Routledge
Taylor & Francis Group

International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: www.tandfonline.com/journals/tsed20

Reviewing the role of the physics curriculum and its assessment in post-16 gender disparities

Helen Gourlay & Tamjid Mujtaba

To cite this article: Helen Gourlay & Tamjid Mujtaba (2025) Reviewing the role of the physics curriculum and its assessment in post-16 gender disparities, International Journal of Science Education, 47:15-16, 2045-2070, DOI: 10.1080/09500693.2024.2397001

To link to this article: https://doi.org/10.1080/09500693.2024.2397001

Published online: 10 Sep 2024.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION
2025, VOL. 47, NOS. 15–16, 2045–2070
https://doi.org/10.1080/09500693.2024.2397001

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Reviewing the role of the physics curriculum and its assessment in post-16 gender disparities

Helen Gourlay [a,b] and Tamjid Mujtaba [a,b]

[a]Department of Curriculum, Pedagogy and Assessment, UCL Institute of Education, London, UK; [b]UCL Institute of Education, University College London, London, UK

ABSTRACT

Physics drives innovation, addressing humanity's problems. Learning physics should be an entitlement for all, but access to the physics curriculum is currently inequitable, frequently being perceived as androcentric and Eurocentric. The proportion of girls taking Advanced Level Physics in England has remained low over the last 30 years. We describe changes to the secondary curriculum and its assessment in England from the 1980s onwards, reviewing research about how these changes might affect girls' physics uptake. Arguably, curriculum and assessment decisions have a gatekeeping effect, locking many students out of physics. Research indicates that the science curriculum and its assessment create challenges for girls in accessing physics and identifying as physicists. Whilst introducing balanced science (including biology, chemistry, and physics) to age 16 prevented stereotypical choices at age 14, curriculum content was viewed by young people and teachers as inflexible, irrelevant, lacking debate, and repetitive. Consequently, changes were made. However, the desired improvement in girls' physics uptake did not happen and subsequent curriculum changes restored the status quo. Policymakers should work more closely with practitioners, including experts from underrepresented groups, when making changes, using research and pupil voice to inform them, to improve inclusion and diversity.

ARTICLE HISTORY
Received 16 October 2023
Accepted 22 August 2024

KEYWORDS
Curriculum; gender; girls; physics; secondary education

Introduction

This review focuses on girls' underrepresentation in physics and the impact of curriculum, pedagogy and assessment on girls' uptake of physics in the post-compulsory phase. We acknowledge that other inequalities exist in physics, for example, intersecting with lower socioeconomic status (SES), and 'race', and that not all boys feel physics is welcoming. A variety of reasons are advanced as to why greater diversity is desirable in physics, including:

CONTACT Helen Gourlay h.gourlay@ucl.ac.uk UCL Institute of Education, University College London, 20 Bedford Way, London, UK

- supplying sufficient physicists and engineers to support economic growth (Atkinson & Mayo, 2010)
- improving decision-making to solve societal challenges by including more diverse views (IOP, 2020).
- enabling young people to fulfil their potential by accessing satisfying careers, and developing their problem-solving skills (IOP, 2020).
- improving the culture of physics (IOP, 2013a).
- improving scientific knowledge (Fine, 2018).
- The problem in England is twofold and will resonate with an international audience.

In England, the Westminster Government has had the power to change the school curriculum since the Education Reform Act (ERA) (DfE, 1988). Historically, courses were administered by a multiplicity of regional examination boards (see, for example, AQA, 2024), reducing to three by the 1990s. The absence of a diverse community of experts contributing to curriculum and assessment design is a challenge, leading to frequent science and physics curriculum revisions, often with limited success in engaging underrepresented groups. Additionally, England does not have a diverse range of people working in physics, with under-represented people including women, those with global majority heritage, LGBT + people and those with disabilities or mental health conditions (Institute of Physics [IOP], 2022). We focus on girls' representation because gendered issues are starkly persistent. Under-representation of women continues despite evidence that gender diversity supports innovation and profitability in industry (Hunt et al., 2018). To increase gender diversity in physics in England, we need to engage more girls with physics beyond age 16 (post-16).

We focus on the secondary curriculum, which is for pupils aged 11–18, and assessment in the 14–16 and 16–18 age ranges. Key information about relevant examinations in England is shown in Table 1.

Many 16–18-year-olds study A Level qualifications. The gender imbalance in A Level physics has persisted over a long period. For example, Osborne, Simons and Collins (2003, p. 1051) note a decline in uptake of sciences over the preceding 20 years, stating that 'analysis by gender shows that the male to female ratio remains stubbornly high at 3.4: 1 in physics'. And whilst IOP (2018) observed a slow increase in numbers of girls taking physics in 2011–2016, they reported a higher male to female ratio of 3.7: 1 in 2016. In the same year, the proportion of all boys progressing to A Level Physics was 6.9%, whereas for girls this proportion was 1.9%. A Level physics is one of the most popular subjects for boys, but not for girls, with the gender balance of physics (ratio of girls to boys) ranked more highly only than computer science in 2021 (Plaister, 2021; Rodeiro, 2007).

Other countries report similar disparities in physics uptake (Fullarton et al., 2003; James, 2007; Van Dusen & Nissen, 2020), although some have better representation of women in higher education than others (Moshfeghyeganeh & Hazari, 2021).

In this paper we evaluate the impact of changes to curriculum and assessment in England on gender disparities in the uptake of physics. We do this by reviewing changes to the science curriculum and its assessment, making links to contemporaneous data about the proportion of girls (and boys) taking physics post-16, and discussing these

Table 1. Summary of relevant examinations in secondary school in England.

Age range	When examined?	Qualification	Designed for/taken by …	Science-specific note
14–16	1951–1987	General Certificate of Education Ordinary Level (O Level)	Upper 20% of students (more academic) (Waddell, 1978)	Science not compulsory. Up to three subjects taken (biology, chemistry, physics).
	1965–1987	Certificate of Secondary Education (CSE)	Next 40% of students (Waddell, 1978)	
	1988-present	General Certificate of Secondary Education (GCSE)	All students	Science compulsory since 1989. Most students obtain two GCSEs in combined science (double science), made up of equal components of biology, chemistry and physics. Some students take three GCSEs in separate sciences (triple science) (biology, chemistry, physics).
16–18 (post-16)	1951-present	General Certificate of Education Advanced Level (A Level)	About 5% of all young people passed one or more A Levels in the early 1950s, rising to about 39% of students passing two or more by 2010 (Bolton, 2012).	Not compulsory. Commonly taken sciences include biology, chemistry, physics and psychology (Campaign for Science and Engineering, 2022).

developments in relation to research focused on factors influencing students' choices. Our research questions are:

- What changes are there, if any, in girls' uptake of physics when curriculum and assessment changes are made?
- Why might these curriculum and assessment changes have this effect, or not have an effect?

In the next section, we review literature about factors affecting girls' uptake of physics. We then outline changes in the school science curriculum in England since the late 1980s. Subsequently, we discuss the impact on girls, where relevant discussing teachers' responses to curriculum change. Finally, we suggest implications for tackling the persistent gender imbalance in physics. In so doing, we do not wish to negatively stereotype either girls or boys, acknowledging that there are within-gender differences, and that there is a great deal of overlap in aptitudes and aspirations between boys and girls. However, on average some differences exist, and hence we sometimes refer to that which is gender-typical.

Literature review: what does research have to say about girls' participation in science/physics education?

In this section, we discuss the research into factors affecting girls' participation in science in general, and physics in particular. Where possible, we identify literature specific to physics education, although sometimes researchers do not disaggregate physics from science, perhaps because when a National Curriculum (NC) was first introduced in England 'Science' was envisaged as one subject (also referred to as balanced/combined science). Most students study combined science to age 16, rather than studying physics as a separate subject. Currently, students take the General Certificate in Secondary Education (GCSE) at age 16, typically studying about nine or ten subjects. Science is worth two GCSEs, referred to as double science. It is still possible to take GCSEs in all three sciences (biology, chemistry and physics), referred to as separate sciences or triple science.

Whilst most research cited is based on the English secondary education phase (age 11–18), we include some material from other countries bearing similarities to the English context. The curriculum and assessment changes discussed took place from the late 1980s to the present, and hence we include literature from this period. We consider the influence of:

- Student characteristics
- Schools and teachers
- Pedagogy and curriculum content
- Assessment

Student characteristics

Discussions about girls in physics, and the physics curriculum, are influenced by wider societal structures, such as the culture of physics and institutions. Archer et al. (2017a) suggest that 'physics and engineering are fundamentally constructed as masculine subjects', with masculinity denoted by perceptions of hardness, and where 'the stereotypical physicist is … white, geeky [and] male' (Gonsalves & Seiler, 2012, p. 157). Gonsalves and Seiler further note that physics communities in university physics departments consider physics is 'apolitical, without culture, and … abstracted from societal influences such as race, gender or class', and is associated with being 'dispassionate, rational, and objective' (Gonsalves & Seiler, 2012, p. 157). While school students frequently enjoy science, some groups, including, for example, working-class boys, as well as many girls, may not demonstrate robust affiliations and ambitions in science, since these ways of being a scientist are at odds with their self-concept (Archer et al., 2010; 2014; DeWitt & Archer, 2015). Analysis suggests that disparities in students' selections are linked to their attitudes and convictions in addition to their characteristics, such as gender and ethnic identity (Archer et al., 2015; Mujtaba & Reiss, 2014).

Girls are not a homogeneous group, and some girls do continue with physics. In a large-scale survey of Year 10 students (aged 15) in England, characteristics associated with girls taking physics post-16 were competitiveness and a degree of introversion (Mujtaba & Reiss, 2013). Girls intending to take physics were often extrinsically motivated by their career aspirations and perceived physics lessons more positively than those who did not. Furthermore, the representation of women in science fields is not adequately accounted for by ability and achievement (Plaister, 2023a; 2023b; Wang & Degol, 2013).

OECD 2015 data, in England and internationally, suggests there are minimal gender variations in science performance among secondary school students (Mostafa, 2019). However, STEM Learning (2019) suggests that boys are more likely than girls to attain the highest grade in physics exams at age 16, which might influence students' decisions about whether to continue with the subject. Additionally, girls frequently express lower confidence in their scientific and mathematical abilities and exhibit reduced aspirations toward science-related careers (Mujtaba & Reiss, 2012; 2014; 2016a). Students' inclinations, such as their curiosity about science, as well as their motivational convictions, including their self-assurance in their capabilities, are linked to their ambitions in science (Bøe & Henriksen, 2015; Regan & DeWitt, 2014). However, disparities in physics uptake are not necessarily due to problematic properties of girls, such as a lack of confidence, as we explain below.

One possibility is that girls might opt for humanities over STEM due to their comparative strength in reading (Mostafa, 2019). Another possibility is the effect of gendered notions of masculinity and femininity. Students may perceive physics as difficult, and therefore only for clever people, with cleverness linked with ideas of masculinity (Archer et al., 2017a; Gill & Bell, 2013; Osborne et al., 2003). Shayer and Adey (1981) suggested that the cognitive demand of the science curriculum in England is too high for most students. Although curricula have changed in the intervening period, maintaining standards has been considered desirable in England (Ofqual, 2018), so students' perceptions of subject difficulty may be correct, and may account for subject choices (Murphy & Whitelegg, 2006).

Furthermore, while girls see STEM careers as well-paid and secure, they are discouraged by perceptions of STEM being male-dominated – particularly physics, engineering, and computer science (Cassidy et al., 2018). In sciences where career representation is more gender balanced, there is higher female representation at university. For example, in academic year 2020–2021, women were more likely to be represented in veterinary sciences (83%), medicine (61%) and subjects allied to medicine (79%) (HESA, 2023). However, female undergraduate students still experience challenges to continuing in science, even where they are in the majority, and evidence of positive impact of female role models is not compelling (Fisher et al., 2020).

IOP (2018) indicates that young people from under-represented groups are put off post-16 physics because they have misconceptions about what physics is, or that they are denied opportunity to study physics by negative stereotyping, e.g. based on disability, ethnicity, or SES background. Furthermore, IOP (2022) highlighted how those with disabilities are likely to have some mental health issues, and that both groups, individually and collectively, are less likely to be represented in physics. How does mental health affect girls? Analysis of over 9000 young people from the Millenium Cohort Study (Gutman et al., 2015) suggests that girls are more likely to display symptoms of ill mental health than boys by the age of fourteen. Furthermore, this difference is exacerbated when combined with low-SES. High levels of depressive symptoms at age 14 (when accounting for mental health at age 11) were more noticeable amongst girls from low-SES families, with no such effect for boys (Patalay & Fitzsimons, 2018). Additionally, Stentiford et al. (2023) suggest that girls are more likely to feel under pressure to achieve academically and therefore suffer from anxiety and ill mental health more frequently.

Schools and teachers

IOP (2012) found that girls in single-sex schools were more likely to continue with post-16 physics than those in coeducational schools, across both state (funded by government) and private (fee-paying) sectors. Furthermore, IOP (2018) suggests the likelihood of a girl in England enrolling onto A-level physics is highly influenced by school type, although girls are still less likely to progress to A level than boys in any school type. In single-sex schools, boys were 2.4 times more likely than girls to progress to post-16 physics, and 4.2 times more likely in co-educational schools.

Reasons include that girls' experiences in the classroom are less favourable than boys', being influenced by both teachers' and other students' behaviours. Girls also receive less teacher encouragement to study physics post-16 (Mujtaba & Reiss, 2012; 2014; 2016a). Teachers' decision-making about students' entries for different examinations, which affects options for continuing study, are also influenced by stereotypical assumptions about girls' abilities (Elwood, 2005). However, STEM Learning (2019) suggests there is little difference in uptake between girls and boys for separate sciences, which are sometimes considered a prerequisite to continue with A Level. Cassidy et al. (2018) suggest that physics classrooms in coeducational schools are dominated by boys, which girls find off-putting, finding that girls experience discriminatory behaviour from boys. IOP (2013b) found that boys and girls make more stereotypical subject choices in some schools than in others, with a further report (IOP, 2017) suggesting a need to address whole-school gender equity. However, some evidence suggests attending an all-girls secondary school is less influential than differences in prior attainment and SES (Plaister, 2023c).

Pedagogy and curriculum content

Research also suggests that curriculum content, contexts, and teaching approaches influence girls' decisions. For example, girls express dissatisfaction with the amount of material to be covered in physics, linked to teachers focusing on exam preparation, which they found 'boring and repetitive' (Cassidy et al., 2018, p. 2). Similarly, Mujtaba and Reiss (2016a) noted that, despite physics being interesting to students, physics lessons were not engaging. These observations may be connected to another longstanding problem in England – the shortage of physics teachers. Osborne et al. (2003) suggest that teaching quality affects girls' choices, and that physics specialist teachers are more enthusiastic and confident about teaching physics, leading to greater uptake by girls, with 'teachers who lack confidence and familiarity fall[ing] back on didactic modes of teaching' (p. 1069). Osborne and Dillon (2008) recommend greater opportunity for enquiry and discussion, together with 'more human related content' (p. 16) as teaching approaches leading to greater engagement, particularly for girls. Bentley and Watts (1986) also suggested that open-ended inquiry was likely to be appreciated by girls, because they would like to have greater autonomy. Solomon (1997, p. 408) argues that group activities and opportunities for discussion might be better learning strategies for girls because they 'collaborate more effectively than boys'.

Osborne and Collins (2000) recommended including contemporary contexts, and introducing technological applications before conceptual material, to attract both boys and girls. They suggest that both boys and girls find some science topics interesting, e.g. astronomy, but that others, e.g. medical physics, are more interesting to girls. More recently, in a systematic review, Bennett (2016) suggests that context-based approaches are likely to improve girls' attitudes towards science. Girls also respond positively to science lessons including socio-scientific issues (Hughes, 2000; Murphy & Whitelegg, 2006).

However, there is debate about which contexts to include. Some topics are perceived as masculine, introducing threat to some girls' self-concept of femininity, with some students conforming to traditional gender roles, due to socialisation, e.g. that women must be caregivers (Kerger et al., 2011). Physics textbooks also reinforce gender stereotypes, by showing men and women in stereotypical contexts, and by presenting physics concepts in situations stereotypically associated with men's interests (Abraham & Barker, 2023). Additionally, girls might typically have fewer everyday experiences in some topics, benefiting from teaching in contexts appealing to both boys and girls, e.g. 'investigating safety helmets for cyclists' when learning about forces and motion (Häussler & Hoffmann, 2002, p. 874). That said, not all girls appreciate attempts to make curricula girl-friendly, particularly those higher-attaining girls who would take physics regardless (Abraham & Barker, 2023).

Teachers perceive girls to be less competent in some areas of mathematics and physics, e.g. mechanics, owing to cultural beliefs about girls' abilities, affecting subject uptake post-16 (Murphy & Whitelegg, 2006). Physics is also perceived to require high-level mathematical skills, further associated with concepts of masculinity and hardness that discourage some girls (Abraham & Barker, 2023). Girls who were not continuing with physics were more likely than boys to include mathematical demands as a reason for leaving. Girls expressing interest in continuing with physics are not discouraged by mathematical content, however.

Science capital is suggested as a lens through which to explain these phenomena (see, for example, Archer et al., 2014). Science capital combines economic, cultural and social capital, with multiple factors contributing to whether young people identify with becoming a scientist. Greater science capital is associated with continuing with STEM subjects, with being 'a white male student from a high SES background [associated with] a large quantity of … science capital' (Cooper & Berry, 2020, p. 162). Archer et al. (2017a) suggest that girls who choose to do physics have much in common with these male students, being proud of doing a difficult subject, and not identifying strongly with stereotypes of femininity.

Assessment

Girls' and boys' attitudes towards different types of assessment may differ, and attainment may depend on assessment methods. For example, greater emphasis could be placed on self-assessment because allowing girls to decide criteria for assessment would better meet their needs and interests than criteria imposed externally (Bentley & Watts, 1986). Additionally, multiple-choice tests may disadvantage girls because they prefer to give discursive answers (e.g. Solomon, 1997), although PISA maths tests found boys attained more highly only on complex multiple-choice questions (a question type not commonly found in examinations) (Liu & Wilson, 2009). Furthermore, gender differences on PISA science tests were not so much about the context being assessed, but more about the particular skills being assessed, where girls performed better on questions about science investigations and boys on explaining phenomena scientifically (Fensham, 2009). Similarly, examiners' preferred writing style affects outcomes (Elwood, 2005), where we infer that more direct writing is preferred in physics, advantaging boys.

Whilst coursework (a teacher-assessed component) is widely believed to advantage girls, its effect is not so straightforward (Elwood, 2005). Exams and coursework have differential effects on boys and girls owing to marks being distributed differently, suggesting that, overall, examination marks influence girls' final grades more than boys'. However, girls' and boys' perceptions of coursework differ, with girls on average more motivated by coursework than boys, particularly for middle- and lower-attaining girls (Bishop et al., 1997). Additionally, girls (and lower-attaining boys) were more likely to consider assessment by 100% coursework appropriate, and boys were overall more likely to think coursework is not essential. Perhaps unsurprisingly, higher attainers (who tend to do well in examinations) preferred examinations to coursework.

Examinations can be modular, in which 'the totality of the assessment is broken into discrete units for assessment, the results of which are combined to give an overall result' (Baird et al., 2019, p. 4) or linear, by summative examination. Girls' and boys' responses to modular assessment are also impacted by various factors, including maturation, and the motivational effect of regular feedback about attainment, and differ for different subjects (Rodeiro & Nádas, 2010). Little research evidence was available for physics or science exams at age 16. The available material, about A Level Physics, suggested that lower-attaining boys might be disadvantaged in comparison with other students if they were not permitted to sit module exams immediately after studying the material to be tested (McClune, 2001). Whilst girls' attainment might not be negatively affected by whether they take modular or linear exams, students find linear exams more stressful (Baird et al., 2019). Since girls are typically more likely to be anxious about academic qualifications (Stentiford et al., 2023), perhaps linear exams are less desirable for girls.

To conclude, uptake of post-16 physics is affected by a range of factors. At the structural level, physics and wider society remain influenced by traditional notions of masculinity and femininity, with physics associated with masculinity, including the perception that it is difficult, that it includes hard mathematical content, and that contexts chosen for teaching are more interesting to boys. Schools' cultures, and teachers' and students' behaviours are, in turn, influenced by wider culture. Teachers may be less encouraging towards girls in physics, and, in co-educational schools, boys' behaviour may be off-putting. Whilst a small proportion of girls who continue with physics are not repelled, many girls (as well as some boys) do not feel like they belong in physics. Possibly linked to the shortage of physics teachers, and therefore teaching quality, girls may find physics lessons boring, preferring discussion and enquiry activities. There may also be differences in girls' and boys' perceptions of different types of assessment, with girls' writing styles being more discursive (which may be a disadvantage in physics), with many girls preferring coursework to exams, and perhaps finding modular assessment less stressful.

Approach to analysis

In reviewing the impact of curriculum and assessment changes in England on girls' participation in physics, we use published research (both academic and professional), curriculum documents, and documents published by governmental bodies (e.g. Ofsted, England's schools inspectorate, and Ofqual, England's qualifications regulator). Library and google scholar searches were carried out using terms such as girls, physics, science national curriculum, assessment, GCSE, A Level, module, coursework. Material included articles:

- From the period immediately prior to the changes discussed, for added context;
- From the period under consideration, i.e. 1988 to present;
- Relevant to the science/physics curriculum and its assessment in England, particularly at GCSE level, also considering A Level, where impacting on uptake post-16.

Themes selected for our analysis were those pertaining to curriculum content and its assessment in the literature review, including *subject difficulty, mathematics, discussion/ discursive writing,* the *nature of practical work, types of assessment,* and *topics/contexts for teaching.*

In the following section, we describe changes to the curriculum and its assessment over time. Subsequently, we outline the impact on girls' uptake of A Level Physics, discussing these observations in light of factors identified as affecting girls' participation.

Science/physics curriculum and assessment changes in England

We present an overview of curriculum and assessment changes in England from the late 1980s to the present, introducing relevant features of the English education system, and the context in which changes were made. Figure 1 shows a timeline of changes.

Before the NC was introduced there was no requirement for 14–16 year-olds to study all sciences. There were two different types of qualification – Certificate of Secondary Education (CSE) and General Certificate of Education Ordinary Level (O Level). Broadly, more academic students took O Level and others took CSE, reflecting the previous academic stratification of English schools into grammar schools (academically selective schools) and secondary moderns (for most others). Most schools became comprehensive (teaching students across the entire attainment range) in the 1970s, with most grammar and secondary modern schools being abolished (with some regional variation). The General Certificate in Secondary Education (GCSE) was introduced for first examination in 1988, creating greater standardisation, since one programme of study was examined across the student attainment range. Students were able to opt in or out of biology, chemistry and physics at age 14. Where O Levels were predominantly assessed by summative exams, GCSEs introduced teacher-assessed coursework, including various types of teacher-assessed practical work (Childs & Baird, 2020).

Subsequently, the 1988 ERA (DfE, 1988) established Science in the National Curriculum (DfE, 1989). The government wished to further standardise courses, partly due to perceptions that academic standards had fallen, but also so that standardised testing could measure schools' and teachers' performance (Childs & Baird, 2020).

The 1989 science curriculum included 17 attainment targets (ATs) describing content to be studied, each assessed by statements of attainment at ten levels, and was no longer explicitly organised into biology, chemistry and physics subjects. Included in balanced science were some topics traditionally included in Physics courses, e.g. AT 10 Forces, but with greater breadth, e.g. AT 9: Earth and atmosphere, AT12 The scientific aspects of information technology including microelectronics (DfE, 1989).

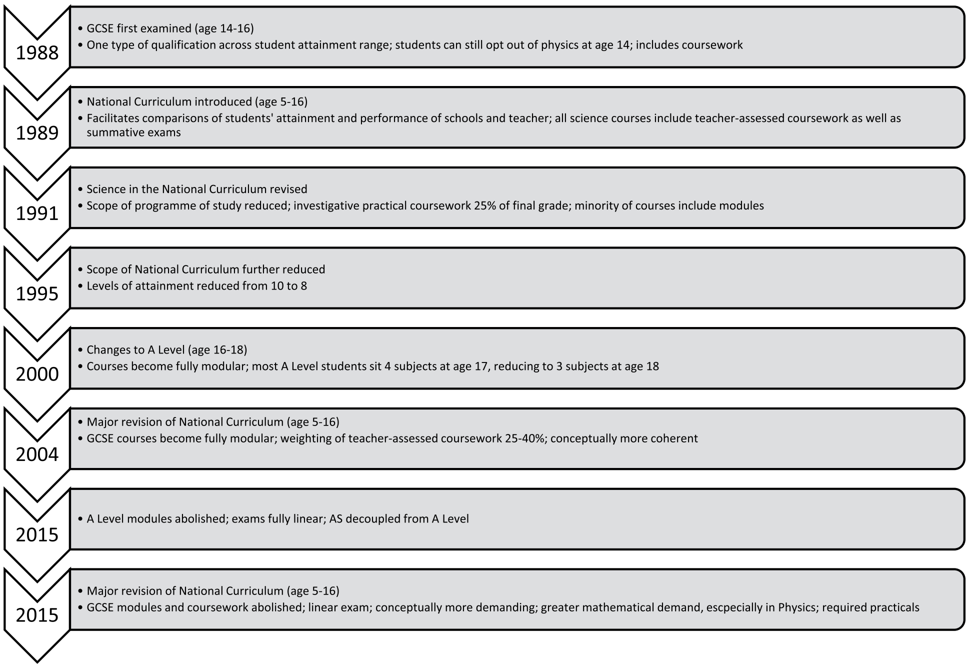

Figure 1. Timeline of curriculum and assessment changes in England.

In state schools, balanced science became compulsory to age 16 – with students no longer permitted to drop biology, chemistry, or physics at age 14. Most schools offered double science in this period (worth two GCSEs), accounting for 77% of students in 2001 (UK Government, 2002), although taking three separate GCSEs (in biology, chemistry, and physics) was also considered balanced. Most courses had linear assessment, although a minority introduced modular components. Notably, the new curriculum included material about scientific methods and the nature of science (NoS):

> AT1 Exploration of science [involving learning about] the procedures of scientific exploration and investigation (DfE, 1989, p. 3)

> AT17 The nature of science – Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social moral, spiritual and cultural contexts in which they are developed; in doing so, they should begin to recognise that while science is an important way of thinking about experience, it is not the only way. (DfE, 1989, p. 36)

The inclusion of AT17 was broadly in line with developments internationally, which had taken place from the early 1970s. Curricula had adopted approaches known as Science and Technology in Society (STS) (Donnelly & Ryder, 2011). Included within such courses were ideas about the NoS, applications of science in society, ethical and empathic ways of thinking, and aspects of social justice (Solomon, 1988).

However, by 1990 that it was evidently impractical for teachers to assess each pupil's progress against this plethora of targets and levels (Childs & Baird, 2020). Consequently, the number of ATs was reduced to four (DfE, 1991):

- AT1: Scientific investigation;
- AT2: Life and living things;
- AT3: Materials and their properties;
- AT4: Physical processes.

Material about NoS was greatly reduced in the updated curriculum (Donnelly, 2001). However, the inclusion of science investigations is noteworthy since it highlights a difference between the sciences and other subjects, i.e. emphasises empirical research (Oakley, 1993). From an international perspective, AT1 is a form of inquiry-based science education (Donnelly & Ryder, 2011). AT1 was teacher-assessed investigative coursework, with a weighting of 25% in the final assessment.

Having been reduced in scope in 1991, the NC was further revised in 1995, 'in response to teacher strikes and protests about the excessive assessment burden on teachers' (Childs & Baird, 2020, p. 366). This resulted in further slimming down of science content (DfE, 1995).

The government changed in 1997, leading to further changes, partly due to different political ideologies, but also reflecting the fact that more young people were progressing to A Levels and university than before. Changes to A Levels were made in 2000, enabling students to take a broader range of subjects (Ofsted, 2001), bringing England more in line with other European countries. A Levels became fully modular, with most students taking four Advanced Subsidiary (AS) Levels in Year 12 (age 16–17) and three A2 courses in Year 13 (age 17–18), where previously the norm had been to study three subjects throughout.

For younger students, there was dissatisfaction with the NC despite previous changes. The Nuffield Foundation consulted curriculum developers, teachers and educationalists, leading to publication of *Beyond 2000* (Millar & Osborne, 1998). One issue as yet unresolved was what an appropriate curriculum would be for all students, now most schools were comprehensive, with the NC being perceived to focus on preparing future scientists. Another was that there remained gender disparities post-16.

The House of Commons Education Select Committee (UK Government, 2002) carried out a review engaging with students' and teachers' views, across England's regions, finding that the curriculum was particularly problematic in the 14–16 age range, with young people and teachers suggesting that:

> the curriculum [is] inflexible, irrelevant, repetitive and prevents debate … As a result, many students lose any feelings of enthusiasm that they once had for science. All too often they study science because they have to but neither enjoy nor engage with the subject. And they develop a negative image of science that may last for life'. (p. 15)

There are parallels with other jurisdictions. For example, when asked about the Canadian curriculum 'students uniformly criticized school science as being socially sterile [and] intellectually boring' (Science Council of Canada, 1984; cited by Aikenhead, 2000, p. 260).

The NC was revised in response to *Beyond 2000* (DfE, 2004), becoming more coherent across the 11–16 age range by emphasising overarching science concepts. Developments were in line with international trends, moving from Vision I to Vision II of science literacy, where:

- Vision I involves developing students' knowledge and understanding of science concepts, as well as developing scientific thinking and an understanding of scientific methods – a vision perhaps more concerned with producing future scientists;
- Vision II considers the applications and implications of science – a vision which perhaps aims to produce citizens capable of making informed decisions for themselves and for wider society (Roberts & Bybee, 2014).

The most substantial changes were in the 14–16 age range, including a new core science qualification, emphasising Vision II. GCSE qualifications are offered by several different exam boards in England. Whilst all exam boards offered courses meeting the new curriculum's goals, we focus on Twenty-First Century Science because it pioneered this change, already being piloted when the updated NC was introduced (Ryder & Banner, 2011). After the compulsory element, different options were available. For students progressing to science A Levels, there were options in Additional Science and Further Science, covering material for future scientists. An alternative was Additional Applied Science, placing greater emphasis on applications of science in the world of work (see, for example, Brimicombe et al., 2006). GCSEs also became fully modular with no summative exam. Coursework was no longer limited to science investigations, with Twenty First Century Science's core course including an argumentation exercise, informed by relevant research (see, for example, Simon et al., 2006).

A further change of government took place in 2010, leading to a plethora of changes to curricula and assessment. These changes include removing coursework, replacing GCSE and A Level modules with summative exams, a further change to the NC (DfE, 2015), and changes to assessed practical work.

Influential in changing the NC in this period were the ideas that the quantity and cognitive demand of content should be in line with the highest-performing countries internationally (Oates, 2011), and the importance of powerful knowledge (e.g. Young & Muller, 2015). Consequently, some more advanced material that was previously studied in A Level moved into the 14–16 curriculum. Content was reorganised into three subjects – biology, chemistry and physics. There is also a strand called 'Working scientifically', with reduced emphasis on Vision II. There are now specified required practicals, assessed in written exams, rather than investigative coursework or argumentation. Additionally, mathematical demand increased, affecting physics more than the other sciences as the relative weighting of mathematical content in biology: chemistry: physics was set at 10: 20: 30 as a percentage of marks available (Ofqual, 2015a).

So far, we have seen that there have been many changes to the curriculum and its assessment in England. So, how did this affect girls' uptake of physics?

Impact on uptake post-16 and discussion

In this section, we evaluate the impact of curriculum and assessment changes on girls' participation in physics, presenting information about girls' uptake of physics post-16 and discussing them in relation to changes implemented. We discuss four phases:

- Implementation of a National Curriculum (from 1989);
- Changes to the A Level Curriculum (from 2000);

- Twenty-first century science GCSE (2006-2015);
- The powerful knowledge turn (2015–present).

Implementation of a National Curriculum (from 1989)

Prior to the NC's introduction, there was a gender disparity in the uptake of biology, chemistry, and physics for examinations at age 16 (The Gate Project, Chelsea College, cited in Mahony, 1985). Table 2 shows data for summer 1980, indicating the percentage of total entries that were from girls or boys in each science subject.

Advanced level (GCE A Level) examination entries at age 18 were also gendered, as shown in Table 3.

Some regarded the NC's implementation as a success for gender equity because it prevented the gendered choices that had previously happened at age 14 (Equal Opportunities Commission, cited by UK Government, 2002). However, introducing double science masked the physics teacher shortage (reported by Smithers & Robinson, 2005), as school leaders deployed biology and chemistry specialists to teaching it, reducing the urgency to recruit more physics teachers (Prowse, 2006). This change was unlikely to improve girls' uptake of physics, as less confident teachers use more didactic teaching styles, which girls find boring (Osborne et al., 2003). To quote a more recent study, 'Physics is fascinating … I fall asleep in class' (Mujtaba & Reiss, 2016b, p. 1). Additionally, whilst more students were studying some physics to age 16 (in double science), there was a decrease in those studying separate GCSE physics, i.e. fewer studied physics in as much breadth as before (Gill & Bell, 2013).

Including greater breadth of science topics was perhaps positive since science relevant to contemporary industries was included, and hence it might be more attractive to students (Osborne & Collins, 2000). However, the loss of material in AT 17 Nature of Science may not have supported girls, since they might appreciate discussion of socio-scientific issues (Murphy & Whitelegg, 2006).

Investigative practical work was thought to be likely to attract girls (Bentley & Watts, 1986). However, research some years after the NC's introduction suggested that 'more girls than boys react overtly negatively to scientific investigations' (Murphy, 2005, p. 137). This observation might be explained by the fact that science coursework became highly prescriptive (Childs & Baird, 2020), where greater autonomy had been suggested for girls (Bentley & Watts, 1986). So, was there a knock-on effect at A Level?

According, to Smithers and Robinson (2005), exam entries for Physics A Level peaked in 1989, coinciding with the last cohort to take O Levels in 1987. Similarly, Donnelly and Ryder (2011) suggest that the peak in Physics A Level uptake was in the mid-1980s. Uptake then generally trended downwards, and the House of Commons Education Select Committee (UK Government, 2002) suggested that introducing the NC had not

Table 2. The percentage distribution of girls and boys in exams at age 16 in 1980 (Mahony, 1985).

	CSE			O Level		
	% Girls	% Boys	Total entries	% Girls	% Boys	Total entries
Biology	70	30	193027	63	37	228,155
Chemistry	40	60	99726	35	65	134,139
Physics	17	83	135119	23	77	55,321

Table 3. The percentage distribution of girls and boys in exams at age 18 in 1980 (Mahony, 1985).

	A Level		
	% Girls	% Boys	Total entries
Biology	56	44	40360
Chemistry	33	67	42973
Physics	19	81	50447

affected this trend. Interestingly, in the same period, more girls went on to do biology and chemistry A Level than before, although these subjects, too, started to decline in the late 1990s (Osborne et al., 2003). The overall decline in uptake of A Level sciences since the 1980s was attributed to a decline in attitudes towards science (UK Government, 2002).

Changes to the A level curriculum (from 2000)

So far, we have seen that there was a general downward trend in uptake of physics post-16, including for girls, which continued after the NC was introduced. What impact did changes to the A Level curriculum have on physics uptake post-16?

A Level physics' uptake continued to drop in the period 2001–2005, with the proportion of boys taking physics dropping from 22% to 18%, and the proportion of girls falling from 5% to 4% (Bell et al., 2007). Additionally, if we intended more students to take a science, at least to AS level, the reform was not a success. Whilst the changes encouraged some of those choosing sciences/maths to take a subject outside this group of subjects, there wasn't a similar crossover from arts to sciences.

> This means that the net effect of broadening the curriculum has been to reduce the amount of science that science specialists study but this has not been matched by an increased uptake by non-scientists. (Bell et al., 2007, p. 24)

Additionally, all sciences were amongst the most dropped subjects after AS. Perhaps sciences were less enjoyable than other subjects but there are confounding variables, including differences in subject difficulty. Not only did students tend to perceive STEM subjects as more difficult than other subjects, but data suggest that a student of a given prior attainment level was statistically likely to achieve a lower grade in STEM (Coe et al., 2008). UK governments have generally wished to maintain standards within individual subjects. Since 2015, there has been a statutory requirement that these standards should remain consistent (Ofqual, 2018), preventing these disparities from being addressed, even if there was consensus that this outcome would be desirable. How does subject difficulty affect girls?

Girls take into account likely grade outcomes when choosing subjects: 'I worry I will get poor grades in physics' (Cassidy et al., 2018, p. 3). Perhaps girls are not lacking confidence, but showing awareness that, on average, a student is likely to get a lower grade in STEM. Additionally, Ofqual (2017) suggest that teachers' advice to students includes consideration of relative subject difficulty, where encouragement from significant others in continuing with physics post-16, including teacher encouragement, was most strongly associated with students' aspirations to continue with post-16 physics (Mujtaba & Reiss, 2014). The double whammy of subject difficulty alongside less teacher encouragement lends itself to girls leaving physics.

Twenty-First Century Science GCSE (2006–2015)

Twenty-First Century Science pioneered curriculum changes, creating 'core science' focusing on scientific literacy, with different routes in the 14–16 age range. However, whilst more students progressed from core and additional science to biology A Level there was a small negative effect on physics uptake (Homer & Ryder, 2014).

The inclusion of argumentation coursework may have appealed to girls, since they typically prefer discursive writing (Solomon, 1997). However, perhaps some physics topics were a missed opportunity in terms of appealing to all students. On one hand, research suggested that astronomy was liked equally by girls and boys (Osborne & Collins, 2000), and the core curriculum included a topic *The Earth in the Universe*, covering the earth's origin and place in the universe, and plate tectonics (see, e.g. Brodie et al., 2006). However, whilst medical physics might attract girls (Osborne & Collins, 2000) it was not included. Additionally, our professional experience was that a topic on *Radioactive Materials,* including debate about nuclear waste disposal, whilst a valuable discussion about a major problem for physics in society, may have been off-putting. Similarly, a topic about *The Earth in the Universe*, may have over-emphasised the deadly effects of asteroid strikes, earthquakes, and tsunamis. Solomon (1988, p. 382) aptly notes that 'there can be little point in teaching and worrying social concerns if this only leaves our students feeling depressed and powerless'. Whilst girls may particularly like physics addressing societal problems or natural disasters, based on their typically greater interest than boys in choosing a career to help people or society (Dicke et al., 2019), perhaps the focus could be more positive, e.g. on the possibilities of nuclear power in a green transition, or on building earthquake-proof buildings and infrastructure.

In terms of teachers' responses, Millar (2006, p. 1499) stated that 'teachers perceive the scientific literacy emphasis as markedly increasing student interest and engagement'. However, Ryder and Banner (2013) link teachers' responses to their positioning, with those identifying as teachers of children being more enthusiastic than most of those identifying as teachers of science (or academic scientists). That said, most teachers agreed that the curriculum's flexibility enabled them better to meet the needs of their students.

There was a slight upward trend in girls taking physics post-16 later in this period (IOP, 2018): Between 2011 and 2016, the proportion of all girls taking A Level Physics rose from 1.6% to 1.9%. However, numbers of boys doing A Level Physics also rose, leaving the proportion of girls in physics classes only slightly higher than before (20.6% in 2011 to 21.4% in 2016). In this light, the 2004 NC (DfE, 2004) was a mild success, albeit with gender disparity unresolved.

The powerful knowledge turn (2015–present)

We discuss some of the developments for students aged 14–16 in this period, which we consider potentially problematic, including subject difficulty, the relative weighting of mathematics, the nature of practical work, the nature of assessment, and the topics included in the core physics curriculum. We acknowledge that some changes may not have impacted adversely on girls specifically, in isolation from intersections with neurodiversity or low-SES. Plaister (2023a) reports that the proportion of girls in the cohort taking A Level Physics was 22% in 2021, i.e. slightly higher than in 2016. However, comparisons may be confounded by the pandemic, with students taking GCSEs and A Levels from 2020 onwards experiencing disruption to education in 2020 and 2021. Either way, the proportion of girls in A Level Physics exam entries remains persistently low.

Moving content from post-16 into the 14–16 curriculum would automatically advantage those who have high science capital (Archer et al., 2014), having been exposed to science and scientific culture from a young age, and those from high-SES backgrounds, being more able to afford tutoring. Another concern about increasing cognitive demand is that it involves adding conceptual items beyond those which are developmentally appropriate for the majority of 16-year-olds (Shayer & Adey, 1981). One might imagine that cognitive demand would affect boys and girls equally or that boys are disadvantaged owing to later maturation. However, perhaps girls are disadvantaged because they are more likely to be concerned about subject difficulty when choosing subjects. This is important when students choose between double and triple science at age 14, since transition to post-16 physics is better from separate sciences (Archer et al., 2017b), as well as at age 16.

Exam stress is widely viewed as causing ill mental health amongst young people in the UK. Stress may have been exacerbated by removing modules and coursework, and by making curriculum material harder. These changes may have impacted girls more than boys since girls may feel more pressure to achieve in exams (Stentiford et al., 2023) and may express a preference for coursework (Bishop et al., 1997).

We further suggest that placing a greater emphasis on mathematics, particularly in physics, is likely to be more off-putting for girls than for boys. Writing about interviews with those who influenced this curriculum change, Wong (2019) notes that discourse considered whether students would be put off science if the additional mathematical component made courses more difficult. However, there appears to have been no specific consideration of gender. Noting that evidence suggests that girls are less confident about science and maths than boys (Mostafa, 2019), including more challenging mathematical content, with a greater weighting for mathematics in physics exams, will have disadvantaged girls, particularly in physics. Abraham and Barker (2023) note a similar concern about increased mathematical content in the physics curriculum in Australia.

Additionally, in revising physics content, material about the earth's place in the universe was much reduced in the combined science curriculum (see, e.g. OCR, 2023), with astronomy mostly taught only to those students opting to study triple science. Thus, most students now study little space science in GCSE. Given its popularity with both girls and boys (Osborne & Collins, 2000) this change does not necessarily disadvantage girls. However, if one's aim is to attract more girls (and boys) to study physics post-16, it is a retrograde step. It is also within currently active fields of physics, e.g. astronomy and particle physics, that we find examples of women physicists, since historically it is only more recently that many women have been able to pursue a career. So, reducing the emphasis on modern physics in the 14 to 16 curriculum is also a missed opportunity to show young people women's contribution to physics. Similarly, the reduction in material addressing vision II of science literacy, is likely to have reduced discussion of socioscientific issues, including a reduction in discursive writing, disadvantaging girls.

A further change in 14–16 science courses, was including required practical work. The nature of assessed practical work has changed since the NC was first introduced, from being predominantly investigative to being predominantly about following standard procedures, and from teacher-assessed coursework to written examination (Ofqual, 2015b). This change has weakened the Vision I component of the curriculum, since it emphasises making measurements with standard equipment, rather than developing a broader understanding of scientific methods. There is debate about whether investigative work is advantageous to girls. Whilst Bentley and Watts (1986) suggested it would attract girls, Murphy (2005) suggested otherwise. However, the more recent success of CREST Awards supports the idea that open-ended inquiry engages girls, with approximately 50% of CREST participants being girls (CREST, 2022).

In 2022, the ratio of boys to girls in A Level Physics was 3.3: 1 in England (IOP, 2022). There is also a continuing disparity between girls' attainment and continuation in post-16 physics, where girls are less likely to continue with physics despite attaining more highly than boys (Plaister, 2023a).

Conclusions and recommendations

Overall, curriculum and assessment decisions have maintained the status quo that physics is not for all, including not for most girls. Whilst there have been many changes to curriculum and assessment since 1988, there has been little positive impact on girls' physics uptake post-16. There has also been little movement on tackling other underrepresented groups in physics, and there is a chronic shortage of specialist physics teachers. Arguably, curriculum changes have not taken these issues into account sufficiently. If we aimed to bring England in line with best practice internationally, perhaps curriculum changes have not made much difference, as England has stayed at about the same position on TIMSS, in which it remains above average internationally (Swensson, 2017). There are several areas requiring support and improvement, with implications for educational policy, for schools and teachers, and for research.

Educational policy

When making changes to curriculum and assessment, policymakers should pay attention to diversity. Part of the challenge is the lack of diverse voices feeding into review processes. Uptake of physics by girls post-16 should also be considered when evaluating policy success.

At present, curriculum content is geared towards a minority of students (future scientists) and thus most do not find physics accessible. Additionally, the curriculum is androcentric, and despite girls' high attainment at GCSE, few choose to continue post-16. More could be done to reduce perceptions of physics as masculine, e.g. by including relevant examples of diverse people working in physics and representing the achievements of women in physics. Redressing the balance between aspects of the curriculum for future scientists and those for all citizens would be welcome, alongside increasing the emphasis on discussing socio-scientific issues and re-introducing open-ended enquiry.

Furthermore, STEM A Levels are harder than other subjects (Coe et al., 2008). Is it not counterproductive to maintain this disparity if we aim to encourage more young people to do sciences, and physics in particular, post-16? Similarly, policymakers should reconsider the emphasis on mathematical skills in GCSE Physics, if it is to widen its appeal. Should not all sciences include a similar mathematical demand?

Historical curriculum reform leaves us with a large number of summative written assessments. We question whether they are inclusive, suggesting that they cater for a particular type of intelligence, rewarding rote learning. Diversity in assessment, which might include some coursework and modules, is likely to support a wider range of students. We note previous issues with coursework, but suggest the weaknesses are unintended consequences of accountability measures, rather than inherent in this type of assessment. A majority of teachers opposed the removal of coursework (Crisp, 2008).

Furthermore, changes have not always reflected teachers' views, something which, together with extra work created by curriculum change, probably contributes to teacher attrition. Just as there is not one scientific method, perhaps there cannot be one science curriculum and one type of assessment for every student, fitting with the identity of every teacher, and appropriate for every school context. Some will align themselves more with preparing future scientists and others with developing informed citizens. Perhaps what is needed is greater choice. However, SCORE (undated, p. 9) argues that 'having multiple routes leads to inequity', recommending a single route to age 16. We question whether achieving consensus is possible, suggesting that policymakers permit greater freedom to develop courses designed to overcome the issues we have highlighted, alongside a reduced core curriculum.

Schools and teachers

IOP (2021) suggests that whole-school approaches to reduce gender inequity and stereotyping may be effective, and we recommend their implementation in all schools. We further recommend that schools review their selection policies at ages 14 and 16. For example, selection policies requiring high GCSE grades for entry to post-16 courses might prevent lower-attaining girls (and boys) with future potential from starting A Level Physics (Plaister, 2023b). However, we recognise that this change is unlikely to happen without changes to school performance measures.

Additional training should also be provided for teachers, helping them to encourage girls to engage with physics and to develop their physics identity. Several promising interventions should be considered. Criticism that contexts chosen for teaching are more interesting to boys, might be overcome by the science capital teaching approach (Godec et al. 2017) or culturally relevant teaching (Mathis & Southerland 2022). In both cases, teachers make connections between their students' existing knowledge and interests and the (physics) curriculum, aiming to improve social justice. Furthermore, culturally relevant teaching emphasises sociopolitical issues, and discussing relevant aspects of social justice, with students having some ownership of learning, features likely to attract girls.

Additionally, lessons including the value of post-16 physics qualifications with examples of people from a diverse workforce might encourage girls to identify with physics (Reiss & Mujtaba, 2017). One issue in including career advice in teaching is that teachers may lack confidence in discussing science careers in lessons (IOP, 2017), so further training should be provided.

Another possibility, not requiring completely overhauling the NC, would be to embed enquiry project work. One such scheme is the CREST Award. Students who complete Silver CREST Awards are 21% more likely to study STEM subjects at AS level, rising to 38% for students eligible for free school meals (CREST, 2022). Furthermore, research on the impact of teacher training using inquiry methods has found a positive impact on girls' engagement with primary science (Mujtaba et al., 2017). We acknowledge that differences in classroom contexts may make inquiry-based approaches less feasible in some than in others, agreeing with Ryder and Banner (2013, p. 721) that future changes must take into account 'the differentiated character of the science teaching community' as well as that of the student body. Any changes in curriculum and assessment must include professional development for teachers to help them enact the curriculum.

Research

Further research is needed to establish whether innovative teaching approaches impact girls' uptake of physics. Similarly, whether inquiry and discussion improve engagement with physics at secondary level, where girls have been found to be inhibited in physics discussions in mixed classrooms (e.g. Mujtaba & Reiss, 2014), requires some longitudinal research. Curriculum design might benefit from more research to produce courses that maximise inclusion, whilst keeping open, and supporting, progression to post-16 physics.

Intersectionality is also important and there is scarce research, and perhaps interest, in examining the challenges faced by girls who fit into several categories of under-representation, or face cumulative disadvantage in terms of academic progression (e.g. Lessof et al., 2016; Witkow & Fuligni, 2011). Further research is needed to address this gap in knowledge.

Recognising diversity

Roberts and Bybee (2014) suggested the general trend for curricula is back towards Vision I, as has happened in England. However, this is not so everywhere. For example, we see a current pilot in New Zealand (NCEA Education, 2023) as attempting to create a 'cross-cultural approach' (Aikenhead, 2000, p. 261). This development is aligned with Vision III of science literacy, encompassing ideas about science held by:

- Cultures that have been less heavily influenced by European people.
- Indigenous cultures.
- Those working outside academia in professional science or science-related roles (Aikenhead, 2007).

In arguing for greater pluralism, this vision was foreshadowed by Reiss (1993, p. 101), who suggests thinking of science as a 'collection of ethnosciences', acknowledging that different people have different conceptions, since they experience different social circumstances.

Sjöström et al. (2017) view the boundary between Visions II and III as a shift from democratic education to being critically reflective, placing greater emphasis on the emancipatory and participatory. In light of recent sociopolitical developments in various countries, women's emancipation has yet to be fully achieved. We see descriptions of feminist approaches to science education, emphasising human values, greater subjectivity, developing wisdom, and community (Bentley & Watts, 1986), as aligned with Vision III.

While recognising the significance of realising Vision I within the curriculum, a more equitable approach would prioritise the implementation of Vision II, equipping students with knowledge of the applications and implications of science, enabling them to make informed decisions for themselves and for the broader community. Furthermore, our review underscores the importance of diversity, emphasising the need for an inclusive curriculum embracing a wide spectrum of perspectives (Vision III). Including the worldviews of various cultures can only serve to enhance the engagement of all students and to foster the development of their critical thinking skills, as they learn to accept difference.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

H. Gourlay http://orcid.org/0000-0001-6457-0772
T. Mujtaba http://orcid.org/0000-0003-1437-9827

References

Abraham, J., & Barker, K. (2023). Students' perceptions of a "feminised" physics curriculum. *Research in Science Education*, *53*(6), 1163–1183. https://doi.org/10.1007/s11165-023-10128-3

Aikenhead, G. S. (2000). Renegotiating the culture of school science. In R. Millar, J. Leach, & J. Obsborne (Eds.), *Improving science education: The contribution of research* (pp. 245–264). Open University Press.

Aikenhead, G. S. (2007). Expanding the research agenda for scientific literacy. In C. Linder, L. Östman, & P.-O. Wickman (Eds.), *Promoting scientific literacy: Science education research in transaction* (pp. 64–71). Uppsala University.

AQA. (2024). CSE exams taken 1965-1987. Retrieved Aug 17, 2024 from https://www.aqa.org.uk/contact-us/certificate-services/past-results-and-lost-certificates/cse-exams-taken-1965-1987

Archer, L., Dewitt, J., & Osborne, J. (2015). Is science for us? Black students' and parents' views of science and science careers. *Science Education*, *99*(2), 199–237. https://doi.org/10.1002/sce.21146

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617–639. https://doi.org/10.1002/sce.20399

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*, *51*(1), 1–30. https://doi.org/10.1002/tea.21122

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (2017a). The 'exceptional' Physics girl: A sociological analysis of multi-method data from young women aged 10-16 to explore gendered patterns of post-16 participation. *American Educational Research Journal*, *54*(1), 88–126. https://doi.org/10.3102/0002831216678379

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (2017b). Stratifying science: A Bourdieusian analysis of student views and experiences of school selective practices in relation to 'Triple Science' at KS4 in England. *Research Papers in education*, *32*(3), 296–315. https://doi.org/10.1080/02671522.2016.1219382

Atkinson, R. D., & Mayo, M. J. (2010). *Refueling the US innovation economy: Fresh approaches to science, technology, engineering and mathematics (STEM) education*. The Information Technology & Innovation Foundation.

Baird, J.-A., Caro, D., Elliott, V., El Masri, Y., Ingram, J., Isaacs, T., Pinot de Moira, A., Randhawa, A., Stobart, G., Meadows, M., Morin, C., & Taylor, R. (2019). Examination reform: Impact of linear and modular examinations at GCSE. Retrieved September 20, 2023 from https://assets.publishing.service.gov.uk/media/5cc6b34140f0b6403803610b/Modular_Linear_GCSE_summary_final.pdf

Bell, J. F., Malcova, E., Vidal Roderio, G., & Shannon, M. (2007). A-level uptake: 'Crunchier subjects' and the 'Cracker effect'. Retrieved August 17, 2023 from https://www.cambridgeassessment.org.uk/Images/504523-a-level-uptake-crunchier-subjects-and-the-cracker-effect-.pdf

Bennett, J. M. (2016). Bringing science to life: The research evidence. In R. Taconis, P. van den Broeck, & A. Pilot (Eds.), *Teachers creating context based learning environments in science* (pp. 21–40). Springer.

Bentley, D., & Watts, D. M. (1986). Courting the positive virtues: A case for feminist science. *European Journal of Science Education*, *8*(2), 121–134. https://doi.org/10.1080/0140528860800202

Bishop, K., Bullock, K., Martin, S., & Thompson, J. J. (1997). Students' perceptions of coursework in the GCSE: the effects of gender and levels of attainment. *Educational Studies*, *23*(2), 295–310. https://doi.org/10.1080/0305569970230212

Bøe, M. V., & Henriksen, E. K. (2015). Expectancy-value perspectives on choice of science and technology education in late-modern societies. In J. Dillon, E. K. Henriksen, & J. Ryder (Eds.), *Understanding student participation and choice in science and technology education* (pp. 17–29). Springer Netherlands.

Bolton, P. (2012). Education: Historical statistics. House of Commons Library. Retrieved Aug 16, 2024 from https://researchbriefings.files.parliament.uk/documents/SN04252/SN04252.pdf

Brimicombe, M., Brodie, D., & Campbell, P. (2006). *GCSE additional applied science: Communications*. Oxford University Press.

Brodie, D., Burden, J., Campbell, P., Daniels, A., Fullick, A., Grayson, A., Holman, J., Hunt, A., Lazonby, J., Marint, J., Nicolson, P., Porter, C., Sang, D., Tracy, C., & Wilson, J. (2006). *Twenty First Century Science: GCSE science higher*. Oxford University Press.

Cassidy, R., Cattan, S., Crawford, C., & Dytham, S. (2018). How can we increase girls' uptake of Maths and physics a-level? (No. R149). IFS Report. Retrieved August 17, 2023 from https://www.econstor.eu/bitstream/10419/201788/1/R149.pdf

Childs, A., & Baird, J. A. (2020). General Certificate of Secondary Education (GCSE) and the assessment of science practical work: An historical review of assessment policy. *The Curriculum Journal*, *31*(3), 357–378. https://doi.org/10.1002/curj.20

Coe, R., Searle, J., Barmby, P., Jones, K., & Higgins, S. (2008). Relative difficulty of examinations in different subjects. Retrieved August 17, 2023 from https://f.hubspotusercontent30.net/hubfs/5191137/attachments/SCORE2008report.pdf

Cooper, G., & Berry, A. (2020). Demographic predictors of senior secondary participation in biology, physics, chemistry and earth/space sciences: students' access to cultural, social and science capital. *International Journal of Science Education*, *42*(1), 151–166. https://doi.org/10.1080/09500693.2019.1708510

CREST. (2022). Impact Report 2021/22 academic year. Retrieved August 23, 2023 from https://static1.squarespace.com/static/5b072a8af79392cac386efed/t/64ac0f3396cfae124c4ee4bf/1688997700009/CREST+Awards+Impact+Report+2021-22.pdf

Crisp, V. (2008). A review of literature regarding the validity of coursework and the rationale for its inclusion in the GCSE. Retrieved September 27, 2023 from https://www.cambridgeassessment.org.uk/Images/499640-a-review-of-literature-regarding-the-validity-of-coursework-and-the-rationale-for-its-inclusion-in-the-gcse.pdf

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, *37*(13), 2170–2192. https://doi.org/10.1080/09500693.2015.1071899

DFE. (1988). Education reform act. Retrieved September 26, 2023 from https://www.legislation.gov.uk/ukpga/1988/40/contents

DfE. (1989). Science in the national curriculum. Retrieved August 31, 2023 from https://www.stem.org.uk/elibrary/resource/27657

DfE. (1991). Science in the national curriculum. Retrieved August 31, 2023 from https://www.stem.org.uk/resources/elibrary/resource/27761/science-national-curriculum-1991

DfE. (1995). Science in the national curriculum. Retrieved September 4, 2023 from https://www.stem.org.uk/resources/elibrary/resource/27764/science-national-curriculum-1995

DfE. (2004). Science in the national curriculum. Retrieved October 1, 2023 from https://www.stem.org.uk/resources/elibrary/resource/27771/science-national-curriculum-2004

DfE. (2015). National curriculum in England: Programmes of study. Retrieved October 1, 2023 from https://www.stem.org.uk/resources/elibrary/resource/358732/national-curriculum-england-science-programmes-study-2015

Dicke, A. L., Safavian, N., & Eccles, J. S. (2019). Traditional Gender Role Beliefs and Career Attainment in STEM: A Gendered Story? *Frontiers in Psychology*, *10*(MAY), 1053–1053. https://doi.org/10.3389/fpsyg.2019.01053

Donnelly, J. (2001). Contested terrain or unified project? 'The nature of science' in the National Curriculum for England and Wales. *International Journal of Science Education*, *23*(2), 181–195. https://doi.org/10.1080/09500690120412

Donnelly, J., & Ryder, J. (2011). The pursuit of humanity: Curriculum change in English school science. *History of Education*, *40*(3), 291–313. https://doi.org/10.1080/0046760X.2010.521196

Elwood, J. (2005). Gender and achievement: What have exams got to do with it? *Oxford Review of Education*, *31*(3), 373–393. https://doi.org/10.1080/03054980500222031

Fensham, P. J. (2009). Real world contexts in PISA science: Implications for context-based science education. *Journal of Research in Science Teaching*, *46*(8), 884–896. https://doi.org/10.1002/tea.20334

Fine, C. (2018). Feminist science: Who needs it? *The Lancet*, *392*(10155), 1302–1303. https://doi.org/10.1016/S0140-6736(18)32400-0

Fisher, C. R., Thompson, C. D., & Brookes, R. H. (2020). "95% of the time things have been okay": The experience of undergraduate students in science disciplines with higher female representation. *International Journal of Science Education*, *42*(9), 1430–1446. https://doi.org/10.1080/09500693.2020.1765045

Fullarton, S., Walker, M., Ainley, J., & Hillman, K. (2003). Patterns of participation in year 12. Retrieved August 28, 2023 from https://research.acer.edu.au/lsay_research/37

Gill, T., & Bell, J. F. (2013). What factors determine the uptake of A-level physics? *International Journal of Science Education*, *35*(5), 753–772. https://doi.org/10.1080/09500693.2011.577843

Godec, S., King, H., & Archer, L. (2017). The science capital teaching approach: Engaging students with science, promoting social justice. Retrieved August 29, 2024 from https://discovery.ucl.ac.uk/id/eprint/10080166/1/the-science-capital-teaching-approach-pack-for-teachers.pdf

Gonsalves, A. J., & Seiler, G. (2012). Recognising "smart-super-physicists": Gendering competence in doctoral physics' Ch 11. In M. Varelas (Ed.), *Identity construction and science education research: Learning, teaching, and being in multiple contexts* (1. Aufl., Vol. 35, pp. 157–172). SensePublishers. https://doi.org/10.1007/978-94-6209-043-9

Gutman, L. M., Joshi, H., Parsonage, M., & Schoon, I. (2015). Children of the new century: Mental health findings from the Millennium Cohort Study. *Centre for Mental Health Report. London, UK: Centre for Mental Health.*

Häussler, P., & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self-concept, and achievement in physics classes. *Journal of Research in Science Teaching*, *39*(9), 870–888. https://doi.org/10.1002/tea.10048

HESA. (2023). Higher education student statistics: UK, 2021/22 - Subjects studied'. Retrieved March 27, 2024 from https://www.hesa.ac.uk/news/19-01-2023/sb265-higher-education-student-statistics/subjects

Homer, M., & Ryder, J. (2014). Measuring the impact of GCSE Twenty First Century Science on progression to post-compulsory science courses. Retrieved October 1, 2023 from https://www.nuffieldfoundation.org/wp-content/uploads/2019/12/Nuffield_21CS_-Final_Report_31_07_14pdf.pdf

Hughes, G. (2000). Salters' curriculum projects and gender inclusivity in science. *School Science Review*, *81*(296), 85–89.

Hunt, V., Prince, S., Dixon-Fyle, S., & Yee, L. (2018). *Delivering through Diversity*. McKinsey & Company. Retrieved October 1, 2023 from https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Organization/Our%20Insights/Delivering%20through%20diversity/Delivering-through-diversity_full-report.ashx

Institute of Physics. (2012). It's different for girls: The influence of schools. Retrieved September 11, 2023 from www.iop.org/sites/default/files/2019-04/its-different-for-girls

Institute of Physics. (2013a). *Closing doors: Exploring gender and subject choice in schools*. Institute of Physics. Retrieved March 26, 2024 from https://www.iop.org/sites/default/files/2019-03/closing-doors.pdf

Institute of Physics. (2013b). Evaluation of Project Juno: Final Report. Retrieved September 11, 2023 from https://www.iop.org/sites/default/files/2020-07/Juno-evaluation-final-report.pdf

Institute of Physics. (2017). *Improving Gender Balance*. Institute of Physics. Retrieved March 26, 2024 from https://www.iop.org/sites/default/files/2019-03/closing-doors.pdf

Institute of Physics. (2018). Why not physics? A snapshot of girls' uptake at A Level. Retrieved October 1, 2023 from https://www.iop.org/sites/default/files/2018-10/why-not-physics.pdf

Institute of Physics. (2020). Limit less: Support young people to change the world. Retrieved August 31, 2023, from https://www.iop.org/sites/default/files/2020-11/IOP-Limit-Less-report-2020-Nov.pdf

Institute of physics. (2021). Teaching without limits: The need for a whole school equity approach. Retrieved August 28, 2023 from https://www.iop.org/sites/default/files/2021-10/Limit-Less-Teaching-without-limits-Secondary-schools-in-Scotland.pdf

Institute of Physics. (2022). Written evidence submitted by the Institute of Physics (IOP) Retrieved October 1, 2023 from https://committees.parliament.uk/writtenevidence/42480/pdf/

James, K. (2007). Factors influencing students' choice (s) of experimental science subjects within the International Baccalaureate Diploma Programme. *Journal of Research in International Education*, *6*(1), 9–39. https://doi.org/10.1177/1475240907074787

Kerger, S., Martin, R., & Brunner, M. (2011). How can we enhance girls' interest in scientific topics? *British Journal of Educational Psychology*, *81*(4), 606–628. https://doi.org/10.1111/j.2044-8279.2011.02019.x

Lessof, C., Ross, A., Brind, R., Bell, E., & Newton, S. (2016). *Longitudinal study of young people in England cohort 2: Health and wellbeing at wave 2*. Department for Education.

Liu, O. L., & Wilson, M. (2009). Gender differences in Large-Scale Math Assessments: PISA Trend 2000 and 2003. *Applied Measurement in Education*, *22*(2), 164–184. https://doi.org/10.1080/08957340902754635

Mahony, P. (1985). *Schools for the boys? Co-education reassessed*. Routledge.

Mathis, C., & Southerland, S. (2022). Our shifting understandings of culturally relevant pedagogy in physics. *The Physics Teacher*, *60*(4), 260–265.

McClune, B. (2001). Modular A-levels – who are the winners and losers? A comparison of lower-sixth and upper-sixth students' performance in linear and modular A-level physics examinations. *Educational Research*, *43*(1), 79–89. https://doi.org/10.1080/00131880010021302

Millar, R. (2006). Twenty First Century Science: Insights from the design and implementation of a scientific literacy approach in school science. *International Journal of Science Education*, *28*(13), 1499–1521. https://doi.org/10.1080/09500690600718344

Millar, R., & Osborne, J. (1998). Beyond 2000: Science education for the future. Retrieved September 4, 2023 from https://www.nuffieldfoundation.org/project/beyond-2000-science-education-for-the-future

Moshfeghyeganeh, S., & Hazari, Z. (2021). Effect of culture on women physicists' career choice: A comparison of Muslim majority countries and the West. *Physical Review Physics Education Research*, *17*(1), 010114. https://doi.org/10.1103/PhysRevPhysEducRes.17.010114

Mostafa, T. (2019). Why don't more girls choose to pursue a science career? *PISA in Focus*, *93*. OECD Publishing. 1–6. https://doi.org/10.1787/02bd2b68-en
Mujtaba, T., & Reiss, M. (2012). Gender differences in 15-year-olds' perceptions of physics, physics lessons and physics teachers. Conference Paper.
Mujtaba, T., & Reiss, M. (2013). What sort of girl wants to study physics after the age of 16? Findings from a large-scale UK Survey. *International Journal of Science Education*, *35*(17), 2979–2998. https://doi.org/10.1080/09500693.2012.681076
Mujtaba, T., & Reiss, M. J. (2014). A survey of psychological, motivational, family and perceptions of physics education factors that explain 15-year-old students' aspirations to study physics in post-compulsory English schools. *International Journal of Science and Mathematics Education*, *12*(2), 371–393. https://doi.org/10.1007/s10763-013-9404-1
Mujtaba, T., & Reiss, M. J. (2016). The relationship between gender, attainment and confidence, and the influence of teacher encouragement. EngineeringUK.
Mujtaba, T., & Reiss, J. (2016b). I Fall Asleep in Class … But Physics Is Fascinating": The Use of Large-Scale Longitudinal Data to Explore the Educational Experiences of Aspiring Girls in Mathematics and Physics. *Canadian Journal of Science, Mathematics and Technology Education*, *16*(4), 313–330. https://doi.org/10.1080/14926156.2016.1235743
Mujtaba, T., Tunnicliffe, S., & Sheldrake, R. (2017). Teachers' perceptions of Inquiry-Based Science Education (IBSE) and the implications for gender equality in science education. *Journal of Emergent Science*, *13*, 10–19.
Murphy, P. (2005). Gender differences in pupils' reactions to practical work. In R. Levinson (Ed.), *Teaching science* (pp. 138–150). Routledge.
Murphy, P., & Whitelegg, E. (2006). Girls and physics: continuing barriers to "belonging." *Curriculum Journal (London, England)*, *17*(3), 281–305. https://doi.org/10.1080/09585170600909753
NCEA Education. (2023). Science. Retrieved October 1, 2023 from https://ncea.education.govt.nz/science/science?view = learning
Oakley, D. (1993). National curriculum for science. In R. Hull (Ed.), *ASE secondary science teachers' handbook* (pp. 23–45). Simon & Schuster Education.
Oates, T. (2011). Could do better: Using international comparisons to refine the National Curriculum in England. *The Curriculum Journal*, *22*(2), 121–150. https://doi.org/10.1080/09585176.2011.578908
OCR. (2023). GCSE (9-1) Specification Twenty First Century Science combined science B. Retrieved September 4, 2023 from https://www.ocr.org.uk/Images/234597-specification-accredited-gcse-twenty-first-century-science-suite-combined-science-b-j260.pdf
Ofqual. (2015a). GCSE subject level conditions and requirements for combined science. Retrieved September 26, 2023 from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819655/gcse-subject-level-conditions-and-requirements-for-combined-science.pdf
Ofqual. (2015b). A new approach to GCSE science practical assessment. Retrieved September 26, 2023 from https://www.gov.uk/government/news/a-new-approach-to-gcse-science-practical-assessment#:~:text = Each%20exam%20board%20will%20have,full%20range%20of%20practical%20work
Ofqual. (2017). Perceptions of subject difficulty and subject choices. Retrieved September 26, 2023 from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/649891/Perceptions_of_subject_difficulty_and_subject_choices.pdf
Ofqual. (2018). Improving GCSE and A level standard setting: A world of learning. Retrieved September 16, 2023 from https://www.gov.uk/government/publications/improving-gcse-and-a-level-standard-setting-a-world-of-learning
Ofsted. (2001). Curriculum 2000: The first year of implementation. Retrieved September 16, 2023 from https://dera.ioe.ac.uk/id/eprint/4516/1/Curriculum%202000%20The%20first%20year%20of%20implementation%20%28PDF%20format%29.pdf
Osborne, J., & Collins, S. (2000). *Pupils'& parents' views of the school science curriculum*. King's College.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. (Vol. 13). The Nuffield Foundation.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199

Patalay, P., & Fitzsimons, E. (2018). *Mental ill-health and wellbeing at age 14 – Initial findings from the Millennium Cohort Study Age 14 Survey*. Centre for Longitudinal Studies.

Plaister, N. (2021). Which A-Level subjects have the best (and worst) gender balance? *Fisher Family Trust Education Datalab*. Retrieved August 28, 2023 from https://ffteducationdatalab.org.uk/2021/09/which-a-level-subjects-have-the-best-and-worst-gender-balance/

Plaister, N. (2023a). How does KS5 subject choice vary by gender and prior attainment? *Fisher Family Trust Education Datalab*. Retrieved August 28, 2023 from https://ffteducationdatalab.org.uk/2023/01/gender-prior-attainment-and-key-stage-5-subject-choice/

Plaister, N. (2023b). Which subjects do high attaining pupils go on to study at Key Stage 5? *Fisher Family Trust Education Datalab*. Retrieved August 28, 2023 from https://ffteducationdatalab.org.uk/2023/01/which-subjects-do-high-attaining-pupils-go-on-to-study-at-key-stage-5/

Plaister, N. (2023c). Why are girls in single sex schools more likely to choose A-Level physics? *Fisher Family Trust Education Datalab*. Retrieved August 28, 2023 from https://ffteducationdatalab.org.uk/2023/07/why-are-girls-in-single-sex-schools-more-likely-to-choose-a-level-physics/#:~:text = And%20there%20is%20a%20far,those%20in%20single%20sex%20schools

Prowse, M. (2006). Number-crunching. *Prospect (London, England)*, (118), 16–17.

Regan, E., & DeWitt, J. (2014). Attitudes, interest and factors influencing STEM enrolment behaviour: An overview of relevant literature. In J. Dillon, E. K. Henriksen, & J. Ryder (Eds.), *Understanding student participation and choice in science and technology education* (pp. 63–88). Springer.

Reiss, M. J. (1993). *Science education for a pluralist society*. Open University Press.

Reiss, M. J., & Mujtaba, T. (2017). Should we embed careers education in STEM lessons? *The Curriculum Journal*, *28*(1), 137–150. https://doi.org/10.1080/09585176.2016.1261718

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol II, pp. 559–572). Routledge.

Rodeiro, C. L. V. (2007). A level subject choice in England: Patterns of uptake and factors affecting subject preferences. Retrieved August 28, 2023 from https://www.cambridgeassessment.org.uk/Images/111069-a-level-subject-choice-in-england-patterns-of-uptake-and-factors-affecting-subject-preferences.pdf

Rodeiro, C. L. V., & Nádas, R. (2010). *Effects of modularisation*. Cambridge: Cambridge Assessment.

Ryder, J., & Banner, I. (2011). Multiple aims in the development of a major reform of the National Curriculum for Science in England. *International Journal of Science Education*, *33*(5), 709–725. https://doi.org/10.1080/09500693.2010.485282

Ryder, J., & Banner, I. (2013). School teachers' experiences of science curriculum reform. *International Journal of Science Education*, *35*(3), 490–514. https://doi.org/10.1080/09500693.2012.665195

SCORE . (undated). The sciences at key stage 4: Time for a re-think? Retrieved September 30, 2023 from https://www.rsb.org.uk/images/score_sciences_at_ks4_final.pdf

Shayer, M., & Adey, P. (1981). *Towards a science of science teaching : Cognitive development and curriculum demand*. Heinemann Educational.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, *28*(2-3), 235–260. https://doi.org/10.1080/09500690500336957

Sjöström, J., Frerichs, N., Zuin, V. G., & Eilks, I. (2017). Use of the concept of *Bildung* in the international science education literature, its potential, and implications for teaching and learning. *Studies in Science Education*, *53*(2), 165–192. https://doi.org/10.1080/03057267.2017.1384649

Smithers, A., & Robinson, P., (2005). *Physics in schools and colleges: Teacher deployment and student outcomes*. Gatsby Charitable Foundation.
Solomon, J. (1988). Science technology and society courses: Tools for thinking about social issues. *International Journal of Science Education*, *10*(4), 379–387. https://doi.org/10.1080/0950069880100405
Solomon, J. (1997). Girls' science education: Choice, solidarity and culture. *International Journal of Science Education*, *19*(4), 407–417. https://doi.org/10.1080/0950069970190404
STEM Learning. (2019). Science education in England: Gender, disadvantage and ethnicity. Retrieved April 9, 2024 from https://www.stem.org.uk/sites/default/files/pages/downloads/Science%20Education%20in%20England_%20Gender%2C%20Disadvantage%20and%20Ethnicity.pdf
Stentiford, L., Koutsouris, G., & Allan, A. (2023). Girls, mental health and academic achievement: A qualitative systematic review. *Educational Review*, *75*(6), 1224–1254. https://doi.org/10.1080/00131911.2021.2007052
Swensson, C. (2017). How similar are the PISA and TIMSS studies? *IOE Digital*. Retrieved September 27, 2023 from https://blogs.ucl.ac.uk/ioe/2017/12/04/how-similar-are-the-pisa-and-timss-studies/
UK Government. (2002). Science education from 14 to 19. Retrieved September 27, 2023 from https://publications.parliament.uk/pa/cm200102/cmselect/cmsctech/508/508.pdf
Van Dusen, B., & Nissen, J. (2020). Equity in college physics student learning: A critical quantitative intersectionality investigation. *Journal of research in science teaching*, *57*(1), 33–57. https://doi.org/10.1002/tea.21584
Waddell, J. (1978). *School examinations*. HMSO. Retrieved August 16, 2024 from https://web.archive.org/web/20150419024441/http://educationengland.org.uk/documents/waddell/waddell1978.html
Wang, M. T., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields. *Developmental review*, *33*(4), 304–340. https://doi.org/10.1016/j.dr.2013.08.001
Witkow, M. R., & Fuligni, A. J. (2011). Ethnic and generational differences in the relations between social support and academic achievement across the high school years. *Journal of Social Issues*, *67*(3), 531–552. https://doi.org/10.1111/j.1540-4560.2011.01713.x
Wong, V. (2019). Authenticity, transition and mathematical competence: An exploration of the values and ideology underpinning an increase in the amount of mathematics in the science curriculum in England. *International Journal of Science Education*, *41*(13), 1805–1826. https://doi.org/10.1080/09500693.2019.1641249
Young, M., & Muller, J. (2015). *Curriculum and the specialisation of knowledge: Studies in the sociology of education*. Routledge.