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3. GIRLS AND PHYSICS: DILEMMAS AND TENSIONS

Abstract: This paper reports on some of the findings from a review of research commissioned by the Institute of Physics into the participation of girls in physics. The review was commissioned in response to concern about the continuing decline in the numbers of girls studying physics post-16 in England. The review includes 177 sources of national and international research literature on the participation of girls in science and in physics and is a narrative review covering 161 pages. The review findings reveal a complex picture of the reasons for girls continuing decline in participation related to their lack of meaningful access to physics which is constrained by a complex web of interactions in girls' curriculum and assessment experience. When this is combined with perceptions of the representation of physics it results in a reduction in girls' self-efficacy and self-concept in the subject as they progress through schooling. The review recommends that purposes for studying physics need to be made explicit for girls in particular, and that this should happen within their curriculum experience rather than outside it. Relevance of the subject to girls' lives outside the classroom is as important as prior knowledge so curriculum interventions and teachers should take this into account. Staff development is needed to help teachers develop strategies to increase the participation of girls and this is particularly important where single sex teaching is used. Long term evaluation of different approaches, further research into the difficulty of physics and access to achievement data is needed

Keywords: Difficulty, Gender, Influences and course choices, Pedagogy, Physics, Physics self-concept, Relevance and attitudes, Representations of physics, Single-sex

1. INTRODUCTION

Over the past decade recruitment to physics A-levels have been continuing to decline, particularly for girls and, coupled with the closure of some university physics departments, this has positioned physics as a 'vulnerable strategic subject'. The Institute of Physics (IOP) has been concerned to uncover sources of this problem and develop strategies to alleviate it, so commissioned a review of research on the participation of girls in physics in order to provide evidence to inform policy-related decision making. This chapter outlines some of the messages from the review and the recommendations that have emerged from it, but space does not allow full consideration of all the aspects considered in the full review (Murphy and Whitelegg, 2006a).

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1.1 Historical Framework

The problem of girls' participation in physics needs to be seen in a social and historical framework. Throughout the nineteenth century and for most of the twentieth, education opportunities for different social classes and genders within those differed not only in the opportunities to attend school, and the type of school available, but also on the subjects taught and curriculum offered within those subjects. Girls and boys were educated to fit their future roles based on their social class and on their gender – girls for the domestic sphere (as wives and mothers within their own homes or as domestic servants in the homes of others) and boys for work in the public sphere outside the home. The sciences, in particular, were taught in the gender-segregated ways which continued to some extent and in some schools until well into the mid- to late-twentieth century. The introduction of the National Curriculum in 1988 in England, Wales and Northern Ireland made all the sciences – physics, chemistry and biology, compulsory for the majority of students. However, compulsory study of physics in this new curriculum has not resulted in an increase in uptake of the subject post-16, particularly for girls. As evidence from the review suggests, the historical and culturally driven representation of physics that developed in earlier times continues to affect some teachers', parents' and students' perceptions of the subject. We argue that physics continues to reflect its historical tradition and can be said to be "inheriting a gender culture". (Murphy and Whitelegg, 2006b, p. 285)

2. METHODS

This is a narrative review, detailed and through, drawing on the practice of systematic reviews by identifying criteria for inclusion, and developing a systematic approach using key words and mapping the field. Hundred and seventy-seven sources of national and international research literature were selected for inclusion. Criteria for selection of the studies examined were research that showed:

- Clarity of purpose and data collection tools and methods used.
- Studies that showed attention to validity and reliability of the analysis and its interpretation.
- Large scale empirical studies using
  - descriptive analyses
  - analytical techniques (e.g., factor analysis using multivariate and univariate analyses).
- Small scale in depth follow-ups of large scale studies.
- Theoretical papers offering well-grounded insights.

Initially, the brief from the IOP was to cover research over last 15 years but in the process of doing the review we found it necessary to include earlier seminal work that was unique and had not been repeated. The Institute also initially only wanted us to consider UK research but this was extended to include research in other countries where work had transferable messages for UK. The research also focussed on the period of secondary education (11–18 years), only examining

research from the primary phase were it was shown to have an important influence on what happened in secondary. Significant studies of post-16 physics were also included as many of the pre-16 studies were concerned with science rather than with physics. Similarly research at Higher Education level was included when it produced messages transferable to the secondary phase.

The literature review is about gender and physics, so how gender is interpreted by the literature is important. The literature recognises gender as socially constructed and not as a fixed attribute of an individual determined by their genes. Gender is therefore not the same as biological sex, but is concerned with how an individual relates to a situation or in this case to a subject. So in the review and this paper, when referring to groups of boys or girls, it should be born in mind that within these groups there will be individuals who are not reacting as a stereotypical 'boy' or 'girl' but who may be behaving or identifying with the opposite gender group. So the differences referred to are trends for a group and not attributable to all members of that group.

A second concern related to the field itself, as there is limited recent research into gender and physics particularly in England. It was therefore felt that the absence of research evidence was equally important as its presence. Consequently a wide range of research literature was explored to point up:

- where understandings about the nature of the problem of girls' participation in physics were emerging in a consistent way;
- how understanding about the issues and their impact had evolved;
- where there was limited research evidence and where there was an absence of evidence.

3. ANALYSIS AND FINDINGS

The review is divided into seven Sections and what follows in this paper is a very short summary of some, but not all of the findings from the review. The evidence cited and the sources referenced here form a small part of the research examined and discussed in the full report.

The nature of the problem of girls' lack of participation in physics is multifaceted and so no single factor can be studied in isolation and be said to account for the problem. The way the outcomes of the review and this paper have been organised is just one way, amongst many, of organising the messages from the literature.

3.1 Interests, Motivation, Course Choices and Career Aspirations

The research indicates that interest and enjoyment of science declines throughout secondary school and that the decline accelerates from age 14 particularly for many girls. This decline in interest linked to girls' self-efficacy in physics and this leads to girls' experiencing physics as difficult (Häussler, 1987; Hoffmann, 1997; Reid and Skryabina, 2002; Lindhal, 2003; Osborne et al., 2003). However even those who retain an interest in science and in physics, may not choose to continue with the subject when they experience a number of other negative factors, such as

those outlined below. So interest and enjoyment alone are not sufficient reasons to continue studying physics.

Career intentions have an important influence on continuing to study the subject. Students, particularly boys, will continue to study if they see it as essential for a career that is appropriate for them (Stokking, 2000). Many girls are not aware of careers that may be suitable for them and where physics plays an important part. Prior achievement also has an important influence on course choices (Sharp et al., 1996; Reid and Skryabina, 2002). Gender is not found to be a direct influence on students' attitudes to physics (Stokking, 2000). More recent research points to the significance of students' evolving physics self-concept, that is their perception of their present and future possible selves in relation to the subject, and this in turn is influenced by how they experience physics in schools. It is in this respect that gender effects might influence attitude development (Krogh and Thomsen, 2005). Because of the greater decline in self concept amongst girls, compared to boys, even girls who are successful in science, and in physics, will ascribe their success to factors other than ability and so still not believe they are good enough to continue with a subject that is generally recognised as difficult (see Section 5 for a discussion of difficulty of physics). Males rate themselves as more successful learners and are more willing to consider maths and science irrespective of their success.

"The type of course studied is a significant influence on both boys' and girls' enjoyment and motivation to learn physics, and this is linked, particularly for some girls, to the match between their goals for their learning and the goals of the course. More girls than boys report that they value social applications and want more social relevance in their physics courses, which can be linked to the higher recruitment and retention of girls to physics courses that emphasise real-life applications." (Murphy and Whitelegg, 2006a)

3.2 Relevance and Curriculum Interventions

Relevance is reported in the review in terms of usefulness either to daily life or to students' goals. Both boys and girls (but more girls than boys) consider that physical sciences are not personally relevant (Stokking, 2000), and personal relevance plays a key role in many girls' motivation for learning (Murphy and Elwood, 1998; Osborne and Collins, 2000). Gender mediates learning from an early age and affects what students become familiar with. It is differences in what is familiar that lie behind what students report they consider personally relevant. Gender differences in what students consider personally relevant influence their perceptions of their competency, so if students, particularly girls, do not perceive a subject as personally relevant, they may also not perceive themselves as competent in it, particularly if they lack self belief in their ability in the subject.

What boys, more than girls, pay attention to and engage with is generally valued and judged relevant in physics and this is evidenced by the sort of applications that have often been used to illustrate physics concepts in the past. More recent approaches have tried to widen participation in physics by adopting a context-led approach, based in contexts that are socially relevant. Advocates of this approach claim that this type of curriculum better meets the needs of all students and there

is evidence to support this (Boaler, 1997; Bennett et al., 2003). The characteristics of a context-based/humanistic curriculum are those where:

- Social situations are used to organise and determine the content studied and assessed.
- The social situation and the problems within it provide the purpose for learning.
- The social situations vary between those of relevance to students' daily lives and concerns and wider social issues of concern to societies generally.
- Physics is represented as a social practice, physics knowledge as a social construction open to change and influenced by social, political, historical and cultural factors.
- The values implicit in physics practices and knowledge are matters for discussion and critique between students and their teachers.

Differences between what girls and boys have learned is relevant and of personal value affects the problems they perceive and whether and how they engage with these problems. So a curriculum that uses this approach must be careful to use context that are relevant to a wide range of learners. Some boys, particularly high achieving ones are more content with abstract nature of physics or its strategic usefulness and some reject context-based approaches as they have learned not to pay attention to social contextual features and feel disadvantaged if asked to do so (Whitelegg and Edwards, 2001).

3.3 Teacher Effects

Teachers' behaviours and attitudes are a key influence on student attitude, motivation, achievement and continuing participation (Labudde, 2000) so an examination of the effects teachers have on their students is an important part of the review. However, the review of the literature revealed that there were no recent *UK-based* empirical studies in science, consequently the Section examines evidence from studies from abroad and some earlier UK-based studies where they still have relevance today. Teachers' expectations have significant effects on students' self-concepts in physics and teachers of physics hold lower expectations for girls in physics than they do for boys (Kenway and Gough, 1998). Supportive teacher-student relationships are more important for girls than boys (Sharp, 2004), particularly in physics where girls' self-concept is less positive than boys'. Personal teacher support was found to be a key predictor of attitudes to physics (Krogh and Thomsen, 2005).

Boys' as a group receive more teacher attention than girls (Kelly, 1988) and the nature of the feedback differs such that girls are more likely to receive negative feedback on quality of work and boys on behaviour. This allows boys to retain confidence in their ability. A study that looked at boys' confidence when they received the sort of feedback more usually given to a girl resulted in boys loosing confidence in their academic abilities. (Dweck in Kelly, 1988) A key finding from another study in Israel (Zohar and Bronshtein, 2005) was that girls with average grades were not encouraged to study physics whereas boys with similar grades were. If teachers hold different perceptions of girls' and boys' abilities in physics

based on their gender and if they also see physics as primarily a boys' subject, these subtle and not so subtle messages are likely to be transmitted to the students.

Maintenance of students' autonomy and responsibility for learning are key factors in encouraging participation in science. Teachers can introduce strategies to develop these qualities in their students. Such strategies (typically found in context-based curriculum) include:

- investigative laboratory work;
- group and class discussion where alternative views are considered and valued;
- problem-solving and project-based activities where students are the decision-makers;
- creative writing involving a wide range of genres in which science understanding is communicated to the public.

3.4 Single Sex School and Groupings

There is very little research into the impact and effectiveness of single-sex groupings in co-ed schools in physics, particularly in England. What research there is suggests that any increase in achievement of girls in single-sex schools is due more to social, environmental and economic factors than the single-sex nature of the school (Sammons et al., 1994; Smithers and Robinson, 1995; Smithers and Robinson, 1997; Elwood and Gipps, 1999). However, some recent studies in England suggest that girls' achievement can be increased by single-sex schooling, particularly for girls of lower ability, but these studies in common with most others in this area was unable to take the social, environmental and economic factors into account (Spielhofer et al., 2002; GSA, 2004). Research does show that girls' subject preferences at younger ages are less polarised in single-sex schools than in co-education schools, but that polarisation occurs later on at around age 15 (Ormerod and Duckworth, 1975; Stables, 1990; Colley et al., 1994).

Research from countries outside the UK show that only when pedagogy and curriculum are effective and inclusive and teachers are gender sensitive do single-sex groupings enhance girls' achievement and self-concept (Parker and Rennie, 2002).

For a significant proportion of girls in single sex schools the research suggests that decline in interest and enjoyment is attributed by the research to curriculum experience (e.g. content overload and fast-pace of study, particularly in top groups), rather than single/mixed sex schooling. (Murphy and Whitelegg, 2006a)

3.5 Measures and Perceptions of Difficulty

Research (Fitz-Gibbon and Vincent, 1994) has found a measured difference of up to one grade lower for physics compared to other subjects. Other unpublished research shows that the difference is between a half to one whole grade (Conway personal communication, 2004). However, regardless of the size of the difference, or the technical concerns about the validity of such measures, the difficulty of physics is accepted as common knowledge amongst teachers and affects who they consider suitable to study physics. Ability in mathematics also affects students' achievement and confidence in physics, and teachers' views on the suitability of

a student for A-level physics study (Sharp et al., 1996). Students' perception of physics as difficult increases with age. This is related to an increase in mathematical demand and increased sense of inadequacy, particularly for girls.

3.6 Performance Patterns in Physics

In this Section, the review considers results of research that focus on the English examination and assessment system and considers the way the specific factors in this system affect girls' participation in physics in England. Some of these factors are unique to the English system and so messages cannot be given that also sit within international contexts. This Section of this paper is therefore limited to a discussion of the factors that have relevance to an international audience. Readers are advised to consult the full review for further discussion.

International survey findings indicate that boys' are demonstrating higher performance in physics examinations although the trend shows a decreasing gap between boys' and girls' performance. The situation in England is similar to this. The majority of students in England and Wales take the Double Award Science GCSE at age 16. In this examination girls overall outperform boys. However, examination of one examination board's results by gender for the physics, chemistry and biology components of the Double Award separately show that girls' overall higher performance is associated with their performance on the biology and chemistry components of the examination. (A similar trend is found on national science tests at age 14.) For the Triple Award examination at 16, where students are entered for the three science subjects separately, far fewer girls than boys are entered for physics and their performance relative to boys is lower at the higher and lower grades in England and Wales but not in Scotland and Eire.

3.7 Impact of Assessment Techniques

The review found little recent research into the effect of situating a physics assessment problem within a real-life context. Social contexts are underrepresented in physics assessments, but those that are found are of more relevance to boys' interests than to girls'.

However it is likely that social contexts and human dilemmas are more likely to be judged relevant and of value by girls more than boys. Some boys are disinterested in relating physics to a context and prefer an abstract approach.

The format of the assessment also affects performance. Research (Murphy, 1982; Powney, 1996) suggests that girls do less well than boys on multiple choice formats, compared with short free response formats. Boys do equally well on both formats. There is also evidence that girls do less well relative to boys on items with graphical and figural data that require this type of response too. The evidence for item effects is equivocal as the effect depends on the interaction with other aspects of the assessment items (Murphy, 1982; Gipps and Murphy, 1994; Willingham and Cole, 1997; Ruddock et al., 2003). The format matters if it alters the construct being assessed.

4. KEY FINDINGS

The review findings reveal a complex problem that limits students', particularly girls', access to physics. Access is constrained via a web of interactions within the curriculum and assessment experience. However, changing access alone will not change girls' participation. More fundamental reconsideration of the contribution of physics to students' future lives is needed.

The limitation on access leads to girls' increased sense of inadequacy and the growing belief of the difficulty in the subject. The Review has revealed that there are many factors in physics curriculum, teaching and assessment that undermine or deny girls' sense of competency. But perceptions of competence alone are not sufficient to influence girls' choices; girls need to perceive a future in physics that will help girls achieve their goals.

Recommendations emerging out of the review suggest that:

- Interventions need to come early in the physics curriculum and its assessment in order to make explicit the value and purposes for studying physics and the range of social issues and careers that it informs.
- Formative strategies to elicit and address differences between students' views need to be developed and made available to teachers. Views of relevance are as important in learning physics as is prior knowledge.
- Long term evaluation of physics curriculum interventions are needed that consider the impact of the curriculum on subgroups of students and on teachers.
- Pedagogic changes are needed that alter the teaching role and the teacher-student relationship so initial teacher training and continuing professional development programmes for physics teachers need to emphasise:
  - *how to develop good relationships with students, particularly with girls;*
  - *how to exhibit leadership and understanding in the classroom;*
  - *the use of a variety of teaching strategies, particularly in open-ended lab work.*
- There is a need for a coherent programme of staff development before any wider implementation of strategies used with single sex teaching groups.
- Further research into the basis for the belief in the difficulty of physics is needed.
- Access to achievement data will help to challenge physics teachers' beliefs about girls' achievement and potential. These beliefs are powerful in shaping girls' self-concept.

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REFERENCES

Bennett, J., et al. (2003). A systematic review of the effects of context-based and Science-Technology-Society (STS) approaches in the teaching of secondary science. *Research Evidence in Education Library*. (London: EPPI-Centre, Social Science Research Unit, Institute of Education.)

Boaler, J. (1997). *Experiencing School Mathematics: Teaching Styles, Sex And Setting.* (Buckingham: Open University Press.)

Colley, A., et al. (1994). School subject preferences of pupils in single-sex and co-educational secondary schools. *Educational Studies 20*(3): 379–385.

Elwood, J. and C. Gipps (1999). *Review of Recent Research on the Achievement of Girls in Single-Sex Schools.* (London: Institute of Education University of London.)

Fitz-Gibbon, C. T. and L. Vincent (1994). *Candidates' Performance in Public Examinations in Mathematics and Science*, CEM Centre Report for the School Curriculum and Assessment Authority: *30*.

Gipps, C. and P. Murphy (1994). *A Fair Test?: Assessment, Achievement and Equity*. (Buckingham, UK: Open University Press.)

GSA. (2004). GSA Survey of maths, science and modern languages at A level Summer 2004. Leicester, Girls Schools Association.

Häussler, P. (1987). Measuring students' interest in physics – design and results of a cross-sectional study in the Federal Republic of Germany. *International Journal of Science Education 9*(1): 79–92.

Hoffmann, L. (1997, September). *An Intervention Project Promoting Girls' and Boys' Interest in Physics: Opening the Door to Physics for Girls.* ESERA Symposium: Gender Issues in Physics. (Paper presented at the first Conference of the ESERA, Rome.)

Kelly, A. (1988). Gender differences in teacher-pupil interactions: A meta-analytic review. *Research in Education 39*: 1–24.

Kenway, J. and A. Gough (1998). Gender and science education in schools: a review with attitude. *Studies in Science Education 31*: 1–30.

Krogh, L. B. and P. Thomsen (2005). Studying students' attitudes towards science from a cultural perspective but with a quantitative methodology: Border crossing into the physics classroom. *International Journal of Science Education 27*(3): 281–302.

Labudde, P. (2000). Girls and physics: teaching and learning strategies tested by classroom interventions in grade 11. *International Journal of Science Education 22*(2): 143–157.

Lindhal, B. (2003, July). *Changing the Subject and Teaching to Get More Students to Science and Technology?* (Paper presented at the 11th Gender and Science and Technology Conference, Mauritius.)

Murphy, P. and J. Elwood (1998). Gendered experiences, choices and achievement – exploring the links. *International Journal of Inclusive Education 2*(2): 95–118.

Murphy, P. and E. Whitelegg (2006a). *Girls in the Physics Classroom: A Review of Research on the Participation of Girls in Physics*. (London: Institute of Physics: 1–61. An electronic copy can be downloaded from: http://www.iop.org/Our_Activities/Schools_and_Colleges/Making_a_Difference/Policy/page_5534.html (last accessed on 15th September 2006.)

Murphy, P. and E. Whitelegg (2006b). Girls and Physics: continuing barriers to 'belonging'. *The Curriculum Journal 17*(3): 281–305.

Murphy, R. J. L. (1982). Sex differences in objective test performance. *British Journal of Educational Psychology 52*: 213–219.

Ormerod, M. B. and D. Duckworth (1975).*Pupils' Attitudes to Science: A Review of Research.* (Windsor, Berks: National Federation for Educational Research.)

Osborne, J. and S. Collins (2000). *Pupils' and Parents Views of the School science Curriculum*. (London: Wellcome Trust.)

Osborne, J., et al. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education 25*(9), 1049–1079.

Parker, L. H. and L. J. Rennie (2002). Teachers' implementation of gender-inclusive instructional strategies in single-sex and mixed-sex science classrooms. *International Journal of Science Education 24*(9), 881–897.

Powney, J. (1996). *Gender and Attainment: A Review*. (Edinburgh: Scottish Council for Research in Education (SCRE))

Reid, N. and E. A. Skryabina (2002). Attitudes towards physics. *Research in Science and Technological Education 20*(1), 67–80.

Ruddock, G., et al. (2003). *Where England stands in the Trends in International Mathematics and Science Study (TIMSS) 2003: Summary of national report for England*. (Slough: NFER Department for Education and Skills, 12.)

Sammons, P., et al. (1994). *Continuity of School Effects.* (London: Institute of Education.)

Sharp, C., et al. (1996). *The Take-Up of Advanced Mathematics and Science Courses – Summary Report.* (Slough: National Foundation for Educational Research report for SCAA, 19.)

Sharp, G. (2004). *A Longitudinal Study Investigating Pupil Attitudes Towards their Science Learning Experiences from a Gender Perspective.* Unpublished PhD thesis. (Milton Keynes, UK: The Open University.)

Smithers, A. and P. Robinson (1995). *Co-educational and Single-sex Schooling.* (Manchester: Centre for Education and Employment Research, University of Manchester.)

Smithers, A. and P. Robinson (1997). *Co-education and Single-sex – Revisited.* (Uxbridge: Brunel University.)

Spielhofer, T., et al. (2002). *The Impact of School Size and Single-sex Education on Performance.* (Slough: NFER for the Local Government Association.)

Stables, A. (1990). Differences between pupils from mixed and single-sex schools in their enjoyment of school subjects and in their attitudes to science and to school. *Educational Review 42*(3): 221–230.

Stokking, K. (2000). Predicting the choice of physics in secondary education. *International Journal of Science Education 22*(12): 1261–1283.

Whitelegg, E. and C. Edwards (2001). Beyond the laboratory: Learning physics in real life contexts. (in R. Duit (Ed.), *Research in Science Education: Past, Present and Future.* (pp. 337–342) Dordrecht, Netherlands: Kluwer Academic Publishers.)

Willingham, W. W. and N. S. Cole (1997). *Gender and Fair Assessment.* (Mahwah, New Jersey/London: Lawrence Erlbaum Associates.)

Zohar, A. and Bronshtein B. (2005). Physics teachers' knowledge and beliefs regarding girls' low participation rates in advanced physics classes. *International Journal of Science Educatiion* 27(1): 61–77.