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Motivation and Engagement with Physics: a Comparative Study of Females in Single-Sex and Co-educational Classrooms

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Abstract

It has been argued that the establishment of single-sex classes for females can increase their motivation and participation in physics. This paper reports on findings from a multi-occasional study among 90 female year 11 physics students across single-sex and co-educational high schools in Australia. The aim of this study was to identify the differences in motivation, engagement and sustained enrolment plans in relation to physics between female students in single-sex from those in co-educational settings. Fine-grained analyses at a physics topic-specific level indicated differences between these cohorts in their interest value, career value, gender-stereotyped attitudes, performance perceptions, sustained engagement and sustained enrolment intentions in relation with physics. Results revealed that both cohorts have high levels of achievement motivation in relation to physics irrespective of their classroom composition; however, females from single-sex schools showed higher values for some constructs across various physics topics. This paper highlights the scarcity of research into females' sustained participation in physics, once they commence studying physics, and the difference class composition makes to females' achievement motivation and future enrolment intentions.

Keywords Motivation · Engagement · Enrolment plans · Physics education · Females and physics · Single-sex/co-educational classrooms · Expectancy-value theory

The question whether female students benefit more from gender-segregated physics classes has been an ongoing debate for physics educators and education researchers for decades. Arguments for and against the efficiency of single-sex classrooms and whether they improve female students' dispositions towards physics remain hotly contested. Debate is fuelled by opinions in support of both camps emanating from the findings from a significant body of research that examines the influence on single-sex learning environments on female students'

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physics motivation. While some of these studies observed a positive effect (e.g. Haussler and Hoffman 2002; Streitmatter 1998), some studies (e.g. Feniger 2011; Sikora 2014) do not observe any effect.

Gendered pattern of student motivation is a dominant topic in physics education literature. Several studies examining physics in high school report that compared with males, females have markedly lower levels of extrinsic and intrinsic motivation, poorer engagement and, subsequently, reduced intentions to select physics as a subject to study in their senior years of school and are less likely to pursue a physics career path (e.g. Ainley et al. 2008; Hazari et al. 2008; Kennedy et al. 2014; Stokking 2000; Taasoobshirazi and Carr 2008; Whitelegg et al. 2007). A range of factors including a lack of positive attitude towards the subject (Mujtaba and Reiss 2013; Scantlebury and Baker 2007), lack of interest in the subject (Barmby and Defty 2006), lack of self-efficacy in the subject (Barmby and Defty 2006), competitive learning styles that are generally encouraged in physics classes (Zhu 2007), the nature of physics curriculum (Goodrum et al. 2001), societal factors (Seymour and Hewitt 1997), lack of knowledge about scientific careers or lack of female role models in physics careers (Blickenstaff 2005) and perceived difficulty level of the subject (Barmby and Defty 2006; Carlone 2003) are associated with lower levels of female enrolment in physics.

Although there are many factors that influence and shape females' disinclination towards physics, a pervasive influence on their negative attitudes towards the subject is the "masculinity" attached to the subject (Archer et al. 2017 p. 98). This ubiquitous alignment of "masculinity" and physics emanates from a complex interplay of various factors including a perceived lack of gender inclusivity of standard physics curriculum (Rennie and Parker 1996), lack of relevance of the physics context and convent to the everyday world of females (Murphy 1990) and differential expectations of ability of females in physics. Females historically have the lowest participation rates and are greatly underrepresented in physics classrooms and careers (Carlone 2004; Cousins 2007), making it a "masculine" domain. Across several Western countries including Australia, England, Canada and the USA, students perceive physics as overtly "masculine" (e.g. Archer et al. 2017; Barmby and Defty 2006; Blue et al. 2018; Gonsalves 2014). Social and cultural factors tend to propagate stereotyped beliefs among adolescent students that females are less suitable or capable to do physics (Archer et al. 2017; Francis et al. 2017; Häussler and Hoffmann 2000; Kessels and Hannover 2008). This stereotype inhibits females, even in industrialised countries, from choosing physics study or a related career path (see Sikora 2014).

Teachers, curriculum and teaching practices are found to be reinforcing this stereotype in the physics classrooms, though most often unintentionally (e.g. Smith and Hung 2008; Zohar and Bronshtein 2005). The content and context of physics courses are sometimes identified as explicitly "masculine" (Murphy 1990), and operating through contexts with which females are less familiar (Rennie and Parker 1996; Goodrum et al. 2001). The abstract nature of physics and the competitive learning approaches promoted in physics classes have been debated as elevating males and placing them at advantage over females (Zhu 2007), fortifying the gender stereotype. A few researchers (e.g. Kessels and Hannover 2008) argue that gendered physics environments can induce or enhance Stereotype Threat (ST) among females.

ST theorists (Steele and Aronson 1995) assert that the intellectual identity, motivation, and performance of females will be adversely affected if they are aware of such stereotypes or they are activated in the learning environment of traditionally "masculine" domains. ST is induced typically by the dominance of males in such environments (Stout et al. 2011). Hence, proponents of single-sex physics education argue that physics classrooms in which females are outnumbered by males can implicitly induce ST in physics (e.g. Inzlicht and Ben-Zeev 2000). Therefore, the absence of males in the classroom can minimise the hidden stereotypical cues (see Vockell and Lobonc 1981) and improve females' physics-related self-concept. The most commonly discussed differences between single-sex (SS) and co-educational (co-ed) settings relate to the dominant presence of males in the classroom (Smyth 2010). In co-ed settings, males have been shown to contribute more to classroom interactions (Lee et al. 1994), get more attention from teachers (cf. Crossman 1897; Hoffmann 2002; Spender 1982; Taber 1992), dominate in "hands-on" activities and even sometimes are disruptive (Francis 2000). Consequently, for a subject such as physics, which is traditionally perceived by students and society as "hard and masculine", co-ed settings are found to reinforce the stereotype and lead to the marginalisation of females (Kelly 1988). Learning in a female-exclusive classroom is viewed by some to be a safeguard since it can protect females from being "unduly influenced by various strategies frequently used by males such as dominance, competition, deflation and suppression" (Hoffman 2002, p.477). Avoiding males in the classroom can increase female students' self-confidence in physics and, in turn, promote more positive attitudes towards the subject (Gillibrand et al. 1999).

Advocates of female-only physics classes further argue that females in a co-ed setting tend to view physics differently from those in SS setting (Murphy and Whitelegg 2006). For instance, females in co-ed schools were found to attach more *masculinity* to physics than females in SS schools (Reid and Skryabina 2003). Furthermore, physics teachers' unintentional gender-differentiated classroom practises in co-ed classrooms were found to have a negative effect on females' academic engagement and achievement. Relevant classroom intervention studies report the implementation of learning experiences that tend to hold the interest of males more than females (O'Brien and Porter 1994) and differential, though unintentional, teacher expectations in co-ed physics classrooms (Hoffmann 2002; Millar and Toscano 2006; Mujtaba and Reiss 2013). Varying expectations in students' capabilities is a co-ed classroom reality, where males are encouraged to solve physics problems on their own whereas females are more often helped by teachers (Whyte 1986, cited in Hoffman 2002; Mujtaba and Reiss 2013).

Kessels and Hannover's (2008) findings provide further support of SS schooling. The results revealed that, females in SS classes showed higher physics-related self-concept of ability than females from co-ed settings. According to these researchers, the prime factor reducing females' ability beliefs and confidence in this "non-feminine" subject is their gender-related self-knowledge which is more salient in co-ed groups than in SS groups (see also Kessels et al. 2006). Moreover, SS classrooms appear as beneficial in boosting females' interest and achievement in physics (Gillibrand et al. 1999) and ensure their increased participation (see also Chapman and Vivian 2017; Gill and Bell 2013; Streitmatter 1998). The advantages of SS teaching and learning contexts for females in physics are posited to result from increased contacts with their teachers; while in co-educational contexts, males tend to monopolise their teachers' attention (Taber 1992).

The *natural* but different learning preferences of males and females is another key factor that teachers often fail to consider in co-ed physics classes (Zhu 2007). Zhu (2007) asserts that females tend to prefer collaborative and cooperative activities while males prefer individual and competitive approaches which fuel opportunities for personal success in physics classes. Teachers' unintentional but differentiated practice can often arise through the lack of awareness of this difference (Hoffman 2002). Female-only classes are assumed to be giving an opportunity for teachers to adapt their lessons to cater for the learning needs of females (Severiens and Ten Dam 1994; Shapka and Keating 2003). Haussler and Hoffman's (2002) intervention study found that teaching females in a SS setting catered for their differing learning preferences and this adaption has led to improvements to female students' confidence in physics as well as bolstered their physics self-concept. Females in SS learning environments were found to have a better self-concept in physics and a stronger aspiration to a science career (Kessels and Taconis 2012). Similar findings were attained by earlier studies (Gillibrand et al. 1999; Mael 1998; Haag 2000 in Feniger 2011).

While there is some compelling evidence for the benefits of SS physics education, research attesting to the long-term benefits remains unclear. For instance, a number of studies do not attach robust evidence to the efficacy of SS schooling in improving female physics participation at higher educational levels (e.g. Feniger 2011; Sharp et al. 1996). In Australia, Ainley and Daly (2002) found that, all things being equal, there were no significant differences between SS and co-ed schools in the take-up of physical sciences. Sikora's meta-analysis of LSAY data (2014) concluded that while females in Australian SS schools were more likely to take up physical science subjects than their counterparts in co-ed schools, SS schooling did not increase the likelihood of females planning a physical science career. The positives associated with studying physics in SS settings appear not to extend beyond the high school years.

Opponents of SS schooling dismiss the proposed merits of SS schooling by asserting that any increase in the physics achievement and psychosocial outcomes of females could be attributed to the array of social, environmental and economic factors rather than the single-sex nature of the school (Ainley and Daly 2002; Elwood and Gipps 1999; Smithers and Robinson 2006; Smyth 2010). In many countries, SS schools tend to be highly selective with respect to both students and teachers (Hattie 2002), or are mostly in the private sector which make it difficult to produce valid comparisons with co-ed schools being typically in the public sector and are represented by a larger spread of socio-economic backgrounds (Yazilitas et al. 2013). Caution in interpreting results from studies into the differences between SS and co-ed schools is needed. For instances, some studies which advocate higher achievement results for females in SS compared with co-ed have been unable to account for the students' background factors (e.g. Spielhofer et al. 2002). Once the variation between the two types of schools in student intake policies, school resources, and preexisting differences in student characteristics are taken into account, SS schools are not significantly different from co-ed schools in student achievement and progression to higher education in physics (Daly 1995; Rodrick and Tracy 2001; Sikora 2014). In fact, the studies finding a null effect between SS and co-ed schools on measures of achievement and the uptake of physics beyond high school and as a career attest that SS school may purport "institutional sexism and further gender stereotyping" (Halpern et al. 2011, p.1706).

A limitation of the research conducted to date on the differences between SS and co-ed schools and the uptake of physics is that they map the physics motivational profile of females in both educational settings at a domain specific level. However, physics is similar to other sciences in that it comprises various topics with differing characteristics. Some topics may be more theoretical while others are more experimental and problem-oriented. The extant literature investigating students' motivational patterns in physics typically use domain-specific measures, under the assumption that student motivation is consistent across various topics. These traditional measures at a domain-specific level are inadequate because the measures lack sensitivity by overlooking the unique characteristics of each topic. To address this deficit, a burgeoning field of research is beginning to examine the multi-dimensionality of physics and has consequently developed measures at a topic-specific level. At the vanguard, research has been analysing gender difference in motivational patterns of students in the diverse physics topics (cf. Abraham and Barker 2015a, b; Angell et al. 2004; Baram-Tsabaria and Yarden 2008; Cavas et al. 2010). More research at a topic-specific level is warranted given these studies show differential motivations exist for students based on the assortment of physics topics. Comparisons of females' achievement motivation in SS and co-ed settings remains an unexplored area.

The current study formed a part of a larger project that examined the sustained physics enrolment intentions of students during their first year of senior high school (year 11) in New South Wales (NSW) schools. Senior high school progression into physics has rarely been the focus of physics education research albeit Australian senior high school structure, where students can opt out of physics after the first year of senior secondary physics if they do not want to continue it to the final year. This context provides a unique opportunity to map the students' retention and motivation in the subject. In addition, females at this level represent a unique group because they have already made a choice to participate in a stereotypically masculine domain. Little has been explored about whether females' motivation and engagement with the subject can be sustained during a prolonged period of physics study. Additionally, the sampling for this study allows for the examination of whether females' physics motivation across topics varies as a function of being at a SS or co-ed classroom. Therefore, this study provided a valuable opportunity to conduct a fine-grained analysis and comparison of achievement motivation of females at a topic-specific level.

Materials and Procedures

Abraham and Barker (2015a) developed the Sustained Enrolment Models for Physics (SEMP) based on an expectancy-value (EV) theoretical background, within which EV motivational constructs and engagement constructs were hypothesised to influence students' further enrolment plans (Eccles et al. 1983). The constructs of SEMP were selected after an extensive search of research literature on physics motivation research based on EV theory. Four module-specific SEMPs were developed, and the theoretical development and validation of SEMPs (see Fig. 1) are discussed elsewhere (Abraham and Barker 2015a, b). The constructs of SEMP are:

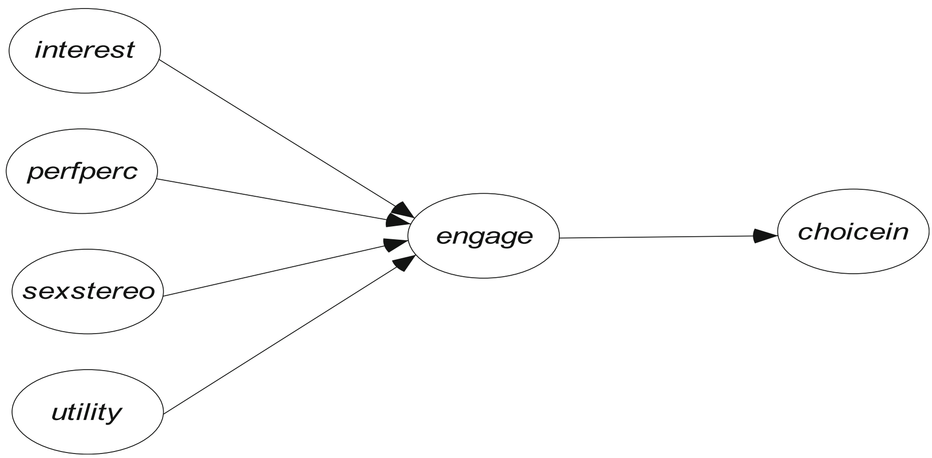

Fig. 1 Conceptual diagram of the Sustained Enrolment Model for Physics

Interest value (*interest*) refers to the "inherent enjoyment or pleasure one gets from engaging in an activity" (Eccles et al. 2005, p. 239). In this study, the interest of a physics module was related to the goals such as having a real desire to study more about the particular physics module and looking forward to learning more about the particular module.

Utility value (*utility*) is defined as the "value of a task acquires because it is instrumental in reaching a variety of long-and short-range goals" (Eccles and Wigfield 1995, p. 216), such as securing a good job, gaining entry to a future career (e.g. Engineering) and pursuing particular study plans at university or higher education institutions.

Performance perceptions (*perfperc*) represents the task-specific beliefs are labelled as students' performance perceptions in that particular physics module. This construct subsumes two highly related constructs, namely students' self-concept of ability in the particular module and their perceptions of task difficulty of the physics module.

Sex-stereotyped attitudes (*sexstereo*) measures the gender role beliefs (Eccles et al. 1983) in the particular physics module, which are a measure of the extent to which an individual believes that the particular physics module is a male domain.

Sustained engagement (*engage*) was measured as a broad construct that is subsumed by interrelated aspects of behaviour, emotion and cognition in the year 11 physics module (Willms 2003).

Sustained enrolment intentions in physics (*choicein*) represented students' sustained intention to choose further physics at the completion of a specific physics module (Abraham and Barker 2015b).

Using the SEMP constructs described above, this study sought to examine whether there is a *degree of difference* (Martin 2003) in achievement motivation, sustained engagement and retention intentions of females in relation to physics in female-only and co-ed classroom settings. The mean values of the constructs indicated how the participants felt about the constructs. Testing for *differences of degree* was explored through testing for statistical significance of mean-level differences between the cohorts. If there are statistical significant mean-level differences, then it can be argued that there are *differences of degree* to which females in both educational settings are motivated (Martin 2003).

Data was collected using the Physics Motivation Questionnaire (PMQ) (Abraham and Barker 2014). The development and validation of the 22–item PMQ and its topic-specific robust psychometric properties are discussed elsewhere (see Abraham and Barker 2014). It includes Likert scale questions which ask the physics students about their experiences and disposition towards each physics module. These questioned were guided by EV theory on physics achievement motivation.

Sample Size and Characteristics

The participants in this study were year 11 female physics students from eight New South Wales (NSW) high schools (five Government and three Catholic schools) located in Western and Northern Sydney. There were four data collection points corresponding to the completion of the four physics modules of the NSW year 11 curriculum, namely The World Communicates (referred to as waves in this study), Electrical Energy at Home (electricity), Moving About (motion) and The Cosmic Engine (cosmic engine). The total sample size across the eight schools varied across the modules (92, 100, 92 and 82, respectively) reflecting the significantly lower female participation in Australian physics classrooms (Lyons 2006). The number of participants from SS schools at the four time points were 45, 57, 53 and 47, while

Table 1 Background factors and future study plans of students

	Females in co-ed (%)	Females in SS (%)
English as first language	45	68
English as an additional language	55	32
Father's highest level of education (University degree)	66	68
Mother's highest level of education (University degree)	66	60
Work pattern (father)		
Full time	86	98
Part time	8	2
Work pattern (mother)		
Full time	35	52
Part time	27	25
Father occupation		
SES class1	60	57
SES class2	22	20
Mother occupation		
SES class1	33	33
SES class2	24	19
University higher study plans	100	100

the number from co-ed schools were 47, 43, 39 and 35, respectively. The survey also included questions on students' personal background and final retention plans in physics.

As discussed earlier, disentangling the effect of the students' home and background factors as well as school factors is one of the challenges faced in comparative studies. In this study, strategies were employed to account for these factors to ensure equivalence in order to proceed with comparative analyses. For instance, purposive sampling secured SS and co-ed schools with similar socio-educational advantage and this equivalence reduced sampling differences.

The Index of Community Socio-Educational Advantage (ICSEA) values of the participating schools were found to be equivalent. Additionally, the participants' socio-economics status (SES) background data were collected using the Australian National University SES (ANU4) scale (Jones and McMillan 2001), and this showed equivalence across the SS and co-ed sample for SES occupations. The SS and co-ed schools were also comparable with regard to their future study plans (see Table 1). Although desirable, the prior academic achievement

Table 2 Mean values of constructs across the four physics modules for both groups

Module	Latent variables											
	interest		*perfperc*		*sexstereo*		*utility*		*engage*		*choicein*	
	1	2	1	2	1	2	1	2	1	2	1	2
Waves	3.34	3.81	3.61	3.73	2.26	1.69	3.41	3.79	3.68	4.05	4.00	4.91
Electricity	3.57	3.60	3.72	3.54	2.24	1.65	2.96	3.49	4.13	4.52	4.21	4.82
Motion	3.69	3.80	3.66	3.69	2.28	1.91	3.43	3.47	4.00	4.24	4.62	4.79
Cosmic engine	3.42	4.49	3.33	4.11	1.98	1.60	2.69	3.31	3.93	4.62	4.89	4.43

interest interest value of the physics module, *perfperc* performance perceptions for the module, *sexstereo* sex-stereotyped attitudes to the module, *utility* utility value of the module, *engage* sustained engagement with the module, *choicein* sustained intention to continue in physics. 1 = female students in co-ed schools; 2 = female students in single-sex schools

Table 3 Fit indices of CFA models including TOS as a latent construct across the four physics modules

Module	χ^2	df	χ^2/df	TLI	CFI	RMSEA	Type of fit
Waves	312.64	233	1.34	0.942	0.931	0.061	Fair
Electricity	359.46	233	1.54	0.931	.942	0.074	Fair
Motion	387.91	233	1.66	0.916	.929	0.085	Fair
Cosmic engine	363.63	233	2.75	0.934	.944	0.083	Fair

χ^2, chi-square; *df* degrees of freedom; *TLI* Tucker Lewis index; *CFI* comparative fit index; *RMSEA* root mean square error of approximation

level of the two cohorts were not compared in this study; however, LSAY reports (see Fullarton and Ainley 2000; Sikora 2014) which are consistent with international trends show that students who choose to study physics in Australian senior secondary schools are generally high academic achievers with high career aspirations and display high self-efficacy in the subject (Barnes 1999; Lyons 2006). Therefore, it is not unreasonable to assume that differences in student background factors would not be sufficient enough to have significant differentiating effects. Given the equivalence of these two groups across the background factors, we recognised that there could be a possibility of variation among females in each cohort.

Results

Comparison of Means

Table 2 reports the mean values across the four physics modules. It shows that participants reported higher or near-average values (mean of the constructs = 3.5) for all variables except for *sexstereo*, across most physics modules. This was not unexpected as they were a group of students who have selected to study physics in their senior secondary years.

Significance Testing of the Mean Score Differences To verify whether the difference across the two groups were significant or not, the standardised factor correlations of the constructs with *type of school* (*TOS*) were examined (Bodkin-Andrews et al. 2010; Kelloway 1998). For this, a new variable, *TOS*, was created as a latent construct. The dichotomous variable *TOS* (SS and co-ed) was allowed to load on this with perfect reliability (error variance of gender was fixed to zero), and the factor loading was fixed to 1, as suggested by Kelloway (1998). A confirmatory factor analysis (CFA) model of all the seven constructs, including the newly created construct, *TOS*, was conducted, and the fit of the model was assessed. Multiple fit

Table 4 Factor correlations with the TOS construct across the four physics modules

Module	*interest*	*perfperc*	*sexstereo*	*utility*	*engage*	*choicein*	*TOS*
Waves	0.271*	0.083	−0.246*	0.168	0.192	0.303*	1.000
Electricity	0.010	−0.126	−0.252*	0.303*	0.206*	0.198*	1.000
Motion	0.055	0.005	−0.254*	0.061	0.121	0.066	1.000
Cosmic engine	0.401*	0.376*	−0.182	0.257*	0.054	−0.154	1.000

interest, interest value of the module; *perfperc*, performance perceptions for the module; *sexstereo*, sex-stereotyped attitudes to the module; *utility*, utility value of the module; *engage*, sustained engagement with the module; *choicein*, sustained intention to choose further physics. *Significant at $p < .05$

Table 5 How interesting was each module to you?

	Very uninteresting (%)		Mostly uninteresting (%)		Neutral (%)		Mostly interesting (%)		Very interesting (%)	
	1	2	1	2	1	2	1	2	1	2
Waves	10	2	12.5	12	35	38	35	36	7.5	12
Electricity	5	2	12.5	14	25	38	42.5	28	15	18
Motion	10	10	12.5	16	17.5	22	35	44	25	8
Cosmic engine	17.5	6	15	2	15	16	25	22	27.5	54

1= female students in co-ed schools; 2 = female students in SS schools

indices, specifically, the χ^2/df ratio, root mean square error of approximation (RMSEA), the comparative fit index (CFI) and the Tucker Lewis index (TLI) were assessed in this investigation (Marsh et al. 1996). χ^2/df values less than 3 and CFI and TLI values greater than 0.90 were deemed acceptable standards for model fit. For RMSEA, a value of 0.05 indicates a *close* fit, values near 0.08 indicate a *fair* fit and values above 0.10 indicate a *poor* fit (Byrne 1998).

All CFA models including *TOS* as a latent construct showed acceptable fit to the data (Table 3). Therefore, further analysis of factor correlations were made to test the significance of the mean score differences. The standardised factor correlations of the six PMQ constructs with the *TOS* construct are given in Table 4.

The results revealed significant differences in the *interest* (for waves and cosmic engine modules) and *utility* (cosmic engine module) value variables, where SS females tended to hold higher values. Likewise, SS females held higher *perfperc* for the cosmic engine module and higher *engage* with the electricity module compared to their co-ed female counterparts. They also had higher *choicein* for waves and electricity modules. Gender role beliefs (*sexstereo*) exhibited more consistency for three of the four modules. Females from SS schools reported comparatively lower values for this construct than co-ed females, although co-ed females also tended to hold low values for this construct (see Table 2). For other constructs, no statistically significant differences were noted across the modules.

The interest level questions on the physics modules were guided by EV theory. These questions, based on the six constructs of PMQ, examined in detail how the two cohorts felt about each of the four physics modules (see Tables 5, 6, 7, 8, 9, 10 and 11).

1 = female students in co-ed schools; 2 = female students in SS schools.

At the completion of the year 11, when the students were making the crucial decision about continuing physics to their final year of senior secondary (year 12) or exiting from physics (discontinuing the subject at year 11), their motivation levels were found the same for both

Table 6 How useful was each module to your career/study plans?

	Not at all useful (%)		Not very useful (%)		Neutral (%)		Somewhat useful (%)		Very useful (%)	
	1	2	1	2	1	2	1	2	1	2
Waves	12.5	14	25	10	27.5	40	25	30	10	6
Electricity	10	12	25	12	25	28	25	38	15	10
Motion	7.5	10	12.5	12	30	22	27.5	44	22.5	12
Cosmic engine	22.5	20	37.5	14	22.5	38	15	18	2.5	10

1= female students in co-ed schools; 2 = female students in SS schools

Table 7 How difficult was each module to you?

	Very hard (%)		Somewhat hard (%)		Neutral (%)		Somewhat easy (%)		Very easy (%)	
	1	2	1	2	1	2	1	2	1	2
Waves	2	2	27.5	12	27.5	46	22.5	30	20	10
Electricity	7.5	6	25	20	30	42	25	26	12.5	6
Motion	5	8	27.5	46	32.5	36	27.5	8	7.5	2
Cosmic engine	15	2	15	8	30	44	30	32	10	14

1= female students in co-ed schools; 2 = female students in SS schools

cohorts. Ninety percent of students in the both cohorts had plans to continue, while 10% indicated they were discontinuing the subject. Tables 10 and 11 summarise the most frequent student responses explaining their decision. The two value constructs (*interest* and *utility*), and performance perceptions were the recurring themes in students' responses from both cohorts for continuing physics. Similarly, there was no notable difference between the two groups in the reasons for discontinuing the subject.

Discussion

Overall, the results provided strong evidence of similarities in physics achievement motivation between females in SS schools and those in co-ed schools. Both cohorts were highly motivated on average; however, there were indications that SS females had higher values for some modules. Although there was evidence for some *degree of difference* between these cohorts in favour with SS students, they do not necessarily support the belief that females overall would be better motivated in SS classes since females in co-ed settings also held high values for the same constructs. Absence of a consistent pattern of the *degree of difference* across the four modules could be interpreted that there may be other contextual factors at play such as parent role modelling, learning experiences they received, characteristics of the topic and the teaching approach that had a greater impact on females' motivation other than SS settings. The lack of uniformity of the results across the modules (e.g. SS females scored higher for one module in their *perfperc* than co-ed females but for other modules they were not different from their counterparts) suggests that there could be other factors that are more influential than the physical absence of males in the classroom that affect their self-concept and interest levels in the subject.

Table 8 How much do you think each module appeals to males or females?

	It is a topic for males (%)		Appeals to males than females (%)		I feel no difference (%)		Appeals to females more than males (%)		It is a topic for females (%)	
	1	2	1	2	1	2	1	2	1	2
Waves	0	0	2	2	93	94	5	4	0	0
Electricity	2	0	28	18	70	76	0	2	0	4
Motion	2.5	0	22.5	4	72.5	90	2.5	2	0	4
Cosmic engine	2.5	0	10	4	82.5	88	5	2	0	6

Table 9 How much would you like to continue learning each module?

	Would not like to continue at all (%)		Sometimes I did not feel like continuing (%)		Neutral (%)		Sometimes I wanted to continue (%)		I would like to continue (%)	
	1	2	1	2	1	2	1	2	1	2
Waves	12.8	4	15.4	4	20.5	34	28.2	36	23.1	22
Electricity	5.1	8	12.5	8	30.8	30	28.2	28	23.1	26
Motion	5.1	14	20.2	8	23.1	32	25.6	24	25.6	22
Cosmic engine	20.5	4	7.7	6	20.5	24	28.2	16	23.1	50

1= female students in co-ed schools; 2 = female students in SS schools

The interest level questions also mapped comparable results. The open-ended responses from both cohorts cited the reason for discontinuing the subject to be the *difficulty level of* the subject and the subject's relevancy to their future career plans. Reasons for continuing in the subject also displayed the high confidence levels for both cohorts in their ability to do physics and the usefulness of the subject for their future. A common and frequent response was the enjoyment they find from studying the subject. Thus, co-ed females were not found lacking in their achievement motivation, engagement and retention plans in relation to physics.

In summary, SS settings in this study were not found to enhance females' disposition towards physics. Although analyses did reveal some module specific differences, these differences were small in magnitude and provide minimal support for the advantages of SS physics classrooms. The findings of this study offer support to earlier observation that "only when pedagogy and curriculum are effective and gender inclusive and teachers are gender sensitive, do single-sex groupings enhance girls' achievement and self-concept in sciences" (Whitelegg et al. 2007, p.32). Perhaps such measures were not an immediate need for this special group of females in sustaining their physics motivation.

Limitations of the Study and Future Directions

The present study provided a novel comparison of physics motivation of a self-selected group of females at a topic-specific level in single-sex and co-ed high school settings. There were, however, a number of potential limitations that are important to consider when interpreting findings and which provide some direction for further research.

The achievement motivation data were collected in a naturalistic setting, that is, in physics classrooms. Consequently, females in co-ed schools completed the survey with their male

Table 10 Reasons for discontinuing physics

Females in co-ed schools	Females in SS schools
Perceived level of difficulty • It is my least favourite subject. I think the topics in year 12 would be hard for me. Lack of relevance • To focus on other subjects	Lack of utility value • Not a part of my career path • It is not relevant to my future career • It is not my career plans and can be too stressful Perceived level of difficulty • My teacher and I think I am not up to learning year 12 physics It was difficult as interesting as it was I didn't have the mathematical ability and those around me were performing better.

Table 11 Reasons for continuing physics

Females in co-ed schools	Females in SS schools
Interest value • Some topics are interesting • Because I find it mostly interesting and the topics we do in year 12 are more interesting than 11 • I find it interesting and I would like to learn about why things work and happen • I enjoy applying maths and understanding how things work • I enjoy learning about how the world around us functions • I find physics very interesting more than any other science course • The laws of physics are interesting. • Physics is very interesting and helps us understands why some of the things in the world are as they are e.g. detailed understanding of technology (GPS) etc. Physics also give a superior edge with the knowledge that I understand how things work rather than just accepting them at face value.	Interest value • It is very interesting and I think Physics is subject that is very applicable to daily events • It is interesting and I like it • The topics in year 12 seem quite interesting • Physics is a good subject and I am interested in it • Because I find it interesting and I enjoy it • Because it was interesting to learn about • Very exciting since it involves such interesting topics and real like applications
Utility value • For my career plans • I need physics to go for my career choice. • It will be good for my uni course • It scales up and I need for uni career	Utility value • Future study plans also it scales you up I think • Because it would help me with my further education and career • It is a useful subject for the course I am taking in uni • I need it for future studies and I like the topics • it is very relevant to my future career and for more future opportunity in university • It is relevant to my potential future careers • More useful than other subjects, I require it for uni • It could allow better opportunity for the course I want to complete in university • I want to do engineering in future. Physics will help • I would like to study a course in university that requires physics it is also very interesting
Performance perceptions • I can do well • I am good at it • I am better at physics than other subjects	Performance perceptions • I am capable of doing these topics • Because I want to do well, improve • I think I would be capable to do well • I like the subject also I am capable of doing well.

colleagues present and this was not the case in SS schools. PMQ contained questions on the perceived masculine nature of physics (*sexstereo* subscale). In order to keep the situation as normal as possible, PMQ was cautious not to include more direct measures on the presence of males in classrooms fearing it might induce ST among females in co-ed classrooms and distort the actual data. Future research should consider including more open-ended questions in this respect. Likewise, it was not possible to generalise the results when there is a large variation from the presented demographics. Although PMQ has been validated and shown to be a robust and gender-invariant scale at a topic-specific level (Abraham and Barker 2015a), but this was not able to be confirmed in this study given the need for a larger sample size to conduct this analysis. Future research should include a larger sample size to conduct invariance testing to provide even more rigour in developing their conclusions. Furthermore, future research into understanding gendered patterns of student motivation in physics should include more than two categories of sex given that not all students identify with being male or female. A larger sample with more than two sex categories would afford the opportunity to examine a more thorough view of stereotypical masculine perceptions of physics with adolescents which can then provide more comprehensive recommendations.

Conclusion

The assumption behind the arguments for same-sex schooling, that is, an all-female environment may diminish the impact of masculine stereotypes and improve females' engagement and sustain enrolment motivation, was not held in this study. Once females commence physics education at a senior high school level, factors such as the *utility value* and *interest value* drive their achievement motivation and consequently the class composition itself is less important. During an extensive period of physics study, females in senior high school are not found to hold stereotypical views about physics being a "masculine" domain or that they are less capable in physics than males irrespective of classroom setting.

Compliance with Ethical Standards

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

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