybe even ’lesbian’.

I argue that this is not homophobic. Quite simply young people on the whole want to clearly portray what their sexual orientation is so as to have a good chance of attracting those they desire.

For some young women therefore any benefits of 'doing physics' are far outweighed by the threats to their sexual-gender identity.

Lyra perhaps implicitly supports the views of the others above. With school subjects arguably in the balance for her academically, she seems to choose to be 'one of the girls'. "My friends choices also slightly influenced me they were more into human aspects i.e. English, psychology – less to do with number. Although I did enjoy working with number, I felt secure doing something most people I knew were doing." Staberg (1994) also found that the *insecure* had traditionally feminine, vocational career plans, the *disinterested*, opting for pathways including languages and economics as they didn't involve too much maths and science.

"A number of studies have indicated that students in coeducational schools construct their gender identities as relational and express this opposition by choosing gendertypical subjects, with girls consequently less likely to take mathematics and science subjects in these contexts (Stables 1990; Dryler 1999)." (Smyth and Darmody, pp276, 2009)

I2 The parents – who are they to think they have influence?

3/17 students referred to parents in their responses. This approximates to 18% which is comparable with 21% males and 10 % females who selected parents as an influence on their subject choices in the quantitative questionnaire in response to question 7. What this seems to suggest is that parents have an influence over their children's subject choices but that it may be more minor than some parents might expect. With qualitative and quantitative data suggesting opposite genders to be influenced most by parents, with such small samples, it may be cautiously concluded that there is not enough evidence to determine if, either gender, is more or less influenced by parents.

However some students seem to suggest that some parental influences may be gendered.

Lyra states, "My parents did not affect me. They allowed me to choose."

Burt states, "Encouragement came from the different generations of my family which all left education to work after secondary school. Instead I was encouraged into a traditional family as a joiner. That was good but didn't fulfil my desire for academics and learning."

Here I would argue that Burt's negotiation into a working class masculinity postponed his studies of science as, "perhaps class-based, masculinities and femininities will affect the way we can join the physicist community". "(Danielsson and Linder, pp137, 2009)

In response to the question, "Why might fewer females choose to study physics than males?" Mary, states, "Parental influences may affect this decision. Girls are given dolls and kitchens and males are allowed to experiment more."

"Interviews with students in the case-study schools indicated that they were strongly reliant on their parents in making decisions about which subjects to choose (see also Smyth, McCoy, and Darmody 2004)." (Smyth and Darmody, 2009, pp282)

"Female students did not generally report that their parents actively discouraged them from taking 'non-traditional' subjects. However, parental constructions of what constituted 'useful' subjects appeared to take account of gender and, to some extent, social class. Useful subjects were seen as those that would enhance access to employment and the way in which 'useful' was defined facilitated the reproduction of gender differences in subject choice patterns." (Smyth and Darmody, 2009, pp283)

I3 The nerdy geeks are doing it hard on their own!

The image of physics as a hard subject done only by swots, nerds or geeks is unattractive to many students.

Sasha states, “Physics may be deemed as a difficult subject for intelligent males.”

Peter states, “Physics may have a negative image to females, being regarded as irrelevant, or ‘nerdy’ – this make speak towards negative attitudes to being academic, in some peer groups.”

Daisy states, “Physics may be seen as ‘old-fashioned’ and studied by ‘geeks’ or professor-types.”

Alex states, “Unfortunately, scientific subjects (like other academic subjects) are deemed ‘not cool’ at a young age.”

In contrast this perceived nature of the subject may be attractive to certain individuals, who like their own company and working on problems alone, though through taking on the challenge they may perhaps reinforce the image.

Alex continues, “Having left home at fourteen, and having spent a lot of time on my own. I was certainly not a ‘cool kid’. Sciences appeal to my logical and lateral thinking, and for a long time sheltered me from more interactive subjects.”

In my opinion this image is popular in Anglo-American culture as portrayed in the American T.V. show, ‘The Big Bang Theory’. The main characters in the show are male nerdy-geeks; physicists who whilst being passionate about their subject amusingly struggle to attract attractive females. They are also perhaps what Daisy refers to as ‘professor-types’ all being Doctors with the apparently inferior one Howard Wolowitz, only having a Masters degree in Engineering. Moreover the main character, Sheldon Cooper whose main aim in life is to get the Nobel prize for Physics, could perhaps be described as non-sexual, i.e. not having a sexual orientation and therefore is more able than most, to stay focussed on the physics.

It is my view that we cannot blame a T.V. show for this image as so often comedies describe so well what people already see in the wider society, though with one of the actresses in the show having a degree in physics perhaps they miss an opportunity to re-address the balance.

Over dinner an academic physicist from one of the elite English universities having met T.V. presenter, Professor Brian Cox once described to me that he still likes nerdy-geek things despite being so good looking, charismatic and appealing to a popular audience. It is perhaps re-assuring to know that there may be at least one physicist with such a good image. He also shows that it is possible to buck the popular trend. Having been in a pop group, he chose to be a physicist and now presents popular T.V.

One of the female students on this course on first meeting her referred to the inspirational Professor Brian Cox which goes to show it may be possible to re-brand the image of physics in order to make it more appealing to a wider audience. Encouraging more Science T.V. shows with attractive male and female role models may help to gradually evolve a new and more positive image of physics so as to make it more appealing to the youth.

What seems apparent here is that some males and some females perceive physics to be a ‘geek’s’ subject. Two qualitative statements from males and two from females above along with 60% males and 50% females responding on the quantitative questionnaire suggesting this.

What is less conclusive is whether physics as a subject is considered gendered. Although from the discussions above it has been noted that the practical part of physics may be perceived as masculine in its association with boys' toys and a traditional work force, others, me included would argue that the subject content of physics like maths is rather gender neutral.

When researching students perceptions of the gendering of mathematics Brandell & Staberg (2008) found that the majority perceived maths as gender neutral. This is echoed by one of Danielsson's (pp10, 2011) cases in regards to physics

"Hanna even very adamantly rejects that the gender issues should be of any importance in the physics community and talks about it as unusually gender neutral, where experience and knowledge is all that matters:

Hanna: It's what you know! Or, experience. It feels like it's the way you get, that you are something, it's not so much regarding gender.

In part, I would argue that this discourse of 'gender neutrality' (Magnusson 1998) is tied to a general academic ideal of individuality and independence. In this sense Hanna's utterance about how what matters is experience and knowledge, that within the physicist community people are judged by what they know, not who they are, is very much in line with what Eduards (2007) argues to be the self-image of the entire academia as an extremely individually oriented system. However, the description of how physics as 'unusually gender neutral' could also be a reflection of how physics is constructed as a science that produces universal, value-neutral and objective knowledge, independent of societal factors (Schiebinger 1991)."

A double contrast seems to be however that if having gender neutral subject content, physics is also seen to be studied by studious males in the post compulsory education sector whilst Brandell & Staberg (2008, pp502) suggest that school girls emphasise studiousness to be feminine as they long for full understanding whereas school boys don't want to be seen as studious if this is constructed as feminine behaviour.

Here I present Knowles' paradox. If studiousness is feminine and physics is academic post 16 physics course should be female dominated.

Clearly this is not the case. Brandell & Staberg (2008, pp506) suggest that the use of the term derogatory remark, "swot" at school may be used to undermine hard work that is more often constructed as feminine behaviour. This may be a way in which boys assert their masculinity.

Furthermore they suggest that girls may well see themselves as harder working than boys, though "the problem is not the diligence but the denigration and the polarisation towards logic and thinking. In our study, the female students' view is that they work more than boys. We do not look upon this fact as a problem. However, the belief that girls must work harder than boys is more problematic as it can be interpreted as an expression for the notion of mathematics as a male domain." (pp506 - 507)

It seems to me therefore that if physics is considered a difficult academic subject, students are not only presented with the challenge to attempt to master the difficult. They also may recognise that working hard in compulsory education is one thing in classes that are balanced on the sexes where they can just about tolerate the "swot" jibes from some boys, but if girls realise that they must work harder than ever to succeed in A level physics whilst studying amongst a majority of boys, who may make more such jibes, the choice to continue with physics is abandoned.

This is a double discrimination for females, once through oppressive remarks in the school physics classroom implying that their studiousness is not valued, then again through de-selecting physics as

an option at A level (where studiousness could be very much valued by the teacher and most peers) they close down the high number of job opportunities it could have led to.

Perhaps the point here is that we must regularly and repeatedly compliment students for their endeavours and that acquiring full and thorough understanding is the reward for becoming academic. We should perhaps take time to reflect on what it feels like to understand and talk about this amongst the other academics in the physics classroom. In this way it may be possible to build a community of practice that celebrates different identities and challenges prejudices through the pursuit of knowledge.

Hatchel (1998, pp383) refers to Christine a girl who eventually started getting high test marks "even being called 'squid head' was a kind of encouragement for her to succeed" suggesting that although such derogatory remarks may be discouraging for girls whose confidence is already questioned and should always be challenged and confronted, when successful and gaining in confidence such remarks may be laughed off or even taken as a compliment.

Easier options

Another reason for not studying A Level physics is that there are easier options. This is supported by the findings from Q13 of the quantitative questionnaire.

Which factor(s) do you think influence people to choose not to study Physics?

40% of females and 35 % of males indicated that "it's considered better to get a higher grade in another subject than a lower grade in physics for the same effort".

Furthermore when asked on Q7 of the qualitative questionnaire,

Why might fewer females choose to study physics than males?

Henry provides more support for this, "Maybe girls are more aware of their career path and the importance of getting good grades at A level and they perceive that it will be easier to achieve higher grades in other subjects."

However by drawing upon both the quantitative and qualitative data suggests to me that 'there being easier options to study than physics is actually a reason why both males and females choose 'other subjects' as opposed to a specific reason for females choosing other subjects. Although Henry suggests it as a reason for females, it seems plausible that males also think this way. Also fundamentally it seems to me that 40% is not too different from 35% so my hunch is that this reason influences males and females approximately equally, although the sample size is too small to demonstrate any statistical significance in the slight difference between each gender. Hence more research is required in this area to determine if females are influenced more than males by opting for easier options.

It may also be worthwhile further investigating quantitatively if there is a noticeable significant difference between genders on this item. If qualitative questioning may be used to explore if a reason for it is as Henry suggests due to 'girls being more aware of their career path'.

The following statements from Sally, who I taught in a 6th form setting four years earlier (when the quantitative data was collected) further support the notion of physics being a hard subject and actually go further to suggest it's the hardest of all subjects.

Having issued her with the quantitative questionnaire in the classroom, the year 13, A2 Physics student asked,

"What do you mean by Physics being perceived to be hard? It is hard!"

Subsequent discussion with the class of five students confirmed that they unanimously considered Physics to be the hardest subject, despite all studying Maths!

Continuing she wrote,

"Physics is more difficult than Maths, because to succeed at Physics you're expected to know some Maths which isn't taught in the syllabus [e.g. logarithms], whereas in Maths you're not expected to know anything from other subjects.

In Physics there are many difficult and abstract concepts we have to understand, but in some subjects you just have to be able to do some set processes without understanding where it comes from. Physics has a very large syllabus, so there's lots to remember especially the formulas.

I find Physics the most difficult subject I study, because in the exam we are expected to work out Maths problems using formulas, derive formulas, explain things and unlike a Maths exam, in Physics we have to write long explanations for things, which I find difficult because I think Physics is a quantitative subject!"

Another way forward in promoting the appeal of physics is perhaps to be honest about it being difficult and to emphasize that when President Kennedy was "choosing to go to the Moon", people chose to study physics, "not because it is easy but because it is hard". Moreover, the hard work will pay off when you have a qualification that is highly employable.

Limitations of the research

The quantitative data in this project although somewhat useful in supporting some of the findings from the qualitative data was collected for a research project I'd optimistically decided to do voluntarily on top of other duties on a secondment placement to a university to support the National Stimulating Physics project (to encourage more people to take up physics post 16) whilst also working on my normal teaching job in a school.

With no obligation to complete the research with too many other competing commitments, there was no sense of purpose with no deadlines. This meant that questionnaires were issued too late and there were an insufficient number completed such that the usual benefit of a quantitative approach i.e. that of affirming statistical significance was not possible with such a small sample and the disadvantage of the approach i.e. that it tells nothing of the human aspect of the phenomena being investigated became all too apparent. The lack of a clearly defined research question meant that lots of data was collected from a large questionnaire for a project that was never completed so that I was sitting on the data for 4 years. By this time my research question had changed to one rooted in gender so much of the data was still never used.

With only 37 quantitative questionnaires completed by males and 20 by females the sample was too small to draw any statistical significance from. Having originally planned to sub-divide the respondents into year and course groups, it became apparent that this would be pointless to the low number of completed questionnaires. Therefore a compromise was decided upon. Year and course groups were merged into two groups, male and female (regardless of the course they were on) to determine if there were any noticeable differences in response between the genders. Although no

statistical significance could be claimed, the intention was that noticeable differences could be investigated further via the qualitative survey.

Consequently question 8 was introduced into the qualitative questionnaire to cross check findings from the quantitative questionnaire. The reason was that there seemed to be a contradiction in responses to two items. The girls on the advanced physics and chemistry courses perceived their own abilities in Maths to be strong and to some extent stronger than the boys, but in contrast boys indicated that they very much enjoyed doing calculations whereas girls indicated that they did not. Being good at Maths but not enjoying it seemed paradoxical to me. Question 8 on the qualitative questionnaire was hence developed to cross check this pattern by presenting statements to the student s and asking them to comment on whether they agreed with any of them.

However students did not confirm what I had seen as an apparent paradox.

There could have been a problem with question 8 on the qualitative questionnaire itself see appendix, however it also highlights the struggle to explore meaning from responses to closed items on quantitative questionnaires and underlines the point that they are not helpful in an exploratory investigation.

For example Maria's verbal statement which I noted in my diary immediately after the session highlights the problematic nature of trying to find meaning from items on a quantitative questionnaire. When I was asked to clarify question 8, Maria acknowledged that she related to the statements saying that, "the maths in physics is easy, when compared to more complicated maths in maths." She stated that she was good at "the maths in physics but, didn't enjoy calculations when she gets stuck." Although this statement give a personal explanation for the possible paradox in the data from the quantitative questionnaire, it shows more importantly in my view that one should not attempt to interpret depth of meaning from the response items of a quantitative questionnaire. My assumption that 'people enjoy doing the work they are good at' may not be how others interpret the statements. Can enjoyment of maths or perceived ability in maths ever truly be measured? For example did respondents relate 'enjoying doing calculations' relative to 'writing an essay' or did they confirm 'not enjoying doing calculations' relative to 'enjoying going on holiday'.

That said Sally's account which resulted spontaneously from being given the quantitative questionnaire, shows not only that themes can connect through time and across educational sectors but even if one makes the fundamental mistake of using the wrong methodology, doing the research is still better than not doing it all, as it can unexpectedly lead to other things as her statement is what sticks with me from it years on and why I continue to develop as an educational researcher.

Summary of findings

These findings follow the sequence through the report. They do not show priority order.

1. The prospect of being the minority sex amongst men in a work force is enough for some women to feel put off making the choice to continue with physics and the careers it leads to through fear of feeling, uncomfortable or even intimidated.

2. Many women perceive physics and the careers it leads to like engineering as *masculine*. They don't find an imagery of manual labour and technology appealing, so perhaps do not research what engineering actually involves in a modern setting.

3. Most physics icons in history are male; there are fewer females to inspire more of them.

4. Many men and women suggest that the games and toys played with during childhood put boys at an advantage when it comes to learning physics more formally.

5. The experience of physics at school was for many uninspiring. The lack of specialist teachers does not help.

6. The teacher's enthusiasm for the subject and emotional connection with the students influences options to take or drop the subject. The influence may be positive or negative, but is more influential upon the choices made by girls than boys.

7. The practical aspect of physics is generally accepted by women and men as beneficial to learning the subject. However whilst accepting these benefits some women find conflict in their 'doing of practical' and their 'doing of gender'. By becoming immersed in what is perceived as masculine they find it difficult to maintain a feminine identity.

8. The educational system is not giving adequate provision for career guidance. The inexperienced youth are left alone to get lost in a maze of career pathways.

9. Parents and guardians are at a loss in giving advice without a career plan. Adolescents might not realise how to cohesively plan a selection of subjects and a subsequent career, let alone seek guidance on it. Although other research suggests that parental influence may be gendered, limited time for key adults to discuss careers opportunities with the adolescents makes challenging the gendering of the subject difficult.

10. Parents have an influence over their children's subject choices but that it may be more minor than some parents might expect. Whether girls or boys are more or less influenced by their parents is inconclusive. However some students seem to suggest that some parental influences may be gendered. Social class also appears to affect parental influence.

11. The image of physics as a difficult and impersonal subject studied by swots, nerds or geeks is unattractive to many students. In contrast this perceived nature of the subject may be attractive to certain individuals, who like their own company and working on problems alone, though through taking on the challenge they may perhaps reinforce the image.

12. A good reason for not studying A Level physics is that there are easier options. Physics might also be the hardest of all subjects. Whether girls or boys are more or less influenced by taking easier options is inconclusive.

Recommendations

1) Establishing positive working relationships between female learners and the teacher is paramount. Teachers should demonstrate an emotional relationship with the subject matter, and repeatedly reinforce its relevance for society to learners.

2) The applications of physics in the real world and the careers it leads to should be made more explicit to students before choosing courses. Teachers of physics and other subjects should be allowed the time to discuss career options with their students as it is my view that the specialists have the best idea about the kinds of careers their subject leads to having already gone through a similar academic-career pathway themselves. Students need informing about what different branches of engineering and applied physics involve to highlight the range of career opportunities. Teachers are thus able to exercise a little more influence through encouraging their students to consider a wider variety of careers, particularly the females as regards physics. Time permitting this should occur periodically through the normal teaching of lessons linking subject content to career pathways to really emphasise that physics is used everywhere at that it is a highly employable qualification to have.

3) Rather than view youngsters, having just left compulsory education at 16 as young adults, who can make rational adult decisions independently, discussions between learners, their parents and their teachers should be encouraged to counteract gender stereotyping and inform subject-career choices, in a meritocracy that is just, productive and fulfilling for all.

4) Through dialogue with the students, teachers may encourage them to engage with the careers advisers who can provide them with important contact details and follow up with researching career pathways. The teacher could hence become the link between the students and the careers service, which to my mind is presently underused. Having already having gained some insight into career possibilities from subject teachers students may be in a better position to seek specific as opposed to generic advise from careers advisers. Parents and guardians could be encouraged to support their children in choosing careers once a process has been initiated. Through such dialogue it may be possible to challenge gender-stereotyping of careers. If teachers highlight the opportunities for all, parents should aim to be holistically personally influential emphasising e.g. that it is O.K. to be a feminine physicist. All in all the careers service for youngsters should become more co-ordinated.

5) Teachers of physics should be made aware of feminist pedagogy as regards males oppressing others in a classroom setting so as to be ready to pro-actively challenge the use of derogatory words or unhealthy competition, as a means not only of correcting the immediate behaviour but to challenge a whole sense of being and thinking and providing opportunities to discuss gender issues and promote gender balance in physics and related careers.

6) Teachers of physics should be made aware that practical sessions although fundamental to developing understanding of the subject, may also be a stage for the gendering of the subject. This trade off could be tackled by questioning whether certain practicals are necessary, if more gender inclusive strategies are viable alternatives and emphasising the relevance and importance of how the practicals which are used enhance learning and how such skills can be applied in careers. Girl only practical groups may avoid boys dominating tasks and allow the girls to be more involved.

7) The nerdy geek image of physics as portrayed in the T.V. show 'The Big Bang Theory' could be accepted in part but also challenged and discussed. By engaging with a potential topic of conversation it may be possible to consider why academics get excited by things others are unaware of and point out that it is still possible to get excited about aspects of everyday life without work consuming you. Through such discussion it might be possible to bring to the forefront of students minds what identity construction through adolescence means in practice and through carefully choosing the identity you wish to have it can be demonstrated that you can be whoever you want to be, even a feminine physicist. Through such discussions positive role models with good images could also be emphasised. Weather forecasters and T.V. presenters may be among them.

8) We should also regularly and repeatedly compliment students for their endeavours by emphasising that acquiring full and thorough understanding is the reward for becoming academic. By taking the time to reflect on what it feels like to understand and talk about this amongst the other academics in the physics classroom it may be possible to build a community of practice that celebrates different identities and challenges prejudices through the pursuit of knowledge.

Ethics, quality control and acknowledgements

Once this report was at the editing stage at the end of May 2012 a version of it containing all statements from the students was given back to the 'Access to Medicine' class for them to check that what I'd written was an accurate account of what they'd written and that I'd not misrepresented their views. It also allowed me to check that they were happy for the report to go forward for publication.

One typing error was corrected, and how the items on Q9 of the quantitative questionnaire were numerically scaled was clarified.

Although not all students read it, those that did all agreed that the report was accurate, did represent their views and should go forward for publication. Comments included, "Well written" (Alex) and "Very interesting" (Lyra).

This also allowed the students to have a sense of closure and satisfaction for having been involved in the research project. I thank them for their contributions without which this report would not exist.

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