Research in Science Education (2023) 53:1163–1183
https://doi.org/10.1007/s11165-023-10128-3

Students' Perceptions of a "Feminised" Physics Curriculum

Jessy Abraham[1] · **Katrina Barker**[1]

Accepted: 16 August 2023 / Published online: 1 September 2023

Abstract

In recent decades, several countries have made efforts to close the historic gender gap in physics through curricular reforms. Research indicates that while the acute underrepresentation of females in physics courses and related careers is linked to a number of interlaced social, contextual and motivational factors, the personal relevance of physics curricula is important. Some researchers argue that physics has been historically perceived as a "masculine" domain which operates through contexts that are unfamiliar to females. Introduction of a "girl-friendly" physics curriculum is one of the prominent measures employed to mitigate this concern, with researchers arguing that a context-based/humanistic physics curriculum will improve gender inclusivity and thereby increase females' motivation to learn physics. However, this approach has been criticised as a "feminisation" of the physics curriculum. This paper uses a mixed-methods approach underpinned by expectancy-value theory, to analyse 247 students' perceptions of an Australian senior secondary physics curriculum and investigates the claim that including "female-friendly" topics will make physics more appealing to females. Findings suggest that while most students found their physics curriculum interesting and personally relevant, neither females nor males found the "feminine" topics particularly appealing. Both male and female students also found there was a lack of mathematical applications, and they identified descriptive topics, such as those addressing social and historical contexts, as uninteresting and irrelevant in a physics curriculum. This paper concludes that gender was non-significant in student perceptions of a senior secondary physics curriculum.

Keywords Motivation · Engagement · Enrolment Plans · Physics Education · Females and Physics · Girl-Friendly Physics · Expectancy –Value Theory

Numerous studies have shown that, relative to males, females find physics significantly less interesting than other branches of science such as biology or chemistry (Hazari et al., 2007; Sax et al., 2016). Girls' disinterest in physics tends to start during junior high school,

✉ Jessy Abraham
J.Abraham@westernsydney.edu.au

Katrina Barker
k.barker@westernsydney.edu.au

[1] School of Education, Western Sydney University, Sydney, Australia

where science is mandatory, resulting in their later underrepresentation in advanced physics classes and in physics-related careers.

Various theoretical frameworks have been applied in an attempt to explain the underrepresentation of females in physics (e.g., Archer et al., 2017; Kelly, 2016). Social cognitive theory (Bandura, 1977), expectancy-value theory (Wigfield & Eccles, 2000), stereotype threat theory (Steele et al., 1995), and the theory of planned behaviour (Ajzen, 1991), for example, have been used to explain females' lack of interest in pursuing physics. While studies offer varying explanations (see Kelly, 2016, for a comprehensive review), a recurring theme is the lack of personal relevance of physics perceived by females. Traditionally, physics has been regarded as a difficult subject demanding high mathematical skills and abstract thinking, and hence is considered a prestigious school subject with high strategic value for future study and career plans (Lyons, 2006; Makarova et al., 2019). However, a growing body of literature suggests that females assign lower career value to physics compared to their male counterparts (Barnes et al., 2005; Hazari et al., 2013; Jugović, 2017; Makarova et al., 2019).

Females' interest in physics is also reported to be significantly lower than that reported by males (Baram-Tsabari & Yarden, 2008). They also perceive physics to be more difficult (Angell et al., 2004; Makarova et al., 2019; Stadler et al., 2000), and show lower levels of self-efficacy and motivation (Kalender et al., 2019) irrespective of their academic performance in the subject. Other social and contextual factors suggested as prominent influences on females' alienation from physics include lack of female role models, gender stereotyped cultural expectations, male-dominated classrooms, gendered experiences and male-friendly learning styles in physics classrooms, disengaging pedagogy, and negative perceptions perpetuated by socialisers and family (see Kalender et al., 2019; Wheeler & Blanchard, 2019, for comprehensive reviews).

The nature of the subject and the culture of the curriculum are influences that have been closely examined in recent decades. Some experts argue that while students have traditionally considered physics a "mathematical, abstruse and difficult subject" (Collins & Osborne, 2000, p. 29), female students are further challenged by the lack of gender inclusivity within the curriculum (Zohar & Sela, 2003). Physics textbooks have been dominated by examples and images representing stereotypical masculine interests and characteristics (Keast, 2021; Wheeler & Blanchard, 2019). Examining the underrepresentation of certain student groups in physics, Archer et al. (2017) suggest that physics has been quintessentially constructed as a subject for academically capable males. This corresponds with Murphy and Whitelegg's (2006) earlier finding that "the contents, contexts and ways of approaching problems and investigations in physics more closely reflect what boys, more than girls, engage with outside school, and those activities associated with what culture defines as masculine rather than feminine attributes" (p.281). Consequently, they argue that "belonging" in physics (p. 284) may be a challenge for some females.

"Masculinity" of the Physics Curriculum

Researchers who believe in physiological gender differences in adolescent students (see Halpern et al., 2007, for a comprehensive review) assert that the culture of physics tends to be overtly masculine. This assumption is often derived from observations regarding the presentation of physics in educational settings, including an excessive reliance on male life experiences in both the context and content of the physics curriculum, a scarcity of female role models incorporated within the curriculum, the marginalisation experienced by females due to their substantial underrepresentation in physics classes, the perceived advantage of certain learning styles to males, and the presence of gendered expectations held by some teachers regarding female success in the subject. Therefore, assertions are put forward suggesting that the masculine nature of physics poses challenges for girls making it difficult for girls to be successful in physics (Baram-Tsabari & Yarden, 2008; Francis et al., 2016). Existing physics education literature offers support for the claims of the "masculinity of physics" and how females perceive this as a barrier for their progression within the subject (see Wheeler & Blanchard, 2019). Researchers argue that females are inclined to excel in "verbal" tasks, while males are better at the "visual-spatial" tasks, making it easier for them to think in an abstract manner and solve problems (Wilson et al., 2016, p. 2); this suggests that males, therefore, have an edge in physics learning environments and on physics performance tests.

The abstract nature of physics promoted in traditional physics curricula, particularly at more senior grade levels, has been emphasised across research studies. It has been suggested that this increasing abstractness puts males at an advantage (Miler-Bolotin, 2015; Zhu, 2007). Topics and learning contexts that are unappealing or unfamiliar to females' lived experiences may alienate even high-ability females from physics (Joyce & Farenga, 1999; Whitelegg & Murphy, 2006; Whitelegg et al., 2007). Examples and contexts drawn from traditionally male frameworks are common in physics curricula (Goodrum et al., 2001; Häussler et al., 1998; Hoffmann, 2002; Rennie & Parker, 1996). For example, Nair and Majetich (1995, cited in Baram-Tsabari and Yarden, 2008) observed that physics topics such as mechanics were dominated by sports and weapon deployment contexts which are considered to be unfamiliar domains for females. Similarly, a content analysis of physics textbooks in New South Wales (NSW) over the period 1995–2020 revealed gendered content and imagery reinforcing the masculinity of the subject (Keast, 2021).

Girl-Friendly Physics

If physics has a masculine image and generally operates through stereotypically masculine contexts, as researchers argue, how can gender inclusivity be achieved in its operation? Two possible approaches are either bringing females' knowledge and skills to correspond more closely to masculine characteristics or including "girl- friendly" topics, which aim to make physics more personally relevant for females. The most pragmatic of these approaches is creating girl-friendly topics, and researchers have identified approaches to this, including using specific language in physics examples and problems that involves familiar and relevant contexts for all students, including "topics that have a natural appeal for girls" or that have been found to stimulate females' interest (Baram-Tsabari and Yarden, 2008, p. 88). Murphy and Whitelegg (2006) term it as a "compensatory approach" (p.293) and illustrate such female-friendly examples and contexts in teaching physics concepts that are assumed to be more relevant for females. For example, "in learning about sound, ultrasonic scans showing foetal development are used; conservation of momentum is illustrated by the movement of female ice skaters" (p. 293). Likewise, McCullough (2007) suggests using contexts that all students are familiar with, such as school activities, food and cars. Nonetheless, employing the same reasoning could lead one to contend that incorporating subjects that are perceived as being appealing to girls, or assumed to be so, may result in boys feeling estranged from physics in a manner that parallels the alienation previously encountered by girls.

Measures have been taken to bring gender inclusivity into physics assessment tasks as well. As an illustration, alterations were implemented to the Force Concept Inventory (FCI) due to a number of its questions included contexts that were found stereotypically masculine (hockey, cannonballs and rockets). Contexts in the revised scale were changed to stereotypically feminine settings (shopping, cooking and jewellery), and abstract classroom lab situations were changed to focus on the daily life experiences of females. The findings from studies employing the revised instrument indicated that performance on a physics assessment can be influenced by context, regardless of gender. Specifically, the gender gap in the revised FCI was diminished when male-oriented contexts were substituted with female-oriented ones, however, a closer analysis revealed that men's performance was lowered instead of improving women's performance. (McCullough, 2004). This indicates that, as gender continues to be a significant factor in predicting students' choice of physics, such fragmented strategies can be regarded as simple and superficial and may potentially restrict females' experiences further (Murphy & Whitelegg, 2006). Moreover, it is worth mentioning that research conducted on contextualised physics assessments does not consistently yield definitive evidence to uphold the assertion that females perform better in such assessments (See Bouhdana et al., 2023 for a comprehensive review).

Contextual Curriculum

In an attempt to widen physics participation, the content and approach to physics has been reimagined in various curricular reforms. The personal relevance of physics has been emphasised by some experts, as it has a significant gender dimension (e.g., Kalender et al. (2019); Murphy & Whitelegg, 2006). Personal frameworks of relevance often place students into clearly marked gender binaries and position them in opposition to each other. For example, Hildebrand (1998) differentiates between masculine and feminine frameworks of relevance applied to science, represented in a set of dualisms. A masculine framework applied to science has been associated with terms such "abstract, quantitative, outcomes, competition, objective, hierarchical, value-free". These terms tend to represent an image of the traditional physics curricula. In contrast, a feminine framework applied to science has been associated with terms such as "holistic, qualitative, process, co-operation, subjective, multiplicity and value-laden" and are terms which tend to be less represented in the image of a traditional physics curricula (p. 6). Given this stark contrast, curricular interventions to reduce the gender gap in physics tend to bring the knowledge and skills of one gender to correspond more closely and Vidor et al., (2020) highlight in their systematic review on gender in physics, a number of limitations associated with this approach.

Another feature of a traditional physics curriculum is the emphasis placed on quantitative aspects. In traditional physics classrooms, focus is given to solving problems that require students to calculate a precise quantitative solution and focus on equations, manipulating them, and calculating an answer. A debatable but noteworthy argument is that instructional strategies that prioritise quantitative aspects of physics such as equations and calculations may lead to students failing to comprehend the fundamental conceptual connections within the problems, thereby fostering inadequate problem-solving techniques (Taasoobshirazi & Carr., 2008).

An alternative curricular intervention is a context-based or humanistic approach; such an approach rejects these dualist images of science and sees them more as continua (Murphy & Whitelegg, 2006; Vidor et al., 2020). Despite debate on the definition of "context", a context-based/humanistic curriculum is believed to increase the personal relevance of physics for a wide range of students (see Murphy & Whitelegg, 2006, for a brief history of this approach). In such an approach:

- 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, and;
- The values implicit in physics practices and knowledge are matters for discussion and critique between students and their teachers. (Murphy & Whitelegg, 2006, p. 294)

Some studies indicate that embedding physics content in appropriate contexts can increase girls' interests in learning physics (Murphy & Whitelegg, 2006). In this approach, students acquire knowledge of the subject matter by relating it to real-world situations and thereby developing links between the subject and its practical applications in their daily lives (Taasoobshirazi & Carr, 2008). Advocates of context-based/humanistic physics argue that students' attitudes towards the subject can be improved by this approach (Frost et al., 2005; Murphy & Whitelegg, 2006). Likewise, Taasoobshirazi and Carr (2008) contend that physics instruction that incorporates context-based approaches is likely to be more successful in enhancing the motivation, problems solving, and achievement of students when compared to traditional instruction. The researchers were optimistic that integrating context into physics material may be more beneficial for females as research shows that females, more than males, feel that physics is irrelevant to them and to their future goals. However, concerns have been raised about findings suggesting that high-achieving students, particularly males, feel disadvantaged and tend to reject learning physics that is embedded in a social contextual framework, preferring the traditionally abstract nature of physics (Whitelegg & Edwards, 2001). Taasoobshirazi and Carr's (2008) review offers support to this argument by recognising that while context-based teaching and evaluation may be more inspiring, it does not necessarily translate to superior academic performance.

Gender Difference in Interest Level in Contexts

Stereotypes suggest that interest in various physics contexts will differ across genders, though this is debatable. A study with 15-year-old Finnish students found that girls identified with physics contexts that were connected with human beings, more than those connected to artefacts and technological processes. Trumper (2006) found that females showed more interest in contexts such as "how the eye can see light and colours", while males' favourite topics were "rockets, satellites and space travel" (p. 53). Similarly, the Relevance of Science Education (ROSE) project also found gender differences in topic/context preference, although no gender difference was reported for astronomical context, which was equally interesting for both genders (Lavonen et al., 2005). Studies with Abu Dhabi high school students made similar findings (Badri et al., 2016).

It has been argued that male students tend to be interested in physics for its own sake, while female students are likely to be interested in physics for what it can do to help humankind and in other socially beneficial contexts (Bøe & Henriksen, 2013). However, such gendered interests are not necessarily mutually exclusive. For example, Stadler et al. (2000) noted that "contexts that are meaningful for girls are usually also meaningful for boys, though the reverse does not hold" (p. 417). Likewise, Haussler (1998, as cited in Hoffmann, 2002) identified common grounds in physics interests. In terms of physics assessment tasks, Murphy and Whitelegg (2006) found that females' attitude and performance in physics items set in technological contexts were significantly lower than those of their male counterparts, but contexts that prioritised human, social and environmental concerns were appealing to males as well as females. Interestingly, a recent study (Wheeler and Blanchard, 2019) observed that given a choice of three different contexts (biological, sports, and traditional), females were more likely to choose questions related to biology contexts, while males were more likely to select traditional physics contexts, although the rationale for their choices were indistinguishable by gender.

It should be noted that such situational interest in physics topics has not been conclusively proven to increase the motivation to study and continue in physics. Furthermore, these studies included students doing physics as a part of their general science education. Perceptions of a context-led curriculum held by high-ability male and female students studying physics as an elective remain largely unexplored. NSW's senior secondary physics curriculum offered a perfect opportunity for this investigation.

Research Context

Elective physics classes in Australia begin in the senior secondary stage; students can opt out after the first year of senior secondary physics (Year 11) or continue physics to the final year (Year 12). This provides physics education researchers an unusual opportunity to monitor students' motivation and persistence with physics after a year of specialist study. In this context, the aim of this research was to examine the thoughts of this unique group of students about the context -led physics curriculum they experienced during their first year of senior secondary schooling.

The NSW school physics curriculum underwent a significant change, along with other science curricula, in 2000. The new curriculum adopted a contextual approach to sciences, with considerations of relevance to society, ethics, history and culture (Sharma et al., 2013). The intended outcome of the paradigm shift was to teach physics in "an integrated manner", incorporating a "more verbal or literate style" (Binnie, 2004, p. 491). Embedded in this syllabus were the nature and history of science and social contexts, the life history of physicists, social implications of inventions and other historical anecdotes (Georgiou & Crook, 2018, p. 21). In NSW, as elsewhere, students who enrol in senior secondary physics tend to be strong academically, with high career aspirations and high self-efficacy in the subject (Barnes, 1999; Lyons, 2006); however, the participation of certain groups, such as females, students from regional and remote locations, Aboriginal and Torres Strait Islander students and students from a low socio-economic background, is markedly low (Ainley et al., 2008). The new syllabus was expected to make physics more appealing and accessible to a wider group of students.

The contextual approach to physics was also expected to bring a holistic experience of the subject's nature and content, together with understandings of its role within society (Sharma et al., 2013). The four modules in the Year 11 physics curriculum—The World Communicates, Moving About, Electrical Energy at Home and The Cosmic Engine—covered content related to electro-magnetic waves and their properties, electricity and its applications, mechanics, and astrophysics, respectively. The content aimed to provide learning experiences through which students would not only learn fundamental concepts but the historical development of these concepts.

A constant criticism of this syllabus, particularly from physics academics, was that it had shifted from traditional and classical physics, thus poorly preparing students for university. There were also debates on whether the content was being "dumbed down" by concepts being placed strongly within a historical and cultural context at the expense of mathematical derivations and problem solving (Sharma et al., 2013, p. 35). Hence, the curriculum was branded as "soft, lacking in substance, weighed down by unnecessary history and sociology and … *feminine* [emphasis added]'' by physicists, higher education experts and the media (Georgiou & Crook, 2018, p. 21). This inadvertently reinforced the erroneous stereotype that contextualised, humanistic physics underpinned by socially relevant dimensions is *feminised* physics while "rigorous and mathematical" approaches are equated to *real* physics.

This "soft" syllabus was replaced in 2018 by a "modular and mathematical" physics syllabus (Georgiou & Crook, 2018, p. 21) with increased mathematical content and reduced "social" dimensions. The newer approach to physics has been hailed as a "return to basics, increased rigour and back to form", perpetuating the "rigorous, mathematical and masculine" image of physics (Georgiou & Crook, 2018, p. 22) in society. However, concerns about equity of access have already been raised, with fears that student groups historically underrepresented in physics, including females, will be further alienated from the subject (Crook, 2017).

This paper analyses perceptions and experiences of a sample of NSW senior secondary students with the *soft and feminised* physics syllabus that was superseded in 2018. The paper also examines the validity of the assumptions that females prefer historical, sociological and humanist narratives, while males prefer mathematical, experimental and problem-solving aspects of physics. Employing a mixed-methods approach, high-ability females who elected to study a "hard" and "masculine" subject are compared with their male counterparts in their motivation, engagement and retention plans with physics.

In this paper, to distinguish between these two binary groupings of participants based on biological sex characteristics, the term "gender" is used. However, it is acknowledged that "sex'" and "gender" are not synonymous terms. "Sex" refers to the biological and physiological characteristics of an individual, and "gender" refers to a perceived identity that may or may not align with biological sex (Traxler et al., 2016.p. 3). However, neither sex nor gender has a fixed binary trait and no implicit assumption that gender is fixed by biological sex is made in this paper. Furthermore, we have applied this oversimplified viewpoint for the sake of convenience for comparing it with existing research. Although binary gender models are found to constrain physics education research (Traxler et al., 2016) previous studies in this area were found to adopt this narrow view. Gender was self-identified by participants into two categories only: female and male and therefore, we refer to the different genders as males and females.

Research Sites and Sample

Participants were 247 Year 11 students, 90 females (36%) and 157 males (64%), representing nine NSW high schools (Government and Catholic schools) located in the Western and Northern regions of metropolitan Sydney. This data was collected at the end of Year 11, while the superseded context-led curriculum was still on offer. The gender disparity in Australian physics classrooms is reflected in the sample (Falkiner, 2012; Fullarton et al., 2003). Around 60% of participants identified themselves as first language speakers of English. There was no representation of Aboriginal or Torres Strait Islander students, consistent with previous research findings (Ainley et al., 2008). Data was collected at the end of the preliminary year (Year 11), just before students were making a decision to continue with the subject to their final year (Year 12) of senior secondary school.

Comparative analyses require equivalence across groups to minimise the influence of students' home and background factors as well as school factors. The sample characteristics, including parental occupations (see Appendix), were consistent with previous research findings that senior secondary physics students enjoy strong academic and social capital (Fullarton & Ainley, 2000). Further strategies were employed to ensure equivalence between gender groups. Purposive sampling was done to select research sites with similar Index of Community Socio-Educational Advantage (ICSEA) values. Additionally, data on the participants' socio-economic status (SES) background was collected using the Australian National University SES (ANU4) scale (Jones & McMillan, 2001), and this showed parity across the two gender groups. Overall, it was reasonable to assume a comparative analysis of males and females was possible; however, it is acknowledged that there may be individual differences within each group. It should be further noted that females in this study represent a unique group. They are "exceptional girls" (Archer et al., 2017, p. 99) motivated to select and study a subject that has historically been portrayed as masculine.

Data Collection

Data was collected using the Physics Motivation Questionnaire (PMQ), based on the expectancy-value (EV) theoretical framework (see Abraham & Barker, 2014 for development and validation of the questionnaire). This study discusses the findings of open-ended items included in the questionnaire.

The major themes within PMQ centre around the significant EV motivational variables that have a direct influence on students' physics enrolment behaviours. These are the *task values* (specifically *interest value* and *utility value*) in relation to the subject, students' expectancy of success with the subject *(perfperc)*, and the gender role beliefs they possess towards the subject (*sexstereo*). Students' perceptions of engagement with physics *(engage)* and their intentions to continue with physics to Year 12 (*choicein*) were also examined. Student responses were measured on a Likert scale (1 = completely disagree to 6 = completely agree) and through open-ended responses regarding students' perceptions of the curriculum. Being a negatively phrased subscale (Abraham & Barker, 2014), lower values for *sexstereo* indicated students did not hold gendered beliefs regarding the subject.

Results

No significant gender difference was evident in students' plans to continue with physics to Year 12. While 93% of males intended to continue studying physics, 90% of females shared the same intention. This is not surprising, as the participants were academically able students, and earlier research has revealed these students held ambitious plans for their future study and careers (Abraham & Barker, 2014), where physics has a strategic value. A summary of PMQ variables influencing their decision to continue with physics also did not reveal a statistically significant difference across genders (See Table 1).

The mean values for both genders were above the scale mean (3.5) except for the question about sex-stereotyped perceptions (i.e., *it is a subject suitable for my gender*). Values lower than the scale mean for both males and females indicated that neither group subscribed to gender stereotyped beliefs commonly attached to physics. Overall, these results were not unexpected, as the participants were a unique group of capable and motivated students who had chosen to study physics and were intending to continue with this subject.

Open-ended responses showed other contextual and personal reasons influencing students' retention plans. These showed no marked gender difference and included, for example, the teacher's teaching methods, the high scaling physics receives for university admission, and the opportunity to practise logical thought processes. Gender disparity was also examined in the reasons for discontinuing the subject. Of the 19 students who intended to leave physics, 11 (58%) students were males and 8 (42%) were females (see Table 2).

As the questions were negatively phrased, values higher than 3.5 indicate that those who were discontinuing physics displayed low achievement motivation, as evident from the ratings for *interest, utility* and *perfperc*. However, they still displayed high levels of engagement with the subject, as the low rating for this item showed. As the respondent numbers were small, significance testing of the gender differences was not conducted, however the difference can be considered minimal. It was pleasing to note that gender stereotyped beliefs were not an important reason for leaving physics. Likewise, no notable gender differences were found among the open-ended responses. The reasons for leaving physics included common themes across genders, such as the teacher, the difficulty level and lack of mathematical skills, and a wish to focus on other subjects.

Table 1 Reasons for Continuing with Physics

I have chosen to continue physics because	Mean values	
	Males (N = 147)	Females (N = 81)
I am interested in physics (*interest)*	4.53	4.81
I like to get involved in the learning activities associated with physics (*engage*)	4.39	4.53
I am good in physics (*perfperc*)	4.02	3.78
It is a subject suitable for my gender (*sexstereo*)	3.07	3.38
It is useful to my future study/career plans (*utility)*	4.46	4.23

Note. 1 = completely disagree to 6 = completely agree; scale mean = 3.5

Table 2 Reasons for Discontinuing Physics

I have decided to drop physics because	Mean values	
	Males (N = 11)	Females (N = 8)
I am not interested in physics (*interest)*	4.09	3.38
I do not like to get involved in the learning activities associated with physics (*engage*)	3.36	2.63
I am not good in physics *(perfperc*)	4.18	3.63
It is not a subject suitable for my gender (*sexstereo*)	1.73	1.38
It is not useful to my future study/career plans (*utility)*	4.00	3.63

Note. 1 = completely disagree to 6 = completely agree; scale mean = 3.5

Comparison of Construct Means

Table 3 reports the mean values of constructs measured by the PMQ by gender. Participants reported higher than average or near average values (scale mean = 3.5) for all variables except *sexstereo.* The difference in means distribution was compared using the independent-samples *t*-test and the power of the difference was tested using Cohen's *d*. Cohen's *d* measures the effect size for the difference between males and females as follows: no effect at $d < 0.2$, small effect at $0.2 \le d < 0.5$, moderate effect at $0.5 \le d < 0.8$, and large effect at $d \ge 0.8$ (Hills, 2011).

While research has indicated that secondary male and female students' general perceptions about physics are typically negative and the majority of students see physics as "difficult", "irrelevant" and "boring" (Owen et al., 2008 p. 114), the perceptions of the current sample were highly positive across both genders. These results suggest that motivation and engagement may not necessarily be a function of gender in senior secondary physics classes, where academic ability and personal relevance of the subject show gender parity.

As Table 3 shows, females displayed high levels of achievement motivation (i.e., *interest, engage and choicein*), equal to or even greater than that of males. Statistically significant differences were found for the *sexstereo* and *utility* variables only, both favouring males. The effect size of the mean difference for *sexstereo* was moderate (Cohen's $d = 0.64$), while that for *utility* was small (Cohen's $d = 0.31$). However, it should be noted that males as well as females held below mean values for *sexstereo*, suggesting both

Table 3 Mean Values of Constructs for All Students (N** = 247)

Construct name											
interest		*perfperc*		*sexstereo*		*utility*		*engage*		*choicein*	
1	2	1	2	1	2	1	2	1	2	1	2
3.96	4.06	3.86	3.66	2.67*[a]	1.86	4.14*[b]	3.79	4.33	4.37	4.70	4.72

Note. interest = interest value of physics, *perfperc* = performance perceptions for physics, *sexstereo* = sex-stereotyped attitudes to physics, *utility* = utility value of physics, *engage* = sustained engagement with physics, *choicein* = sustained intention to continue in physics; 1 = male students; 2 = female students. * significant at 0.01. *a = moderate effect; *b = small effect. N** = all students (males = 157, females = 90) genders did not consider physics as a subject suited to men. Likewise, while males held comparatively higher *utility* for physics for future career/study plans, females also attached high values to this, and the effect size of the mean difference was small. Taken together, the achievement motivational profile did not show a major difference across genders.

Table 4 present data related to the four modules included in the Year 11 physics curriculum, showing the ratings given by male and female students for each module in terms of interest value, career value, perceived difficulty, gender-related beliefs, and engagement. The modules on Electricity and Cosmic engine were identified by males to be more useful for their future career/study plan relative to females and this difference was statistically significant. The only finding that favoured females was for the module Waves. Females were statistically more likely to continue studying the Waves module than males.

Table 5 presents a gender comparison of student interest in various topics subsumed in the Year 11 physics curriculum. Measured on a rating scale from 1 (not interesting) to 5 (very interesting), most mean values were in the upper half of the scale, indicating interest in all sections except for assessment tasks and the historical contexts of physics.

There was no statistically significant difference between the two groups in interest levels except for *Life of scientists* and *Historical development of physics*. Although female students expressed statistically significantly stronger interest than males in these "soft" topics, and viewed such topics less negatively than males, their interest levels were still lower than the scale mean. Furthermore, the effect size of such differences was "small" in both instances (Cohen's $d = 0.28$ and 0.25 respectively). This finding contradicted expectations that females may like topics placed in a historical and philosophical context. Instead, like male students, they liked problem solving and experiments. This result supports earlier research findings that students who recognise the strategic value of physics prefer its traditional format: mathematics intensive and laden with problem solving. This supports Angell et al.'s (2004) findings that students who are well-adapted to physics are those who have an interest in the traditional paradigm for physics. Interestingly, these students also tend to perform better since "those with an orientation towards 'physics content and basic laws' are rewarded with the highest grades, whereas students oriented towards 'physics history, contexts, and processes' do not receive the same acclaim" (p. 694).

Analysing the findings on construct means comparisons (see Tables 3 and 4) in the context of the observed parity of *perfperc* across the genders yielded interesting insights. Stereotype Threat Theory (STT) cautions that mere presence of negative stereotypes might lead to stereotype threat effects (Doucette & Singh, 2020; Steele et al., 1995) and negatively influence females' achievement orientations, sense of belonging, and intrinsic motivation (Thoman et al., 2013) particularly in subjects such as physics (Galano et al., 2023; Marchand and Taasoobshirazi, 2013; Maries et al., 2018). Such stereotypes could make females feel that they do not belong to the study of physics and eventually leading to their attrition from the physics pipeline (Randolph et al., 2022). Although the current study did not examine the relationship between STT and academic performance in physics, it was pleasing to note females did not report STT and their expectancies of success were not tampered with, although the majority of physics classes were outnumbered by males (see, Abraham & Barker, 2015 for a detailed analysis). These findings support Ladewig et al. (2022)'s study findings that females who are highly interested and talented in physics and made voluntary selection of physics for higher education tend to be not susceptible to stereotypes.

When asked open-ended questions about what made physics interesting to them, responses did not differ greatly across genders. The majority found physics interesting and enjoyed studying the subject. They considered physics the "most relevant and important subject to understand the fundamental working of the world" (male student). However, as

Table 4 Mean Values for Each Physics Module (Males N = 150; Females N = 90)

Construct	Module							
	Waves		Electricity		Motion		Cosmic engine	
	1	2	1	2	1	2	1	2
How interesting was each module to you?	3.18 (1.028)	3.32 (1.004)	3.41 (0.954)	3.48 (1.030)	3.71* (1.047)	3.37 (1.203)	3.71 (1.290)	3.78 (1.364)
How useful was each module to your career/study plans?	3.14 (1.168)	3.00 (1.142	3.55* (1.123)	3.17 (1.158)	3.4 (1.169)	3.40 (1.169)	2.99* (1.268)	2.63 (1.185)
How difficult was each module to you?	3.24 (1.112)	3.34 (1.015)	3.20 (1.073)	3.08 (1.052)	2.96 (1.182)	2.74 (0.966)	3.24 (1.123)	3.29 (1.073)
How much do you think each module appeals to males or females?	2.80 (0.625)	3.03 (0.409)	2.68 (0.718)	2.81 (0.579)	2.71 (0.672)	2.92 (0.534)	2.80 (0.684)	3.01 (0.530)
How much would you like to continue learning each module?	3.02 (1.168)	3.53* (1.169)	3.34 (1.159)	3.54 (1.168)	3.61 (1.218)	3.38 (1.266)	3.62 (1.412)	3.69 (1.345)

*Note: Scale mean = 3; 1 = male students; 2 = female students * = significant at 0.01*

Table 5 Mean Values in Interest Level for Topics in the Year 11 Physics Curriculum

Topics	Gender	
	Males (N = 150)	Females (N = 90)
Laws of physics	3.76	3.71
Problem solving	3.60	3.37
Experiments	3.91	3.92
Assessment tasks	2.79	2.62
Real life situations	3.81	3.89
Contribution to humanity	3.46	3.53
Abstract nature of physics	3.47	3.45
Life of scientists	2.54	2.89*
Historical development of physics	2.67	3.00*

**Significant at 0.01: Scale mean = 3*

previous studies have also noted (Angell et al., 2004), females in the current study tended more than males to describe physics as "explaining the world", "relating to everyday life", "explaining how and why things are happening in certain ways", and "relevant to my life". Males, in contrast, used terms such as "interesting", "fun", "cool", "hands-on", "stimulating thought", "applicable in life", and "we got to play with energy" more often than females. Females were more expressive in giving a personal relevance to the subject such as "being able to learn the many laws of physics has changed the way I perceive life. Experiments were very interesting enabling us to observe things myself" (female student) and "I got to relate it to normal everyday activities as well as understand beyond what meets the eye" (female student). This was slightly different from the view, for example, of a male student that "it is interesting to understand how to break or manipulate laws of physics in life".

Students' dissatisfaction with the inclusion of socially oriented contexts and historical dimensions in their physics curriculum was obvious. Neither gender found such "soft" topics appealing or relevant. For example, a female student asked: "life of scientists? Shouldn't we be learning more about what they did rather than their lives?" Similarly, a male student considered that the "history part of the subject was personally irrelevant and a waste of time". No positive appreciation of the social/historical narratives in the curriculum was received; instead, students found this material "boring" and "irrelevant in physics". However, although socially oriented contexts were of little interest, responses showed that students enjoyed contexts linked to everyday experiences and daily life applications.

It was interesting to note that both males and females commented on the difficulty level of the subject without any prompt. Literature suggests that students, whether they are successful or not, perceive physics as hard (Ekici, 2016). The majority of students in this study, irrespective of their motivation level or gender, found physics hard. A continuing male student found physics "a lot harder than I thought" and another male student described Year 11 physics as "an interesting subject, while some of it almost killed my brain". Similarly, a female student commented "I expected to perform well, however I wasn't quite aware of how difficult the subject is and how much hard work is involved". Another female seconded this perception when she stated that it provided a "detailed look into the modules which apply to our daily life, but it was a difficult course". The level of difficulty and effort involved was also acknowledged by students of both genders who were intending to discontinue physics. A female student's comments reflect this: "I knew physics will be difficult though I thought I could manage to understand all topics, but physics as a subject, was very difficult". Similar sentiments were expressed by males exiting physics.

Discussion

This study's results contradicted findings from earlier studies about the female- friendliness of certain topics. To make physics female-friendly, researchers have suggested removing overtly "masculine" topics, such as mechanics and electricity, from the syllabus (Murphy & Whitelegg, 2006), because these topics have been found to be less interesting for females (Baram-Tsabari & Yarden, 2008; Hoffmann, 2002; Osborne & Collins, 2000; Woods, 2008). Open-ended responses from female students in this study did not support this claim. Female students in this study wanted "more on Motion (topics related to mechanics) and electricity" and "math-based calculations on motion topics" with the same frequency that males wanted "lots of formulae and the Motion" topic. However, previous studies have involved students learning physics as a mandatory subject, while this study's sample consisted of students (male and female) who had chosen to study physics. Similarly, a sizeable majority of students of both genders did not like the fact that the Cosmic Engine module was descriptive and not mathematically intensive. This contrasts somewhat with previous studies indicating that females like astrophysics more than males do (Lavonen et al., 2005; Osborne & Collins, 2000; Trumper, 2006) and instead indicates that these females shared with males a classical preference for mathematically intensive physics.

When the few discontinuing students were asked why they were leaving physics after a year of study, different reasons were given by male and female students. Females' reasons included a lack of career value, low interest value and low performance perceptions; in contrast, males did not give a specific reason, but indicated the subject was "boring", that they had "no motivation" to continue, and that physics was "not a subject for me". Females would have continued the subject if it was more "fun and interesting", "had more practical [tasks]", and "less calculations", suggesting a personal deficit in mathematical skills. However, the majority of males did not identify differences that would have made them continue with physics, leaving the subject simply because they "are not into physics".

Perhaps students' perceptions were best captured from their responses in relation to the *expected* and *enacted* curriculum (Vickers & Ha, 2007). Looking back at Year 11 physics, 52% of males and 50% of females said the physics experience they received was the same as they initially expected. Open-ended responses on students' general expectations about physics were also similar across genders: they experienced physics as a "difficult but interesting subject", as they had expected. A male student found it similar to what he expected in the sense that "it required a lot of work" and "for every interesting thing we learnt, there was something also which was entirely new learning and/or difficult just as I imagined". Females had the same expectation, as they had heard from friends and family about physics as a "difficult and complicated" subject.

Apart from the difficulty level, students found the *enacted* physics curriculum "softer" than the traditional and classical physics they had expected, and findings contrasted with earlier research suggesting that females prefer the social and historical side of physics. Students of both genders in this study expressed a preference for problem solving and experiments. The physics they had expected involved "crazy calculations to experiments and really hard experiments" (male student) and they expected it to be "more mathematical and less qualitative" (female student). The mathematical rigour of physics was an integral expectation, and students were disappointed to see this missing. This was evident from the comment of a female student who was continuing with physics: "I thought 70% math but, in the end, it was 70% theory which did not make sense. Why do we have to learn about the history"? Similar sentiments were shared by both male and female students; for example, "I expected it to be more mathematical based but [it] was not" (female student). A substantial number of females and males wanted "more practical and mathematical reasoning" in physics, while some males wanted to have "more work on forces/engineering side of physics". Both females and males were unimpressed by the "soft" syllabus having "too many theories [rather] than practical work and calculations".

The overall findings of this study do not support the earlier research assumptions that females tend to search for social meanings in the study of physics (Kelly, 2016) while males view physics as valuable in itself (Stadler et al., 2000). However, the findings do reinforce Whitelegg and Edwards' (2001) observation that high-achieving students are more content with the abstract nature of physics and recognise its strategic value for future career and study. Such students may not value the social contextual features in the physics curriculum or see their relevance to physics. Interestingly, students concurred with the view that physics is "frightful, but fun", as a previous study has noted (Angell et al., 2004, p. 684). Perhaps the ongoing discussion in Australian media might have influenced them to form a traditional view of how physics ought to be approached.

General conclusions drawn from our study augment Danielsson's (cited in Gonsalves et al., 2016) argument on resolving gender issues in physics by providing assumed female-friendly solutions by considering gender as a stable variable. Such approaches do not explore the variability of experiences across genders and constructs two different kinds of physics learners; "male students who enjoy the abstract and practical work of physics and female students who look to relate physics to in their own lives and who have lower self-confidence, specifically towards practical work" (p.1). Our conclusion is that students' attitudes towards the curriculum were primarily influenced by their expectancies and the values they associate with the subject.

Nevertheless, our study findings should be interpreted with caution, as the female participants were "exceptional girls" (Archer et al., 2017. p.9). Exceptional girls in this study were characterised by their high achievement and strong future study and career plans as well as high levels of reported achievement motivation. These high achievers may have successfully overcome stereotype threats and they may not have been exposed to, or have resolved gendered expectations from teachers, parents, or society. Therefore, the findings of this study do not imply that a physics curriculum based on contextualisation is not a desirable or effective choice. Instead, it suggests that both females and males in this study, who pursue physics for its strategic benefits, did not perceive the pertinence of such contexts favourably. To put it differently, the incorporation of social contexts and historical narratives in the superseded NSW senior secondary curriculum did not result in the *feminisation* of the curriculum, as some specialists erroneously asserted. Future studies can explore whether the appeal of physics can be enhanced by including socially relevant contexts for females in non-specialist stream.

Limitations

This study has some potential limitations. These include the relatively small size of the female sample, reflecting the male domination in Australian physics classes. In addition, only binary gender categories were self-identified in the sample. Future research could avoid the narrow definition that was applied to our study in order to have a more comprehensive understanding. Finally, findings of this study cannot be generalised, as the sample included students from metropolitan Sydney only. Students from regional Australia might have different perceptions. The sample is not representative of the population of students studying physics because in this study, the participants were senior secondary students who chose to pursue physics.

Conclusion

The findings in this paper suggest that the perceptions of high-ability students participating in physics at an elective level did not vary significantly across genders in terms of their motivations for studying physics or their perceptions of a contextual curriculum. Both males and females subscribed to a traditional view of physics and gave prominence to the strategic value of the subject. Neither gender showed an affinity towards the "softer" type of physics, providing social or historical contexts. Females did not display any aversion to logical and mathematical physics. Students found the context-led secondary physics challenging, just as they had anticipated a traditional curriculum would be. They also found it interesting and engaging but expected a stronger mathematical focus. An examination of the perceptions of NSW senior secondary students regarding the current physics curriculum, which is being praised as a revival of classical physics, would be intriguing.

Appendix

Reliability Estimates of PMQ Subscales and Sample Items

Subscale	Sample item	Cronbach's alpha
Interest	I have a real desire to study more physics	0.882
Perfperc	I know I am able to do well in physics	0.868
Sexstereo	I think boys are naturally better than girls in physics	0.925
Utility	Physics is a great module for my career interests	0.824
Engage	I was enthusiastic to participate in the activities associated with physics	0.754
Choicein	I want to continue physics to Year 12	0.98[a]

Note. Interest = interest value of physics, *perfperc* = performance perceptions in physics, *sexstereo* = sex-stereotyped attitudes to physics, *utility* = utility value of physics, *engage* = sustained engagement with physics, *choicein* = sustained intention to continue in physics; [a] = estimated value.

Factorial Structure of PMQ

Fit indices of Confirmatory Factor Analysis model of PMQ

χ^2	*df*	χ^2 /*df*	TLI	CFI	RMSEA	Type of fit
492.51	187	2.634	0.905	0.923	0.082	Mediocre

Note. χ^2 = chi-square; *df* = degrees of freedom; TLI = Tucker–Lewis Index; CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation.

Sample Characteristics

Highest Parental Education Level of Participants

	Father education %	**Mother education %**
Did not complete secondary school	5.6	4.6
Completed secondary school	10.5	20.9
Trade or technical qualification	11.6	8.1
University degree	65.1	57.8
Don't know/missing	6.8	6.8
Total number of respondents	232	230

Note. Total number of respondents denotes the number of responses taken into account after data screening.

Parental Occupation of Participants

	Father occupation %	**Mother occupation %**
SES Band 1	59.4	40.6
SES Band 2	18.9	21.8
SES Band 3	13.2	24.5
SES Band 4	1.8	5.7
SES Band 5	6.6	7.2
Total number of respondents	227	225

Note. Total number of respondents denotes the number of responses taken into account after data screening.

SES Bands adopted from Australian National University (ANU4) SES scale (McMillan et al., 2009).

Funding Open Access funding enabled and organized by CAUL and its Member Institutions

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

References

Abraham, J., & Barker, K. (2014). Sustaining young people's enrolment intentions in relation to physics: Development and validation of a tool. *Australian Journal of Educational and Developmental Psychology, 14*, 93–116.

Abraham, J., & Barker, K. (2015). Exploring gender difference in motivation, engagement and enrolment behaviour of senior secondary physics students in New South Wales. *Research in Science Education, 45*(1), 59–73.

Ainley, J., Kos, J., & Nicholas, M. (2008). Participation in science, mathematics and technology in Australian education. *ACEReSearch*. Retrieved September 30, 2020, from https://research.acer.edu.au/acer_monographs/4/

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Angell, C., Guttersrud, Ø., Henriksen, E. K., & Isnes, A. (2004). Physics: Frightful, but fun. Pupils' and teachers' views of physics and physics teaching. *Science Education, 88*(5), 683–706. https://doi.org/10.1002/sce.10141

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (2017). The "exceptional" physics girl: A sociological analysis of multimethod 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

Badri, M., Mazroui, K. A., Al Rashedi, A., & Yang, G. (2016). Variation by gender in Abu Dhabi high school students' interests in physics. *Journal of Science Education and Technology, 25*(2), 232–243. https://doi.org/10.1007/s10956-015-9589-x

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review, 84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Baram-Tsabari, A., & Yarden, A. (2008). Girls' biology, boys' physics: Evidence from free-choice science learning settings. *Research in Science & Technological Education, 26*(1), 75–92. https://doi.org/10.1080/02635140701847538

Barnes, G. R. (1999). *A motivational model of enrolment intentions in senior secondary science courses in New South Wales schools* [Unpublished doctoral dissertation]. University of Western Sydney, Macarthur.

Barnes, G., McInerney, D. M., & Marsh, H. W. (2005). Exploring sex differences in science enrolment intentions: An application of the general model of academic choice. *Australian Educational Researcher, 32*(2), 1–24. https://doi.org/10.1007/BF03216817

Binnie, A. (2004). Development of a senior physics syllabus in New South Wales. *Physics Education, 39*, 490–495. https://doi.org/10.1088/0031-9120/39/6/004

Bøe, M. V., & Henriksen, E. K. (2013). Love it or leave it: Norwegian students' motivations and expectations for postcompulsory physics. *Science Education, 97*(4), 550–573. https://doi.org/10.1002/sce.21068

Bouhdana,I., Charland, P., Foisy, L., Lapierre, H., Léger, P., Allaire-Duquette, G., Potvin,P., Masson, S., Riopel, M., Mahhou, M. (2023). Effects of reading contextualized physics problems among men and women: A psychophysiological approach. *Trends in Neuroscience and Education*, 30, https://doi.org/10.1016/j.tine.2023.100199.

Collins, S., & Osborne, J. (2000). Pupils' and parents' views of the school science curriculum. *School Science Review, 82*(298), 23–32.

Crook, S. J. (2017). The new syllabus raises the bar, but how will schools clear it? The Conversation. Retrieved September 30, 2020, from https://theconversation.com/new-physics-syllabus-raises-the-bar-but-how-will-schools-clear-it-73370

Doucette, D., & Singh, C. (2020). Why Are There So Few Women in Physics? Reflections on the Experiences of Two Women. *The Physics Teacher, 58*(5), 297–300. https://doi.org/10.1119/1.5145518

Ekici, E. (2016). "Why do I slog through the physics?" Understanding high school students' difficulties in learning physics. *Journal of Education and Practice, 7*, 95–107.

Falkiner, A. (2012). National trends in year 12 course completions. Policy note. Group of 8. Retrieved August 30, 2020, from https://files.eric.ed.gov/fulltext/ED536031.pdf

Frost, S., Reiss, M., & Frost, J. (2005). Count me in! Gender and minority ethnic attainment in school science. *School Science Review, 86*, 316–325.

Fullarton, S., & Ainley, J. (2000). *Subject choice by students in year 12 in Australian secondary schools*. LSAY Research Reports. Australian Council for Educational Research. Retrieved August 15, 2020, from https://research.acer.edu.au/lsay_research

Fullarton, S., Walker, M., Ainley, J., & Hillman, K. (2003). Patterns of participation in year 12. Retrieved August 15, 2020, from https://research.acer.edu.au/lsay_research/37

Galano, S., Liccardo, A., Amodeo, A. L., Crispino, M., Tarallo, O., & Testa, I. (2023). Endorsement of gender stereotypes affects high school students' science identity. *Physical Review Physics Education Research, 19*(1), 010120.

Georgiou, H., & Crook, S. (2018). Watching the pendulum swing: Changes in the NSW physics curriculum and consequences for the discipline. *Science Education News, 67*(1), 20–24.

Gonsalves, A. J., Danielsson, A., & Pettersson, H. (2016). Masculinities and experimental practices in physics: The view from three case studies. *Physical Review.Physics Education Research*, 12(2) doi:https://doi.org/10.1103/PhysRevPhysEducRes.12.020120.

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools*. Department of Education, Training and Youth Affairs.

Halpern, D. F., Benbow, C. P., Geary, D. C., Gur, R. C., Hyde, J. S., & Gernsbacher, M. A. (2007). The science of sex differences in science and mathematics. *Psychological Science in the Public Interest, 8*(1), 1–51. https://doi.org/10.1111/j.1529-1006.2007.00032.x

Häussler, P., Hoffman, L., Langeheine, R., Rost, J., & Sievers, K. (1998). A typology of students' interest in physics and the distribution of gender and age within each type. *International Journal of Science Education, 20*(2), 223–238. https://doi.org/10.1080/0950069980200207

Hazari, Z., Tai, R. H., & Sadler, P. M. (2007). Gender differences in introductory university physics performance: The influence of high school physics preparation and affective factors. *Science & Education, 91*, 8.

Hazari, Z., Sadler, P. M., & Sonnert, G. (2013). The science identity of college students: Exploring the intersection of gender, race, and ethnicity. *Journal of College Science Teaching, 42*(5), 82–91. http://www.jstor.org/stable/43631586.

Hildebrand, G. M. (1998). Re/constructing gendered achievement profiles. Paper presented at the Annual Meeting of the American Educational Research Association. San Diego, CA, April 13–17. Retrieved August 30, 2020, from https://files.eric.ed.gov/fulltext/ED421500.pdf

Hills, A. (2011). *Foolproof guide to statistics using IBM SPSS* (2nd ed.). Pearson.

Hoffmann, L. (2002). Promoting girls' interest and achievement in physics classes for beginners. *Learning and Instruction, 12*, 447–465. https://doi.org/10.1016/SO959-4752(01)00010-X

Jones, F. L., & McMillan, J. (2001). Scoring occupational categories for social research: A review of current practice, with Australian examples. *Work, Employment & Society, 15*(3), 539–563. https://doi.org/10.1177/09500170122119147

Joyce, B. A., & Farenga, S. J. (1999). Informal science experience, attitudes, future interest in science, and gender of high-ability students: An exploratory study. *School Science and Mathematics, 99*, 431–437. https://doi.org/10.1111/j.1949-8594.1999.tb17505.x

Jugović, I. (2017). Students' gender-related choices and achievement in physics. *Center for Educational Policy Studies Journal*, *7*, 71–95. https://doi.org/10.26529/cepsj.170

Kalender, Z. Y., Marshman, E., Schunn, C. D., Nokes-Malach, T. J., & Singh, C. (2019). Gendered patterns in the construction of physics identity from motivational factors. *Physical Review Physics Education Research, 15*(2), 020119. https://doi.org/10.1103/PhysRevPhysEducRes.15.020119

Keast, V. (2021). Gender bias in New South Wales Higher School Certificate (HSC) physics. *Australian Journal of Education*, 000494412110592. https://doi.org/10.1177/00049441211059239.

Kelly, A. M. (2016). Social cognitive perspective of gender disparities in undergraduate physics. *Physical Review Physics Education Research, 12*(2), 020116. https://doi.org/10.1103/PhysRevPhysEducRes.12.020116

Ladewig, A. K., & Neumann, K. (2022). Stereotypes in the German Physics Olympiad - Hurdle or no Harm at all? *Frontiers in Education., 7*, 957716. https://doi.org/10.3389/feduc.2022.957716

Lavonen, J., Byman, R., Juuti, K., & Meisalo, V. (2005). Pupil interest in physics: A survey in Finland. *Nordic Studies in Science Education, 2*(1), 72–85. https://doi.org/10.5617/nordina.486

Lyons, T. (2006). The puzzle of falling enrolments in physics and chemistry courses: Putting some pieces together. *Research in Science Education, 36*(3), 285–311. https://doi.org/10.1007/s11165-005-9008-z

Makarova, E., Aeschlimann, B., & Herzog, W. (2019). The gender gap in STEM fields: The impact of gender stereotype of math and science on secondary students' career aspirations. *Frontiers in Education, 4*, 1–11. https://doi.org/10.3389/feduc.2019.00060

Marchand, G. C., & Taasoobshirazi, G. (2013). Stereotype Threat and Women's Performance in Physics. *International Journal of Science Education, 35*(18), 3050–3061. https://doi.org/10.1080/09500693.2012.683461

Maries, A., Karim, N. I., & Singh, C. (2018). Is agreeing with a gender stereotype correlated with the performance of female students in introductory physics? *Physical Review Physics Education Research, 14*(2), 020119.

McCullough, L. (2004). Gender, Context, and Physics Assessment. *Journal of International Women's Studies, 5*(4), 20–30. https://vc.bridgew.edu/jiws/vol5/iss4/.

McCullough, L. (2007). Gender in the physics classroom. *The Physics Teacher, 45*(5), 316–317. https://doi.org/10.1119/1.2731286

McMillan, J., Jones, F.L., & Beavis, A. (2009). *A new scale for measuring socioeconomic status in educational research: Development and validation of the Australian Socioeconomic Index 2006*. [Paper presentation]. Australian Association for Research in Education (AARE) Conference, 30 November – 4 December 2009, Canberra.

Miler-Bolotin, M. (2015). Technology enhanced teacher education for 21st century: Challenges and possibilities. In X. Ge, D. Ifenthaler, & J. M. Spector (Eds.), *Emerging technologies for STEAM education* (pp. 135–153). Springer.

Murphy, P., & Whitelegg, E. (2006). Girls and physics: Continuing barriers to "belonging." *The Curriculum Journal, 17*(3), 281–305. https://doi.org/10.1080/09585170600909753

Osborne, J., & Collins, S. (2000). *Pupils' and parents' views of the school science curriculum*. King's College.

Owen, S., Dickson, D., Stanisstreet, M., & Boyes, E. (2008). Teaching physics: Students' attitudes towards different learning activities. *Research in Science and Technological Education, 26*(2), 113–128. https://doi.org/10.1080/02635140802036734

Randolph, J., Perry, J., Donaldson, J. P., Rethman, C., & Erukhimova, T. (2022). Female physics students gain from facilitating informal physics programs. *Physical Review Physics Education Research, 18*(2), 020123.

Rennie, L., & Parker, L. (1996). Placing physics problems in real-life context: Students' reactions and performance. *Australian Science Teachers Journal, 42*(1), 55–59.

Sax, L. J., Lehman, K. J., Barthelemy, R. S., & Lim, G. (2016). Women in physics: A comparison to science, technology, engineering, and math education over four decades. *Physical Review Physics Education Research, 12*(2), 020108. https://doi.org/10.1103/PhysRevPhysEducRes.12.020108

Sharma, M., Stewart, C., Wilson, R., & Gökalp, M. (2013). Can a syllabus change impact on students' perceptions of science? Fragmented and cohesive conceptions of physics. *EURASIA Journal of Mathematics, Science & Technology Education*, *9*, 33–44. https://doi.org/10.12973/eurasia.2013.914a.

Stadler, H., Duit, R., & Benke, G. (2000). Do boys and girls understand physics differently? *Physics Education, 35*(6), 417–422. https://doi.org/10.1088/0031-9120/35/6/307

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*, 797–811. https://doi.org/10.1037//0022-3514.69.5.797

Taasoobshirazi, G., & Carr, M. (2008). A review and critique of context-based physics instruction and assessment. *Educational Research Review, 3*(2), 155–167.

Thoman, D. B., Smith, J. L., Brown, E. R., Chase, J., & Lee, J. Y. K. (2013). Beyond Performance: A Motivational Experiences Model of Stereotype Threat. *Educational Psychology Review, 25*(2), 211–243. http://www.jstor.org/stable/43549773.

Traxler, A., Cid, X., Blue, J., & Barthelemy, R. (2016). Enriching gender in physics education research: A binary past and a complex future. *Physical Review Physics Education Research, 12*(2), 020114(15). https://doi.org/10.1103/PhysRevPhysEducRes.12.020114

Trumper, R. (2006). Factors affecting junior high school students' interest in physics. *Journal of Science Education and Technology, 15*, 47–58. https://doi.org/10.1007/s10956-006-0355-6

Vickers, M., & Ha, M. T. (2007). The imagined curriculum: Who studies computing and information technology subjects at the senior secondary level? In J. Lynch (Ed.), *Gender and IT* (pp. 27–39). Common Ground Publishing.

Vidor, C.D., Danielsson, A., Rezende, F., Ostermann, F. (2020). What are the problem representations and assumptions about gender underlying research on gender in physics and physics education? A systematic literature review. *Revista Brasileira De Pesquisa Em Educação Em Ciências*, *20*(u), 1133–1168. https://doi.org/10.28976/1984-2686rbpec2020u11331168.

Wheeler, S. R., & Blanchard, M. R. (2019). Contextual choices in online physics problems: Promising insights into closing the gender gap. *Frontiers in Psychology, 10*, 594. https://doi.org/10.3389/fpsyg.2019.00594

Whitelegg, E., & Edwards, C. (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). Academic Publishers.

Whitelegg, E., Murphy, P., & Hart, C. (2007). Girls and physics: Dilemmas and tensions. In R. Pintó & D. Couso (Eds.), *Contributions from science education research* (pp. 27–36). Springer.

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Journal in Educational Psychology, 25*(1), 68–81. https://doi.org/10.1006/ceps.1999.1015

Wilson, K., Low, D., Verdon, M., & Verdon, A. (2016). Differences in gender performance on competitive physics selection tests. *Physical Review Physics Education Research, 12*(2), 020111. https://doi.org/10.1103/PhysRevPhysEducRes.12.020111

Woods, C. (2008). *Factors predicting high ability girls' enrolment in Year 11 and 12 physics and intermediate mathematics in regional and rural North Queensland* [Paper presentation]. Australian Association for Research in Education (AARE) Conference, 30 November – 4 December 2008, Brisbane.

Zhu, Z. (2007). Learning content, physics self-efficacy, and female students' physics coursetaking. *International Education Journal, 8*(2), 204–212. file://ad.uws.edu.au/dfshare/HomesBNK$/30000688/Downloads/1122-116-PB.pdf.

Zohar, A., & Sela, D. (2003). Her physics, his physics: Gender issues in Israeli advanced placement physics classes. *International Journal of Science Education, 25*, 245–268. https://doi.org/10.1080/09500690210126766