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Female senior secondary physics students' engagement in science: a qualitative study of constructive influences

Mary C. Oliver[1], Amanda Woods-McConney[2*], Dorit Maor[2] and Andrew McConney[2]

Abstract

Background: Prompted by fewer females compared to males enrolling in physics and advanced mathematics at both secondary and university levels, our research investigated the views and experiences of female students currently studying upper secondary school physics. We interviewed 18 female students about influences they considered important to their own science education, interest in science, and future science-related aspirations. Our purpose was to identify the experiences that these students most strongly associated with the generation and maintenance of their engagement in science, particularly represented in this research by their enrolment in upper secondary physics.

Results: The research team used a systematic, iterative process to identify the main themes in the transcribed interview data. We identified the influence each girl reported as the strongest (ranked first). We also combined *all* influences that the participants had nominated, regardless of their ranking, to further examine all factors participants suggested as influential in their sustained engagement in school science (represented by their decision to study upper secondary physics). Systematic analysis of the interview data confirms that the influences on these females' choices to study physics at upper secondary originate from a combination of their teachers, their school's science culture, members of their family, the participants themselves and their peers.

Conclusions: The interviews highlighted the idiographic complexities in understanding the wide range of important influences on these students studying physics at upper secondary school and their engagement in science. The unique contribution of this work is giving voice to the participants and reflecting on what these high-achieving females have to say about the influential factors in their decisions to pursue science. Supportive teachers and the school science culture play essential roles, and other cultural and/or social factors such as family members and peers are identified as important. References to the culture and expectations of the school, family holidays, and conversations with siblings are support factors that seem to interact and overlap. At the same time, the importance of policy-amenable factors such as competent and caring science teachers, and science-supportive school cultures should be emphasised and encouraged.

Keywords: Gender, STEM, Influences, Science enrolment, Engagement, Qualitative

* Correspondence: a.woods-mcconney@murdoch.edu.au
[2]Murdoch University, South St., Murdoch 6150, Western Australia
Full list of author information is available at the end of the article

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Background

Greater student engagement and attainment in Science, Technology, Engineering, and Mathematics (STEM) continues as an elusive outcome for education policy and practice in many countries across the Western world (Hill et al. 2010; Lyons 2006; Osborne et al. 2003; President's Council of Advisors on Science and Technology (PCAST) 2012; Tytler et al. 2008). As noted by Anderhag et al. (2013), various reports have foreshadowed that many Western countries will experience a future shortage of workers adequately prepared for scientific, engineering and technical industries (OECD, 2007; Tytler et al. 2008). The Australian Industry Group (AIG) recently reported that "75% of the fastest growing occupations require STEM skills and knowledge…young people are not acquiring the STEM skills we need" (AIG, 2013, p. ii). Likewise, Australia's Chief Scientist has consistently underscored the importance of STEM education to the future wellbeing of Australia's society and economy, and has reported that there remains:

> …too little time on average spent teaching science in primary school; declining interest in the study of STEM disciplines in senior secondary school; limited growth, even decline in particular areas of the natural and physical sciences, in branches of engineering and information technology at tertiary level; STEM skill shortages in the workforce (Office of the Chief Scientist 2013, p. 10).

Similar to other countries, across Australia it appears widely accepted that increasing the numbers of students pursuing STEM education has the potential to promote the development of knowledge-based, specialist skills important for national growth and wellbeing (MCEECDYA 2008). Despite this apparent consensus, recent decades have seen decreasing enrolment in post-compulsory secondary school science and mathematics courses (AIG, 2015; Kennedy et al. 2014; Lyons & Quinn 2010; Office of the Chief Scientist 2012; Mack & Wilson 2015; Wilson & Mack 2014). Furthermore, the proportion of Australian school students participating in Year 12 (final year of secondary school) advanced science and mathematics has been in decline since the mid-1990s (Kennedy et al. 2014). Over the past 20 years, Australian students older than 15 years do not typically participate in upper school science and mathematics education at a high level compared with other countries such as Japan, Singapore, South Korea and Finland (Wilson & Mack 2014). Declining enrolment trends in STEM are not, however, always viewed as problematic. Despite almost universal agreement that decreasing enrolments have potentially negative consequences, there are also occasional claims regarding the oversupply of qualified STEM graduates with some experiencing difficulty finding full-time work (Norton 2013).

What does seem clear, however, is that if *all* students are not appropriately supported and provided opportunities to pursue STEM subjects, degrees and careers (Woods-McConney et al. 2014; Schmidt et al. 2015), it is likely that the strength and diversity within STEM disciplines, as well as their associated social and economic outcomes, could be eroded. Specifically related to this study, emphasis on gender-inclusive opportunities in school science over the past three decades and evidence that there is little difference in the abilities of males and females in doing, studying or achieving in science (Woods-McConney et al. 2014: OECD, 2010; Quinn & Cooc 2015) are not yet reflected in the number of females entering post-secondary courses in science and engineering (Mack & Walsh 2013). For example, in a recent study that examined more than 6000 secondary students' interest in STEM careers, males expressed greater interest in engineering and maintained that interest throughout high school; females initially declared greater interest in medicine and health careers but reported lower levels of interest in STEM careers by the end of high school (Sadler et al. 2012). Enrolment data from Western Australia schools show that, historically, more than twice the number of males enrol in Year 12 physics as compared with their female peers. More generally, Australian enrolment statistics show that the proportion of females taking physics and more advanced level mathematics continues to decline (Kennedy et al. 2014; Wilson & Mack 2014).

Declining enrolments in physics and advanced mathematics is not a new phenomenon. Over the past decade, several studies have investigated student decisions to enrol in advanced, upper secondary school science. Lyons (2006) interviewed high-achieving 15-year-old students in Australia about their upper secondary school course choices including physics and chemistry. In the USA, Simpkins et al. (2006) used data from the *Michigan Childhood and Beyond Study* to investigate students' mathematics and science course choices as they progressed from fifth to tenth grade (Years 5–10). As part of the *Lab in a Lorry* project in the UK, Barmby et al. (2008) examined student attitudes as they progressed from Years 7 to 9, with follow-up interviews regarding students' self-reported plans for future participation in science. Typically, these studies investigated students' thinking about future enrolment in physics and advanced mathematics. Few studies have investigated the views of students currently enrolled in advanced secondary school science and mathematics.

Thus, prompted by studies that investigated student views about future enrolment in upper secondary school science, and the continuing low enrolment of females in physics and advanced mathematics, our research investigated the views and experiences of female students currently taking secondary school physics. We interviewed female students about influences they considered important to their own science education, interest in science, and future science-related aspirations. These students had successfully navigated their way through secondary school science and deliberately chose to continue in physics in their last 2 years of school, in contrast to current enrolment trends. What set of experiences facilitated these female students' sustained engagement in science generally and in physics particularly? Our aim, therefore, was to identify experiences that in the view of these students were most strongly associated with the generation and maintenance of their engagement and interest in science.

To achieve this aim, we posed the following research question:

> What do female students describe as important influences or experiences in generating and sustaining their interest and engagement in science, particularly represented by studying upper secondary physics?

Female secondary students' preferences, participation and performance in science

In STEM education, despite arguably substantial attention from researchers, school practitioners and policy-makers, gender-related differences in student preferences, participation and performance remain a challenge for many Western countries. For example, in a cross-country analysis of PISA 2006 data, Sikora and Pokropek (2012) found that in all 50 participating countries career preference followed a gender divide, with females expressing a preference for careers in biology, agriculture or health, and males for computing, engineering or mathematics. Using the same data, Buccheri et al. (2011) explored interest in science and career aspirations of more than 7000 top-performing students from four high-performing countries (Australia, Finland, Korea and Switzerland). Gender-specific differences in interest in the different sciences were apparent yet varied. In chemistry, there was no gender difference between Korean and Australian students, but large differences for students in Finland and Switzerland. Females in Australia and Korea preferred human biology to chemistry and physics, and Korean males preferred human biology to the physical sciences. When asked about their future occupation at age 30, student responses reflected a gender divide with very few females stating an interest in engineering, for example, especially in Australia and Switzerland.

The finding that "gender determines specific science interest and vocational choices" patterned differently across the four countries (Buccheri et al. 2011, p. 173) and may reflect socio-cultural differences. Tellingly, for top-performing students in all four countries, females had lower levels of self-concept in sciences than males, a finding that is also reported for US college students (Riegle-Crumb et al. 2011). Given that science self-concept, interest and success in science are likely to augur well for pursuing a career in science (DeWitt et al. 2013), it may seem appropriate to focus on improving student self-concept in science. However, Sikora and Pokropek's (2012) analysis showed that the gendered pattern of career preference was unlikely to be reduced by bridging the gender gap in self-concept. Moreover, and perhaps concerning to more industrialised countries where there have been efforts to "close the gender gap", preference for careers along gender lines appears to be stronger where individual subject choice and curriculum may unwittingly contribute to "perpetuating gender stereotypes and…exacerbating gender segregation in science" (Sikora & Pokropek 2012, p. 256).

Analysis of international assessments of 15-year-olds also reveals that levels of science self-efficacy are gender-patterned (OECD 2015, p. 84). Females reported higher levels of self-efficacy when responding to health-related questions compared with males, and lower levels on other aspects of PISA 2012 science questions, including questions about "thinking like a scientist". When only the top-performing students were considered, there was a small gender gap in science achievement favouring males (OECD 2015).

These findings suggest that career aspirations, self-concept and achievement in science may be formed at an earlier age. Using a survey of more than 9000 students aged 10/11 years, and interviews with 170 students the same age in England, Archer et al. (2012b) found that females who expressed positive science career aspirations required them to "engage in considerable identity work…to navigate dominant associations of science with cleverness" (p. 982) and in doing so, to balance their identity as scientists, and of being clever, with notions of femininity. This, the authors suggested, was a greater challenge to females who were not part of the mainstream middle class. Hazari et al. (2010) developed an identity framework, using recognition, interest, achievement and competence as dimensions to better understand how students "see themselves in relation to the field of physics" (p. 982). In this large-scale survey of US college STEM students, the authors found little evidence of large gender differences. Rather, any significant differences emerged "at a nuanced level" (p. 988) with respect to the interaction of pedagogy and content in physics classes. These authors describe females' experience of high school physics, as "not including their perspectives and what is meaningful to them" (p. 999).

Similarly, a study in Australia found that there was little gender difference in science career aspiration of 3800 Australian 15-year-olds but a gender divide with respect to science subject participation (Quinn & Lyons 2011). While males enjoyed science "more in relation to other subjects" (p. 231), the authors also noted that females might enjoy other subjects more than science. So, instead of a gender difference in overall enjoyment of science, the relative enjoyment of the different subjects may mask the finding that there was little difference in overall enjoyment of science when comparing males and females. Again, these findings are not conclusive and underscore the need for more direct study.

In the USA, gender and ethnicity-related gaps in participation and attainment were explored in a longitudinal study of third to eighth grade (Year 3–8) students. The gender gap in science achievement, favouring males, was slightly larger than in mathematics (Quinn & Cooc 2015, p. 342). This longitudinal study found that prior achievement in mathematics was linked to science achievement in eighth grade with suggestions that "subject matter inequities at school and class level" (p. 344) need further examination. These findings are generally consistent with results in the UK and Australia. Continued gender-related discrepancies, favouring males in the mathematical and physical sciences, in post-compulsory courses have been shown in the UK, but on the other hand, participation and performance in the biological sciences appear to be "gender-neutral" for UK upper secondary students (Institute of Physics (IOP) 2013) and favours females in Australia (Kennedy et al. 2014). The UK Institute of Physics (IOP) highlighted the low participation of females (20%) in upper secondary "A" level physics courses because high achievement for females at age 16 does not translate into similar proportions of females continuing with upper secondary physics (IOP 2012, 2013). Further, the finding that few females choose "A" level physics suggests that "girls are making a conscious choice not to study Physics" (Daly et al. 2009, p. iv) even when they are more than adequately qualified. In other research, attitudes to physics were largely determined by self-concept, experiences of school physics and the presence of a personally supportive physics teacher (Murphy & Whitelegg 2006). Another study demonstrated that stereotypical attitudes, such as "physics is a male subject", can act as deterrents in upper secondary school physics enrolment (Abraham & Barker 2015b). The same study reported that perceptions of students' own ability and task difficulty predict future enrolment patterns in physics at school (Abraham & Barker 2015b).

Further, in the UK, multi-level modelling was used to investigate the progression of females to upper secondary physics courses and found this to be associated with achievement in physics and mathematics courses at age 16 (Gill & Bell 2013). Additionally, "doing" more science between 14 and 16 was more favourable for progression to post-16 courses (Homer et al. 2014). Typically, students in "high uptake" of physics courses were in schools with a focus on "curriculum diversity, examination grades required for further study, career-related matters and student aspiration" (Bennett et al. 2011, p. 686). In Australia, Lyons (2006) examined the complex issue of declining enrolments in upper secondary physics and chemistry and reported that students found lower secondary high school science to be "irrelevant, uninteresting and difficult" (p. 285). Another study, surveying 3959 Year 10 Australian students found that females with lower levels of self-efficacy are "more sensitive to anticipated difficulty" (Lyons & Quinn 2010, p. 112).

Thus, Australia appears similar to the UK with a gender divide evident in upper secondary enrolment in physics. Overall, the number and proportion of students taking upper secondary physics in Australia has declined since the early 1990s (Kennedy et al. 2014). This pattern is replicated in other studies investigating enrolment in secondary mathematics courses, particularly in more advanced courses. In Australia, the data show that fewer females are enrolled in advanced or intermediate mathematics courses than boys (Roberts 2014). In New South Wales, Australia's most populous state, participation in upper school mathematics courses has declined for both males and females, but much more markedly for females, with the gender gap present since the 1980s (Wilson & Mack 2014). Declining levels of participation are likely to have consequences for physics enrolment at university, as high school mathematics was found to be a strong predictor of achievement in university physics courses in the USA (Hazari et al. 2007). A large survey of students enrolled in Year 11 physics in schools in New South Wales reported little gender difference in motivation or engagement but rather "differences in the *degree* to which boys and girls are motivated" (p. 59) noting that there was no consistent pattern of a gender difference across the four modules studied (Abraham & Barker 2015a). The authors suggested that in studying physics in Year 11, females were "most likely [to] possess high motivation and engagement for physics that is on par with their male counterparts" (Abraham & Barker 2015a, p. 67).

Schools in England that are successful at attracting and retaining females in upper secondary physics courses, have been characterised as having a future focus that values the study of science, and as schools where students participate in work placements, career days and university visits (Bennett et al. 2011). Gill and Bell

(2013) found prior attainment and gender, mathematics qualification at age 16, and for females, attending an independent or grammar school positively impacted on the uptake of "A" level physics. The socioeconomic status of the school seemed to exert "a significant effect on the overall number of students progressing to 'A' level physics *but little effect on the proportion of girls in the cohort*" [our emphasis] (IOP 2013, p. 15). In the USA, it may well be that the pedagogies associated with teaching and learning physics (including the development of females' self-concept and persistence) in some schools are more supportive of females than others (Hazari et al. 2007). Peer support and friendship groups also appear to support female students' achievement in science and mathematics. Using data from the National Longitudinal Study of Adolescent Health and Adolescent Health and Academic Achievement, Riegle-Crumb et al. (2006) examined the role of friends in enrolment in pre-tertiary high school courses. The finding that "effects of same-sex friends' on course taking in these subjects [physics and mathematics] were stronger for girls in a predominantly female friendship group" (p. 219) suggested closer investigation. Again, what limits or facilitates female students' progression in secondary school science, and particularly in the physical sciences and mathematics, is complex and clearly warrants further study.

In summary, previous research about female preferences, participation, and performance in science and mathematics in upper secondary school reveals a complex picture. Notwithstanding such complexity, gender-related gaps tending to favour males continue to be evident, particularly in physical science and mathematics. Our analysis of the research, however, revealed few studies that interrogated female students directly or deeply about the array of influences that seem to underpin their choices about studying science at secondary school, although many have suggested that this work be undertaken (Alexander et al. 2012; Gill & Bell 2013; Homer et al. 2014; Wang 2013). To contribute to addressing that apparent deficit in the literature, yet grounded in the assortment of findings and potential explanations from previous research, this study directly asked female students currently enrolled in upper secondary school physics, about strong influences important to their own science education experiences, including current interests and future aspirations. By interviewing deeply a select group of high-achieving female students enrolled in upper secondary school physics, we sought to better understand the influences that instigated and sustained their engagement in science generally, as well as influences that facilitated their continued commitment to studying science, characterised singularly and specifically by their enrolment in upper secondary physics.

Methods

Participants

We conducted this study in the context of a large Australian city. Research participants were purposively drawn from cohorts of high-achieving females in schools with (historically) top-performing students in senior secondary physics. We selected high-achieving female students currently enrolled in schools with established track records of success in upper secondary physics because these students represent the extreme positive case of female engagement in secondary science. Despite the prevalent, demonstrated tendency for female students to avoid upper secondary school science, these females were successfully studying physics in schools with established success in science generally, and physics particularly. This best-case approach allowed us to ask the participants to reflect on their experiences and to identify constructive, beneficial influences on their sustained engagement in science. At the same time, purposive selection of these female students who were all clearly engaged in science minimised potential barriers that we judged as extraneous to the aim of this research. For example, a lack of opportunity to take science subjects because they were not offered at school, or low family SES, are barriers to engagement in science that could confound our purpose of better understanding beneficial, strong influences for female engagement in science generally, and for choosing to study physics particularly.

Specifically, we contacted schools with the highest-performing students in physics based on state examination results over a 2-year period. A representative from the science department in each school, typically a science department head teacher, identified several high-achieving female students in physics to potentially participate in the study. In all, 18 nominated female students, enrolled in physics during Year 11, the penultimate year of senior secondary school, agreed to participate in the research and were interviewed by members of the research team. Two government (public) and four non-government (private) schools consented to allow their students to participate in this research. All six schools are considered to be academically focused, based on their historical records of students going to university, and draw their students mainly from families with higher SES backgrounds. One school is an all-girls school, and five are co-educational with similar numbers of males and females. Two of the six schools cater for Year 8–12 students, while the others serve kindergarten through Year 12. Although only three females were taking physics in one of the non-government (private) schools, they represented 16% of Year 12 students. Thirty-five females were taking physics in one of the government (public) schools, representing 14.5% of Year 12 students. The percentage of females studying physics relative to all Year 12 students ranged from 4% in one co-educational private school to 28% in the one all-girls school. Overall, it was evident that proportionally few females are studying physics, even in these high-SES, high-performing secondary schools with established track records of success in science.

Interviews

Our purpose was to gain a more detailed understanding of influences that spark and maintain female participants' engagement in science. To achieve this, we used a case study approach with semi-structured interviews. Individual semi-structured interviews allowed greater scope for probing questions to be asked in real time, during the interview. In other words, we developed a conversation with each participant to seek elaboration and clarification about their responses and reflections. Interviews with each participant typically lasted between 20 and 45 min and began with a short reminder that the purpose of the study was to better understand females' engagement in science. A reminder was also verbally provided about our ethical commitments (confidentiality, participant review of the interview transcript, etc.) in the research. Responding to semi-structured prompts, each participant described science at her school, her current science subjects (including physics) and any types or approaches to teaching or learning she found interesting or engaging. The participants described what they liked about science, past experiences that may have prompted their engagement in science and any influences for them to choose science in upper secondary school, and specifically to study physics. After the participants described these influences, we asked them to rank the importance or strength of each influence. The students were also prompted to describe their plans for further study in science at university and their future plans, if any, for science as a career.

All interviews were digitally recorded and transcribed. After a member of the research team reviewed the transcripts, they were returned to the interviewees for further clarification or editorial corrections. Minor changes were necessary on three transcripts and these revised transcripts were returned to the respective interviewees for confirmation. All interviewees returned their transcripts and confirmed that the data were accurate. Once all transcripts were confirmed they were de-identified for analysis.

Data analysis

Overall we used an inductive approach to data analysis, which was both systematic and iterative. First, we generated an initial list of codes with two researchers collaborating to code all interview data. We agreed to avoid paraphrasing the participants' words and instead used an in vivo approach to ensure that we did not over-interpret the transcripts in this initial phase of data analysis (Braun & Clarke 2006; Saldana 2009). This process involved revisiting the transcripts numerous times to ensure that the students' voices were authentically represented. In this first phase, we identified the initial codes manually (i.e. without the use of software).

Second, once the initial codes were identified and collated, we nominated emerging themes (reflecting the influences proposed by participants). At this stage all data were transferred to *NVivo* to facilitate further analysis. Also, we involved a third researcher to review the initial coding and assist in grouping codes into potential themes. This process ensured that all coders held a mutual understanding of the codes and how they were organised into themes.

Third, we focussed on responses to the part of the interview in which participants were asked to identify factors that influenced their interest and engagement in science manifested by continuing to study science at school, and further, to select physics as an upper secondary subject. We identified the factor or influence each participant reported as the strongest (ranked first) and using *NVivo*, re-examined the entire dataset to unpack influences into aspects (of the participants' nominated influences).

Finally, we identified and retrieved specific transcript excerpts relevant to each influence and its related aspects, and continued this process to generate an analysis authentically reflecting the students' voices. Together, this systematic approach resulted in a reasonable and defensible scaffold for organising and analysing the factors that these 18 high-achieving female students had communicated as influential in their sustained engagement in science, most clearly exemplified by their decisions to enrol in upper secondary school physics.

Results

In this study we asked, What do female students describe as important influences or experiences in generating and sustaining their interest and engagement in science, particularly represented by studying upper secondary physics?

In answering this question we prompted participants to identify and rank order influences that prompted and sustained their engagement in science. Using *NVivo*, we grouped the influences based on the female students' rankings from one to four (one being the most influential). For this select group of students, the following emerged as most influential (most often ranked first): school, ranked first by 5 participants; teachers, ranked first by 4; family, by 3; self, by 3; and peers, by 2.

We also combined *all* influences that participants had nominated, regardless of their ranking, to further examine all factors that participants suggested as influential in their sustained engagement in school science (represented by their decision to study upper secondary physics). Examining the participants' nominated influences in this way, 15 participants identified teachers as influential in their sustained interest in science; 10 identified their family; 9 selected peers as influential; 6 identified themselves; and 5, their school.

Figure 1 portrays the five top ranked influences in its outer circle and related aspects in its inner circle. Aspects located closer to the circle's centre reflect higher frequencies compared with those placed nearer to the outside.

School

Five students nominated their school as the most influential in sustaining their interest in science, referring mainly to the "science culture" of the school. Two participants, when asked to identify and rank the factors that influenced their interest in science said "probably school culture first…that's what they push you to do". (12[1]); "I think there's a lot of emphasis on science at school. It's definitely where they try to steer people" (11). Other school-related opportunities, such as national science competitions, influenced her choice as noted when she said "everyone says the science department is so good; if you're a bit unsure what to do, do science" (11). With further analysis, it became clearer that a school's culture included aspects of science teachers (which we have discussed as a separate influence), the academic focus of the school, the status of science within the school, school expectations, competitiveness and opportunities to excel, and peers within the school (also discussed as a separate influence).

The status of physics is an aspect of school that one participant expressed with pride, "everybody wants to do it" (10). Furthermore, this participant explained how teachers had said "you're definitely capable" but they did not say it to everyone (10). Another participant clarified, "if you can do physics you're seen as one of the top students at the school" (12). The culture of the school was an important influence in these students' engagement with science.

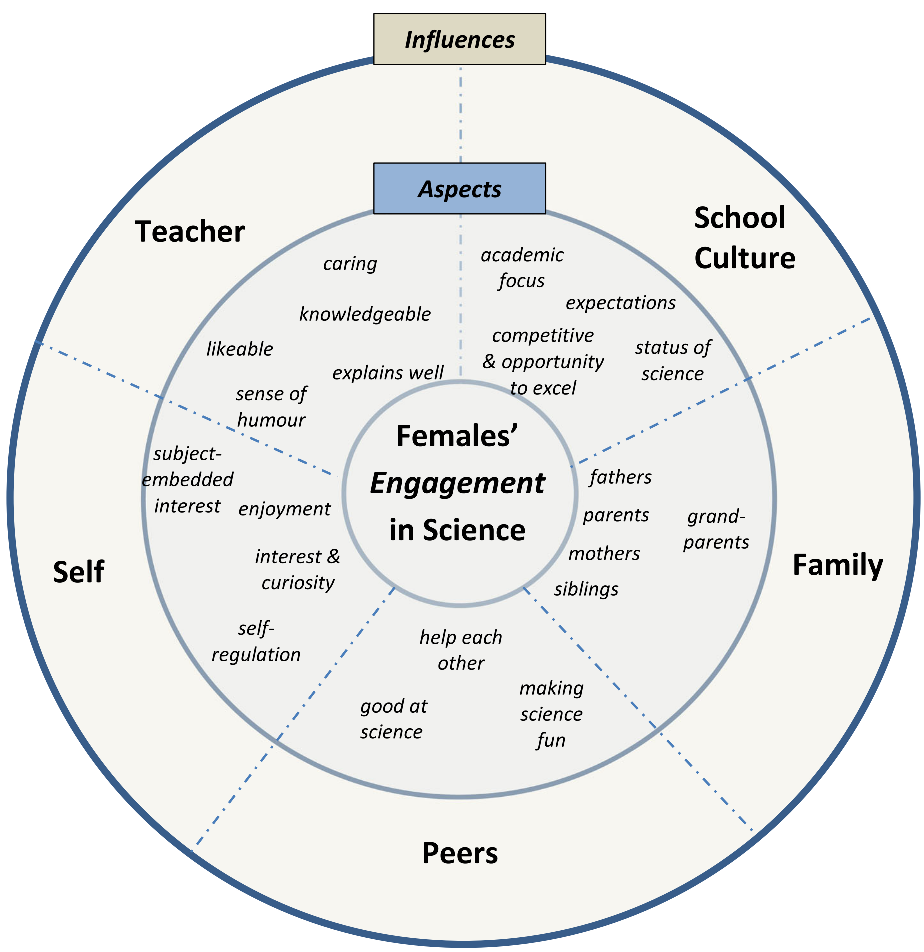

Fig. 1 Top ranked influences and related aspects nominated by participants as important to their interest and engagement in science

School staff expectations were a particularly important aspect of the school as an influence on selecting physics as noted when one student said “so it ends up being sciences” (12). Another participant explained that “they really want you to excel” (11). In other words, the school culture emphasised academics combined with other cultural features such as competiveness and explained that “it’s very academic-based” (12) and “it’s a competition almost. I really like that” (10). Furthermore, “I think it [enrolment in physics] was the right choice personally because I do focus on academics quite a lot” (08). When asked to elaborate about their experiences in the school, the participants also talked about the “added-on” benefits that school provided. For example, “it [the school] gives you a lot of opportunities to really excel in what you want to do” (06), and there is always “some form that you could challenge yourself and extend yourself” (16). All of these aspects, including the school’s academic focus, competiveness and opportunities to excel provided positive influences that sustained these high-achieving females’ engagement in science and pursuit of physics in upper secondary.

Teachers

Teachers were ranked first by four participants and 15 students ranked their teachers as influential in their decisions to continue studying science generally and physics particularly. Participants described their teachers as knowledgeable, having good explaining skills, a sense of humour and caring. It is important to note that these characteristics were mentioned spontaneously by student participants rather than being solicited by the interviewers. For example, citing teachers’ skills at explaining science, one participant noted

> My physics teacher was explaining solenoids…he’s not just saying something, he’s asking us questions so we can think about it as he’s teaching. …If we don’t get it, he can explain it further (18).

Similarly, a number of participants described their teachers as knowledgeable. One student explained that teachers “really know the course and stuff really well. And they know what you need to know so they teach you quite well” (06). This aspect also extended to the “outside world”, helping students appreciate relationships between what happens in the classroom and the real world. When describing one teacher a participant explained that the teacher “doesn’t just tell us the concepts—he sort of extends us. So we’ll talk about a concept and then he’ll give lots of really good real life examples” (13).

Several students mentioned teachers’ sense of humour. One participant said her teacher

> …does these very funny pracs [practicals]. We were doing electricity and he decided to get his gherkin electrocuter out and he got a gherkin and he stuck it with a ton of power and it was like “pppzzzz”. He was showing us how human skin would react to electricity. That was funny just because it was a gherkin (14).

The participants also mentioned teachers’ caring. For example, when describing their teachers, participants noted

> They all stay after school to help us out on specified days (13).

> They connect with the students, which I think is important if they want to teach us. They are interested, wanting to help us (10).

> I think my physics teacher specifically goes out of his way to help the girls. But I just feel that, it’s not patronizing or anything, but it’s good (15).

Participant comments also indicated an overall sense of how good their teachers are and how much these students like them as professionals. One student explained that she “could tell that they’re passionate about it [science]. So because of their passion, you want to get involved in it” (04). The students further emphasised the competence of their science teachers as an aspect of their school’s culture and influence. In particular, the students noted that their science teachers are not only nice, but “cover a lot of things, very interesting things, very relevant” (10). These participants were able to identify how important their teachers are for sparking and sustaining their interest in science. According to one participant, the teachers in her school are enthusiastic about science and create an environment in which “it’s nice to be able to look at school teachers and say “yeah, they’re kind of my friends” whereas in some other areas maybe that’s not true” (03).

Family

More than half of the student participants identified the positive influence of family members, many of whom had been pivotal in developing their interest and engagement in science. Further, three participants considered family as the top influence in their decision to take physics. Looking beyond first ranking, many of the students saw their mothers or fathers as an inspiration to their engagement in science. Others specifically referred to a sibling as an important influence, and a few referred to their grandparents as influential.

Participants referred to their parents as being supportive and providing opportunities that may have sparked their interest in science generally, and physics, specifically. For example, one participant, when talking about her childhood experiences, reflected that her "parents always brought me books because when I was little that was pretty much all I did was read" (03). Another participant described family holidays and said "we would travel a lot…that would be a bigger influence in science as well" (05). Thus, some parents may exert an influence on their daughter's affinity to studying science as described by one participant when she said "it's just kind of what I grew up with. My dad used to take us to the hospital when he visited a patient so we spent a lot of time in hospitals when we were younger" (18). Another participant noted that her father, a mechanical engineer

> …would help me a lot during my year seven because that was when we started learning about forces, the push and pull and all those, the simple bits. But I found that kind of hard to understand at first so he would help me, demonstrate, and do little experiments with me (05).

Clearly, the participants were influenced by their parents' occupations, hobbies or subjects the parents studied.

At other times it was the students themselves who initiated the parental activity that stimulated their interest. One participant described past holidays and said that "during the holidays I'd ask Mum to write ten maths questions on the board before she'd go to work and then she'd leave it there then I'd wake up and do them" (08). Another student remembered that "everyday my mum would make me do two or three pages of this [science] book" (16). It was also striking, however, that parents did not always influence participants' choices. A participant explained that "my parents aren't really science people…[I] don't think they understand much about science at all, especially with high school science" (14). Another participant explained that "my parents are not involved in what I'm actually doing but they just support me with what I like to do" (15). Thus, the notion of parental influence or support varied.

In addition to parents, siblings were important to a number of the participants. Two participants described their relationships with their older brother and explained that

> My brother's…gone through everything I've gone through in terms of school stuff…I can trust him to give me the right explanation when I didn't understand my teachers (15).

> My brother tried to choose the fun bits of chemistry to interest me and I really enjoyed it. He even made up a fake exam with little pictures of molecules all scattered throughout to entertain me. My brother, I absolutely adored, and so anything he did I wanted to do as well. It wasn't just about learning; it was also about having fun with my brother (03).

Grandparents were mentioned as important influences by a few participants, who illustrated how their grandfather or, in one case, grandmother inspired them. One student reflected that she interacted with her grandfather and said "my grandpa also had a telescope. We did go through star atlases, that kind of thing" (09).

Thus, several of the participants credited family members in influencing their engagement in science. They cited family members specifically for the range of opportunities they provided, from visits to the Australian bush, to hospitals or science centres. The students also talked more generally about the encouragement they received from family members, combined with expectations that were not only focused on school.

Self

Three participants described themselves as the top influence regarding their interest in science, and a few nominated "self" as an important influence. More generally, participants explained aspects related to the influence of self and identity with emphasis on enjoyment, interest including curiosity, self-regulation and subject-embedded interest.

Enjoyment of science, as an aspect of self, took many forms. For example, "when I was younger every year for my birthday I'd get those encyclopaedia books…I just liked reading about facts and learning stuff like that. I was really pulled to physics…I enjoyed reading facts and how things worked" (12). Another participant liked to read so she could feel "clever and curious" (03). This aspect also led to the participants looking forward to science classes because "it was quite enjoyable" (14), or "when we got an investigation" (08). Classroom science experiments also carried over to the home environment as described by one participant who said "I would go home and say, 'Oh look Mum, this is an acid, and this is a base'…I was kind of interested that way" (05).

For these participants, interest in science, as an aspect of self, included curiosity. For example, "I found that in depth, you learnt part of it so [you asked] how does this work? I just wanted to know how everything worked" (10). Another student reflected that "I find quantum physics really interesting" (06). An interest in science was emphasised by one student when she clarified that "from Year 10 up we did a lot more things in science that applied to the real world. So I thought that was really interesting, for me" (15). Later in the conversation when discussing her science experiences over the past 5 years the same student clarified her interest in science

"I guess what interested me was the stuff where you could see it being applied, not the abstract things. I mean for chemistry, you can see how you would apply it, but I never use it in real life" (15). Similarly, another participant, when describing her experiences of science over the past 6 years noted that initially, in primary school

> We didn't know that we were doing science. It was science as in we went outside and looked for plants and all those types. It was the biological sciences in that time. But then as soon as we came into high school…that's when it really opened my eyes to science, all the experiments. I just personally found it interesting because it's more about the world and we can apply it to real life situations (05).

Another participant noted that "science was more interesting. So that's why I chose to do lots of science in years 11 and 12" (04).

Subject-related interest further indicated that the students had strong interest in physics and in some cases in mathematics to support their physics studies. The physical sciences were emphasised by one student who explained that "I really like physics and chem quite a bit so I picked them as subjects and [I'm] doing them this year" (01). Some of the students explained that they liked chemistry and mathematics and therefore also liked physics. In other words, physics made sense and they "loved it and understood it" (08). Another participant said "I enjoyed it. I was really pulled to physics" (12). Other participants suggested that they had an ambition to have a science career, identified their own attraction towards science, or found science interesting. One student explained that her "actual ambitions might be a top one [influence] because I want to do a science-based career" (13).

The self-regulation aspect revealed an interesting scenario that developed among the participants. While trying to understand physics, they also tried "to explain things so that others would understand" (01). As one participants explained

> I'm always on top of my work and I always know what's going on. So I get asked lots of questions in class because I was listening and I did my work in class and I didn't muck around (12).

This student could articulate how she took control of her own learning and applied this to helping others. Similarly, other participants described a goal and a strategy to achieve the goal, explaining "I usually work to get it" (15). Another student said that "if I don't understand something we do in class, then I'll make sure I read over the stuff we've done so that I can actually understand it" (04). Excerpts like this illustrate autonomy and control with the participants regulating their own actions to achieve their goals, aimed at success in and beyond school.

Peers

Two students ranked peers as the top influence on their sustained engagement in science and decision to study physics, and when all influences were combined, seven more participants identified peers as an important influence (for a total of nine that selected peers as influential). When the influence of peers was further analysed, three additional students discussed their peers without including them in their top three or four influences. The most frequently stated aspect was that the participants' peers help each other, with the additional aspect of their peers being good at science. The students also explained that their peers make science fun.

One participant, when describing how she and her friends interact, noted that they are actively involved in "helping each other if we need [help]" (12). There was a feeling of complementarity that the students explained science to each other when necessary. This is because "everybody knows different parts of this [science] so we're able to help each other out" (10) and…because "we're all best friends…" (12). Similarly, students noted that simply finding answers from their peers before asking the teacher was important. Being "good at science" (7) was important and part of their peers' influence. The participants tended to rely on each other, noting that my "friends are really good at physics as well…But we help each other with sciences" (06), and another noted that her friends "have been interested in science as well" (07). Furthermore, these participants recognised the benefit of helping each other and explained the importance of discussing the concepts with peers.

> You're on the same level of education…they think of things differently to teachers so they can just explain it in their own words, maybe in simpler terms and stuff (02).

The students explained that they had a strong affiliation with their peers and motivated each other, illustrated by a participant who noted that "lots of my friends are science-y kind of people as well" (04). According to one student, the peer interactions could also include a subtle pressure to enrol in science.

> If your friends have an interest and motivation to do science, then you would have to [also enrol in science]. Yeah, your friends influence you a lot. They make you change just to fit in I suppose. So that's a big factor (14).

Another aspect noted by participants in relation to peers was making science and studying science fun. One student said that out of the nine students studying physics, she was one of three females in the class (six males). She described her social group and explained that "other people have questions, sometimes funny questions, sometimes silly questions. That's what also makes it enjoyable I suppose" (14). These participants suggest that their peers make learning science fun.

The participants in this study worked with other peers in their classes and, not surprisingly, have friends who worked together. Nine of the 15 participants who attended co-educational schools (as compared to the all-female school with three participants) worked with their female peers who were typically their friends. A number of participants mentioned "girls stick together" (14 and 16), and "girls work with girls" (7). Another student described why she works with her female peer "I work with the person next to me because she's my friend" (18). Sometimes the all-female grouping was because there were limited numbers of females in the physics class. For example, in one school there were only two females out of the 20 students in the physics class. These participants worked together and one participant explained that "if it's a pair [group] it's with a girl" (9). She explained that in groups of three or more, the group was mixed because there were only two females in the class. In another co-educational school there were small classes because the school accommodated the timetable to ensure that all students had the opportunity to enrol in physics. Three of the females in a class with seven students (four males) worked together. One of the females in this friendship group preferred to work with her female peers because the males "are messy and do it [the physics work] bad [ly]" and further explained that "girls work harder" and "come prepared" (10). Another student from this school, but in a different class, explained that "we're all best friends" (12) but did not specify that she worked specifically with her female peers. Two other females from different co-educational schools explained that they worked with their friends, but they worked in a mixed gender group. One student explained that there were more males than females in her physics class and that in general the "girls stick together" (5). However, she described her study group further and explained that one male studied with them. Another female who described her study group stated that she worked with her friends "even boys" (13). Only one of the 18 participants specifically stated that she preferred to work with her male peers, at least in mathematics. She explained that in advanced specialist mathematics she was the only female and did not "mind being the only girl" (17). Overall the rest of the students explained that they worked with their friends and the majority of participants explained that they worked and studied with their female peers.

Discussion

In this research, our purpose was to better understand, from the perspective of female students, strong influences that initiated and sustained their engagement in science at school. Our examination of current/recent science education literature indicated that most empirical studies seeking to explain low female enrolment and/or engagement in physical science and related advanced mathematics have relied on *prospective* designs in which girls were asked about their *future* plans for course enrolment or careers. Quite differently, the current study purposively chose upper secondary students already studying physics, which demonstrated their commitment to science, and then asked them to think *retrospectively* to identify important influences in their decision-making. In its design, this study is different from the majority we examined. Furthermore, an important consideration in our design was to select female participants currently enrolled in upper secondary physics and not hindered or disadvantaged by a lack of science course offerings, or by lower SES backgrounds. In other words, our purpose was to better understand strong influences on female science engagement in what could reasonably be considered a best-case scenario.

We acknowledge that our purposive selection of students who chose upper secondary school physics limits us to probing the influences on engagement in science for students who likely already have a positive view of science. Indeed, this reflects our purpose in this research. We also readily acknowledge that the design of this research inherently limits the potential applicability of its findings to female students with different cultural or socioeconomic circumstances. As a way to build on previous work to understand important influences in female student choices about science study or careers, we purposively chose this bounded group to circumvent the potentially confounding effects of SES, or opportunity to learn. Consequently, we are able to say with high confidence that for these participants, school and home have been largely congruent in valuing science. Both school and home environments have combined (intentionally or unintentionally) to nurture and support these females' positive attitudes towards science, and to provide opportunities and encouragement to learn, personally experience and further understand science.

As we have attempted to show here, our findings in this study suggest that the "whole is other than the sum of its parts" (Koffka 1935) where influences and aspects overlap to support students interest, engagement and progression in science. For the secondary school female students who participated in this research, choices about engaging in science generally, and physics specifically, derive from a complex interplay of several factors. Systematic analysis of the interview data confirms that the influences on these females' choices to stay engaged in science, and to study physics at upper secondary comprise a combination of their school's science culture, their teachers, family, the participants themselves and their peers. Our findings add to survey data that have examined predictive influences on students' engagement with, and enrolment plans in upper school physics using the Sustained Enrolment Models for Physics (SEMP) for Year 11 students (Abraham & Barker 2015a, 2015b). Additionally, our findings complement large-scale, cross-national comparisons such as PISA. At the student level, large-scale survey data can dampen individual explanations and therefore offer different insights about the interplay of influences, and experiences associated with individual engagement in science. The interviews analysed and reported here highlight the complexity in understanding the wide range of strong, but individualised influences on these students' sustained engagement in science.

In this cohort of high-achieving participants, we found female students engaged with school science and were interested and challenged by their classes. At the same time, there was less evidence of a personal "fit" with the subject in that none of the participants specifically indicated that she would continue to study physics at university. Nonetheless, the participants characterise school as an enjoyable place to be, with humour and support for their learning and success, consistent with the characteristics of a positive school culture (Hinde 2004). The participants' expressed values, assumptions and beliefs about schooling resonated with the schools' culture and this augurs well for the students' own success (Van Houtte 2005). Certainly, there is considerable variation among schools in supporting students' engagement in science and the nuanced characteristics of these schools' cultures warrant further scrutiny (Anderhag et al. 2013).

The students' positive comments about their teachers' influence are mirrored in research about US high school students who reported that good teachers are "energetic, caring, passionate, and patient" (Gilmartin et al. 2007, p. 997). Scantlebury (2012) has long argued for research that focuses on teacher attitudes and classroom practices that impact females in science; for the high-achieving young women in this study, teachers are crucial mediators in their achievement and aspirations in science. The students at one school described an extremely supportive teacher ("I think my physics teacher specifically goes out of his way to help the girls"), which resonates with findings by Abraham and Barker (2015a) who showed the importance of teachers using supportive pedagogical approaches. This is also consistent with Krogh and Thomsen's (2005) findings that female students' relationships with their teachers play an important role in student learning. Teachers created supportive learning environments, inspired the participants in their school science experiences and were directly helpful to individual students, actions that reflect competent teaching professionals (Avalos 2011) and that supported these female students' success in physics. By contrast, in an older report, gender-differentiated expectations of students by physics teachers appeared to adversely impact females (Murphy & Whitelegg 2006).

This study further suggests that participants' families played a pivotal role in instigating and supporting their engagement and achievement in science (Sonnert 2009). Alexander et al. (2012) discussed how parents supported their children's interest in science by "creating contexts for exploration and learning of science concepts" (p. 782). This type of family support was evident in these students' accounts of their own engagement in science and resonates with the work of Louise Archer's group (e.g. Archer et al. 2012a, 2012b) who found that "families espoused cultural discourses that value science as an appropriate and desirable career route" (Archer et al. 2012a, p. 980). Family support, whether provided by parents or siblings, was important in helping to construct participants' identities both as females and [potential] scientists and facilitated their positive attitudes towards science. Zeldin et al. (2008) also described how support from family members and others buttressed female students' confidence to succeed in disciplines widely perceived as male-dominated.

In the Netherlands, only the "highest-achieving girls pursued" (p. 374) science and technology tertiary entrance classes in school (Korpershoek et al. 2010). In Western Australia, the low numbers of females taking tertiary entrance physics seems to mirror this phenomenon. Equally notable was the females' reticence to claim that the numerate sciences were "easy"; rather they enjoy the challenge and effort commonly associated with physics. Nevertheless, even for these most able female students, there was little sense of parity with their male peers. Comments such as "well, boys are just naturally good" and "I'm not sure I could do physics at uni" suggest that many still perceived a gender divide in favour of males with respect to achievement in physical and mathematical sciences, accounted for by natural ability, rather than effort (e.g. Tinklin 2003). Students also commented that they were frustrated by family members who viewed physics as a *boys' subject* and questioned their choice of subjects. With regard to the participants themselves, however, aspects such as effort, motivation and interest were common themes. What was particularly striking from the participants' comments was a strong work ethic and commitment to doing their very best at school.

Our results also suggest that female students' relationships with their peers were multifaceted and extended beyond attending classes together. Relationships among the female students influenced some participants to study physics and influenced others to stay in science. The students materially supported each other in physics and talked about physics even outside of class, sharing problems and working together. The students explained that they enjoyed the social aspect of being with friends. These findings were consistent with US research that found female students were more likely to take physics if they had female friends with higher grades in science (Riegle-Crumb et al. 2006). Specifically, for traditionally male subjects, such as physical science and mathematics, female students with female friends who excelled in science have a higher probability of enrolling in advanced science and mathematics classes. Our finding that peers and parents encouraged female students was also supported by a more recent study in Israel (Gabay-Egozi et al. 2014). While some females may have been friends before they started physics, others enjoyed their peers having something in common. Again, this finding was consistent with US females who described a high level of involvement with their female friends (Riegle-Crumb et al. 2006). Our participants' descriptions reflect cohesive social groups that work as resources for succeeding in physics.

Conclusions

Australia's international competitiveness, like that of many highly developed countries, is increasingly dependent on high-level, science-based technical skills, knowledge and innovation. This research provides teachers, policy-makers and educational researchers insights into science engagement for females. The unique contribution of this work is giving voice to the participants and hearing what these high-achieving females have to say about strong influences in their decisions to pursue science. These participants, purposively selected and representative of a best-case, had an abundance of support structures. On the surface it may seem as though they had a straightforward path into science. However, it is important to keep in mind that these participants continued with upper secondary school physics *despite* well-documented enrollment and attitudinal trends away from science. Along the way even these students encountered self-doubt, stereotypical attitudes and other potential barriers to continuing their engagement with science. It may be difficult for science educators to modify cultural and/or social influences such as those associated with the views of family members, but an emphasis on keeping science relevant and interesting can spark and sustain students' enjoyment and curiosity in science. The important role of competent and caring science teachers who make science engaging, relevant and fun should not be underestimated. We suggest that teachers and administrators be made aware of the fundamental importance of a school science culture with an emphasis on high expectations, academic focus and opportunities for students to excel. We also recommend that students, teachers and teacher educators know the benefits of working in social groups for mutual support.

Our findings in the current study are consistent with many previous studies, in that the decision-making picture that emerges around females' enrolment choices in science is complex and multifaceted. While this may not be a surprise, it does provide, in our view, a timely and valuable reminder to science educators, science teachers and policy-makers that simple fixes are unlikely to bear much fruit in improving female enrolment in secondary physical science. It is also a valuable reminder to these key stakeholder groups that knowledgeable, caring science teachers and supportive school science cultures are critical sine qua non factors in sustaining girls' interest and confidence in doing science at school. Lastly, in our view the development of a robust understanding around any intractable issue in education progresses as science does, with the careful accumulation of evidence from multiple studies in different settings and contexts. This study provides one more valuable piece of evidence on the path to improving the participation of girls in science.

Endnote

[1]Two-digit numbers within parentheses immediately following direct quotes indicate a particular participant. Student participant identifiers range from 01 to 18.

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Author details
[1]The University of Nottingham, Room B18 Dearing, Jubilee Campus, Wollaton Road, Nottingham NG8 1BB, UK. [2]Murdoch University, South St., Murdoch 6150, Western Australia.

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