Predicting adolescent girls' intentions to study science in senior high school

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Women continue to be under-represented in science fields in Australia and internationally. Efforts to fix the 'leaky pipeline' producing this inequality are frustrated by declining enrolments in higher-level school science subjects. Researchers and policymakers need a better understanding of the factors which influence girls' decisions to take science in senior high school. In this pilot study, we examined whether growth mindset in science, achievement goal orientation, self-efficacy, and perceived peer and teacher support influenced intentions to study senior biology, chemistry, and physics. Participants were 125 adolescent girls aged between 14-17 years living in Australia. Online surveys were used to gather demographic and attitudinal data in a cross-sectional design. Regressions were used to examine the psychological and social factors that predicted subject-selection intentions. Self-efficacy in biology and social support from science teachers positively predicted intentions to study biology. Endorsing a growth mindset in science positively predicted intentions to study chemistry and physics. Self-efficacy for learning chemistry and physics positively predicted intentions to study those subjects. The results suggest that girls who have greater confidence in their ability in science and endorse a growth mindset are more likely to continue their study of physics and chemistry in the senior years of high school.

Introduction

Attaining gender balance in STEM fields where women continue to be under-represented will produce higher quality research and increase productivity in those fields (Marginson, Tytler, Freeman & Roberts, 2013). For many girls, the decision to abandon STEM subjects occurs in the senior years of secondary school, when students first make subject selections. Recent figures show that fewer girls choose to study senior physics and advanced mathematics courses (Kennedy, Lyons & Quinn, 2014), and tend to be under-represented in groups that report very positive attitudes towards these subjects (Berger, Mackenzie & Holmes, 2020; Sheldrake, Mujtaba & Reiss, 2019). This limits the ability of these girls to pursue STEM careers and study at university level (Campbell et al., 2020). Thus, it is important to examine the factors that influence girls' decisions to take science subjects in the senior high school years. While many sociocultural, contextual, biological, and psychological factors may influence girls' decisions to pursue STEM subjects and careers (Holmes, Gore, Smith & Lloyd, 2018; Wang & Degol, 2013), individual and social factors are promising avenues for future intervention, given their potential malleability in school settings. In this study, we focused on three individual factors that are theoretically associated with girls' participation in science: self-efficacy, achievement goal orientation, and growth mindset. We also focused on two social factors: perceived support from peers and teachers.

Self-efficacy is an individual's perception of their competence (Bong & Clark, 1999), and is associated with girls' achievement, perseverance, and engagement in science (Britner, 2008). Evidence suggests that self-efficacy is subject-specific, and that self-efficacy in science subjects (i.e. biology, chemistry, and physics) should be conceptualised separately (Louis & Mistele, 2011). For example, research shows that academic self-concept, a related self-belief, varies by science subject (Jansen, Schroeders & Lüdtke, 2014). In the same study, girls were found to have lower self-concept than boys in physics and chemistry, but higher self-concept in biology. Self-efficacy is believed to influence subject selections by contributing to interest and achievement (Patrick, Care & Ainley, 2011), but the extent to which self-efficacy is differentially related to the pursuit of different science subjects is less understood.

Achievement goals describe the cognitive and affective states behind students' learning behaviours; namely, mastery goals for those aiming to *develop competence* in a task, and performance goals for students wanting to *demonstrate competence* relative to others (Berger & Archer, 2018). A further distinction is made between *performance-approach* goals, which manifest as a desire publicly to demonstrate superior ability compared to others, and *performance-avoid* goals, which indicate a desire to avoid unfavourable judgments when compared to others (Berger & Archer, 2016). In science subjects, achievement goals are related to achievement, self-efficacy, and anxiety in those subjects (Britner, 2008; Pajares, Britner & Valiante, 2000). Mastery goals are positively related to self-efficacy and performance-avoid goals are associated with science apprehension; thus, achievement goals serve an adaptive motivational function in science (Pajares et al., 2000). As students who endorse mastery goals are more likely to prefer challenging tasks (Ames & Archer, 1988), it is possible these students are also more likely to choose subjects perceived as more challenging (i.e. physics and chemistry). Similarly, students who endorse performance-avoidance goals may be more likely to opt-out of challenging subjects due to fear of negative evaluation (Britner, 2008). Despite this theoretical link between goal orientation and subject selections, we did not locate any studies that have examined whether goal orientations influence intentions to study biology, chemistry, and physics in senior high school. To date, research into science achievement goals has found that while there are no gender differences in achievement goal adoption when science is treated as a single domain (Pajares et al., 2000), girls perform better in science when teachers present assessment as mastery-oriented rather than performance-oriented (Souchal, Toczek, Darnon, Smeding, Butera & Martinot, 2014).

Girls' beliefs about their ability being fixed or malleable may also be significant in their uptake of traditionally male-dominated science subjects (Dweck, 2008). One hypothesis is that growth mindset may be protective if girls receive negative messages about their ability in STEM subjects (Hill, Corbett & St. Rose, 2010). Indeed, growth mindset is related to higher achievement, increased enjoyment of school, and higher self-efficacy (Blackwell, Trzesniewski & Dweck, 2007; Huang, Zhang & Hudson, 2019; Romero, Master, Paunesku, Dweck & Gross, 2014; Yaeger & Dweck, 2020). While research has found that growth mindset predicts taking more challenging mathematics subjects (Romero et al., 2014), it is unknown whether growth mindset in science is related to girls' intentions to study science in the senior years. Given that mindsets appear to be subject-specific (Scott & Ghinea, 2014), it is important to investigate this possibility.

Social factors are also involved in adolescents' science attitudes. Perceived social support is the perception that support is available if required (Bokhorst, Sumter & Westenberg). Adolescents may obtain support from a variety of different sources, and in school environments these sources may include classmates and teachers. Previous research suggests that perceived support is related to adolescents' school attitudes. For example, instrumental support from teachers is related to increased engagement in adolescents (Strati, Schmidt & Maier, 2017). Furthermore, peer support of achievement in science is positively related to adolescents' attitudes towards science (Stake, 2006). It has been postulated that social support for girls is especially important for motivation in subjects that are traditionally male-dominated (Leaper, Farkas & Brown, 2012; Riegle-Crumb & Morton, 2017). It is therefore critical to investigate the role of social support in girls' decisions about pursuing senior science and whether this varies for biology, chemistry, and physics.

The aim of this pilot project was to examine the role of individual differences and social processes in girls' intentions to study science in the senior years of high school. Specifically, we examined whether growth mindset, achievement goals, self-efficacy in science, and perceived social support influenced intentions to study biology, chemistry, and physics. We focused on girls in Years 9 and 10, which are the middle two years of high school in Australia. Students in Years 9 and 10 have studied high school science for two or three years respectively. In Australia, students make their senior school subject selections at the end of Year 10, and science subjects are not pre-requisites for entry to university courses.

Materials and methods

Participants

Participants were 125 girls from across Australia aged between 14-17 years (*M* = 15.37, *SD* = .61). The data were collected in October and November, 2018. In terms of social background, 6% identified as being of Aboriginal and/or Torres Strait Islander descent (Australia's indigenous peoples), 17.6% spoke a language other than English at home, 10.4% were born in a country other than Australia, and 71.2% had at least one university-educated parent. The sample is broadly representative of the Australian population of adolescent girls, with some exceptions (see Gore, Holmes, Smith, Fray, McElduff, Weaver & Wallington, 2017). The proportion of students who identified as Indigenous is comparable with that reported in a major sample of Australian adolescents (Holmes et al., 2018), although in both that study and our study, the proportions are higher than the 3% of the Australian population estimated by the Australian Bureau of Statistics (Gore et al., 2017). The proportion of students with at least one university-educated parent would appear to be high compared to the 31% of the Australian adult population with a degree qualification; however, it should be noted this varies widely by sub-national jurisdiction in Australia, with Chesters (2017) reporting that up to 69% of parents in the Australian Capital Territory have a Bachelor's degree or higher. This study was approved by the Human Research Ethics Committee (HREC) at Western Sydney University.

Measures

Growth mindset

Growth mindset in science was measured using eight items adapted from Dweck (1999). While the original scale measured implicit beliefs about ability in general, in this study the original items were varied to specifically measure implicit beliefs about ability in science, e.g. 'No matter who you are, you can significantly change your science ability level' (reflecting a growth mindset in science) and 'You have a certain amount of science ability, and you can't really do much to change it' (reflecting a fixed mindset in science). Participants were asked to identify the extent to which they agreed with each statement on a scale from 1 (strongly disagree) to 6 (strongly agree). Four items measured growth mindset and four items measured fixed mindset; the fixed mindset items were reverse coded. This scale demonstrated good internal reliability (Cronbach's □ = .90).

Achievement goal orientation

Trichotomous achievement goals were measured using three scales of three items each, namely mastery-approach (α = .84), performance-approach (α = .86), and performance-avoid (α = .84) adapted from Elliot and Murayama (2008). The original items were changed to measure achievement goal orientation in science, e.g. 'My goal is to learn as much as possible in science'. Participants were asked to rate the degree to which they agreed with each item on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Internal reliabilities were acceptable: α = .84 (mastery-approach), α = .86 (performance-approach), α = .84 (performance-avoid).

Perceived support from teachers and peers

Perceived support was measured by adapting the *Child and Adolescent Support Scale* (Malecki, Demaray, Elliott & Nolten, 1999). One subscale measured perceived support from science teachers (e.g. 'My science teacher(s) makes it okay to ask questions'; 'My science teacher(s) explains things that I don't understand') and the other measured perceived peer support in science (e.g. 'My science classmates help me with projects in class'; 'My science classmates give me ideas when I don't know what to do'). Each subscale included eight items, each measured using a Likert scale ranging from 1 (never) through 6 (always). The internal reliabilities of the teacher support and peer support subscales were α = .94 and α = .93, respectively.

Self-efficacy

Following Bandura's (2006) guidelines for measuring self-efficacy, self-efficacy regarding ability to learn biology, chemistry, and physics was measured by a single item for each subject in which participants were asked to rate their degree of confidence from 0 (cannot do at all) to 100 (highly certain can do).

Intentions to study science

Participants identified their intention to study biology, chemistry, and physics in the senior years by rating how likely they were to study these subjects using a Likert scale from 1 (very unlikely) to 5 (very likely). These items are provided in the Appendix.

Procedure

Participants were recruited to complete an online questionnaire administered via *Qualtrics* through paid *Facebook* and *Instagram* advertisements targeted at teenagers located in Australia. As participants were recruited directly and the research was low risk, parent/guardian consent was not sought. Instead, we obtained HREC permission to judge potential participants' capacity to understand the research and to consent for themselves using a mechanism in the questionnaire (see Friedman et al., 2016). Potential participants were provided with the participant information statement and asked whether they consented to participate in the research. They were then presented with two multiple choice questions about the participant information statement that tested their understanding of the voluntary nature of participation in the study, ability to withdraw at any time, minimal risk of experiencing discomfort, and the anonymous nature of data collection (e.g. "Is my being in this study voluntary?" Correct response: "My being in this study is voluntary and it is perfectly okay to not agree to participate or to quit in the middle of it"). Potential participants (n = 161) were given two opportunities to answer the questions correctly and needed to answer both correctly to proceed to the questionnaire proper. Potential participants who did not answer both questions correctly after two attempts were not permitted to begin the survey (n = 36). Thus, the success rate was 77.6%, with 125 girls proceeding to complete the survey.

Results

Analyses were conducted using IBM *SPSS Statistics Version 25*. All inferential tests are reported at a 95% confidence level and missing data was excluded pairwise.

Correlations

First, we used Pearson's correlations to examine the bivariate associations between variables (see Table 1). Biology intention was related to mastery-approach and performance-approach goals, perceived social support from science teachers, and self-efficacy in biology. Chemistry intention was related to endorsing a growth mindset in science, mastery-approach and performance-approach goals, perceived social support from science teachers, and self-efficacy in biology, chemistry, and physics. Finally, physics intention was related to endorsing a growth mindset in science, mastery-approach, performance-approach, and performance-avoidance goals, and self-efficacy in chemistry and physics. Chemistry intention was related to biology and physics intention, but physics intention was not related to biology intention.

Regressions

Next, we conducted three regressions (Table 2). Growth mindset, achievement goals, self-efficacy, and perceived support from teachers and peers were entered as predictors, and intentions to study biology, chemistry, and physics in the senior years were entered as dependent variables in each of the regressions.

Table 1: Correlations between study variables, means, and standard deviations

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Growth mindset	—											
2. Mastery approach	.15	—										
3. Perf. approach	.11	.54*	—									
4. Perf. avoid	.04	.19	.45*	—								
5. Teacher support	.06	.20*	.11	.13	—							
6. Peer support	.11	.11	.25*	.12	.20*	—						
7. Biology SE	.18	.42*	.24*	.05	.13	.01	—					
8. Chemistry SE	.15	.54*	.34*	.12	.26*	.09	.36*	—				
9. Physics SE	.04	.53*	.29*	.28*	.21*	.09	.13	.53*	—			
10. Biology intent.	.16	.21*	.26*	.09	.25*	-.01	.35*	.17	-.15	—		
11. Chem. intent.	.32*	.43*	.37*	.13	.26*	.14	.23*	.63*	.25*	.42*	—	
12. Physics intent.	.27*	.39*	.28*	.23*	.07	.16	-.05	.35*	.67*	-.02	.31*	—
M	4.70	4.36	4.35	4.01	4.67	4.17	83.77	78.04	68.40	3.73	3.96	3.02
SD	.86	.71	.75	1.00	1.03	1.08	13.16	19.70	24.83	1.53	1.49	1.67
n	125	112	112	112	111	110	112	112	112	112	112	112

Note. SE = self-efficacy; *$p < .05$

Table 2: Regressions predicting intentions to study biology, chemistry, and physics in the senior years of high school

Predictor	Biology intention			Chemistry intention			Physics intention		
	B	*SE*	□	*B*	*SE*	□	*B*	*SE*	□
Growth mindset	.18	.18	.10	.37	.14	.21*	.46	.15	.24**
Mastery approach	-.18	.27	-.09	.06	.22	.03	-.05	.25	-.02
Perf. approach	.50	.27	.25	.31	.21	.16	.13	.23	.06
Perf. avoid	-.05	.17	-.03	-.04	.13	-.03	.04	.15	.02
Teacher support	.33	.15	.22*	.13	.12	.09	-.17	.13	-.11
Peer support	-.17	.15	-.12	.02	.12	.02	.13	.12	.08
Subject SE	.03	.01	.29*	.04	.01	.51***	.05	.01	.66***
R^2		.22			.48			.52	
F for change in R^2		3.3**			10.8***			13.07***	

Note. SE = self-efficacy; * $p < .05$; ** $p < .01$; *** $p < .001$

The first regression was significant, accounting for 21.5% of the variance in biology intention, $R^2 = .22$, $F(7, 84) = 3.30$, $p = .004$). Self-efficacy in biology ($\beta = .29$, $p = .010$) and perceived social support from science teachers ($\beta = .22$, $p = .031$) positively predicted biology intention. The second and third analyses were also significant, accounting for 47.5% of the variance in chemistry intention, $R^2 = .48$, $F(7, 84) = 10.84$, $p < .001$) and for 52.1% of the variance in physics intention, $R^2 = .52$, $F(7, 84) = 13.07$, $p < .001$) respectively. Endorsing a growth mindset in science positively predicted the intention to study chemistry ($\beta = .21$, $p = .010$) and physics ($\beta = .24$, $p = .003$). Similarly, self-efficacy for learning chemistry positively predicted chemistry intention ($\beta = .51$, $p < .001$) and self-efficacy for learning physics positively predicted physics intention ($\beta = .66$, $p < .001$).

Discussion

In the context of ongoing concerns about girls' under-representation in STEM fields (Holmes et al., 2018), it is not known whether their implicit beliefs about ability (i.e. growth mindsets) are related to their intentions to continue studying particular science subjects in the senior years of schooling. The current pilot study was designed to address this gap in the literature. To our knowledge, ours is the first study to investigate the association between *science-specific* growth mindsets and girls' subject selection intentions. Indeed, we found that growth mindset positively predicted adolescent girls' intentions to study chemistry and physics, but not biology. This aligns with previous findings that growth mindset predicts participation in subjects perceived to be more difficult (Romero et al., 2014), and may shed light on the persistent gender disparities commonly observed in physics (Kennedy et al., 2014). Fostering a growth mindset in girls may provide a mechanism to support their aspirations for future study in traditionally male-dominated disciplines.

In previous studies, girls' self-efficacy in science subjects was found to be associated with adaptive attitudes and behaviours in those subjects (Britner, 2008). Our findings add to this picture by indicating a positive relationship between self-efficacy and intentions to undertake biology, chemistry, and physics. Pajares and colleagues (2000) observed a relationship between achievement goal orientations in science subjects and self-efficacy in those subjects. However, while we found mastery-approach and performance-approach goals were strongly correlated with self-efficacy and subject-selection intentions, these goals were not significant predictors of subject-selection intentions in the presence of the other variables entered into the models. These findings confirm the particularly important role of self-efficacy in girls' decisions to continue science in senior high school, particularly in physics and chemistry which had strong regression coefficients. For these two subjects, which are often perceived as more difficult, it also appears important for girls to have a growth mindset about their ability in science.

It has been argued that social support is important for girls' motivation in traditionally male-dominated school subjects (Leaper et al., 2012). While we found small but significant correlations (as might be expected theoretically) between perceived teacher support and mastery-approach goals on one hand, and perceived peer support and performance-approach goals on the other, these motivational orientations were not predictive of girls' intentions to take science subjects. Indeed, when analysed altogether, perceived teacher support only predicted intentions to take biology. It is possible, however, that the role of perceived teacher support varies for intentions to study different science subjects. For example, our correlation analysis indicates that teacher support was positively related to self-esteem in chemistry and physics. Given that self-esteem can be influenced by social messages (Chen & Usher, 2015), it is possible that the relationship between teacher support and intentions to study chemistry and physics are mediated by self-esteem. Future longitudinal research could investigate this potential relationship. Interestingly, perceived peer support was not a significant predictor of intentions to study any of the sciences, and was not correlated with self-esteem in any of the sciences. While previous research suggests that peer support is important for girls' attitudes and motivation in science

(Leaper et al., 2012; Stake, 2006), it did not emerge as a predictor of science subject intentions in this study.

While not a focus of our study, our correlation analysis also showed that intentions to study chemistry were positively related to intentions to study biology and physics. Intentions to study biology were not related to intentions to study physics, however. A similar pattern emerged in the relationships between girls' self-esteem in the different science subjects. This finding aligns with previous research that suggests that students' self-concepts are positively related in subjects that they perceive as being similar (Jansen, Schroeders, Lüdtke & Marsh, 2015).

Limitations and future research

There are several limitations to this preliminary study which may temper generalisability. First, the study was conducted with a relatively small, female sample. The large □ weight of performance-approach in biology but insignificant *t*-test suggests this variable might be important in the regression, but the small sample size prevented a clear determination. Second, the sample was self-selecting, online, and geographically-restricted to Australia. The self-selecting nature of the sample likely resulted in a greater proportion of participants with university-educated parents electing to complete the online survey. The purely online distribution of the survey also meant we relied on participant honesty in representing themselves as adolescent girls. While research has found participant recruitment via social media to be a "viable platform for social research" and that results likely "can be generalized to a larger population" (Rife, Cate, Kosinski & Stillwell, 2016, p. 69), we would still treat the generalisability of these results with caution due to the relatively small sample size. Finally, the outcome variables were planned rather than actual behaviours. Future research into girls' science intentions can address these limitations by (i) investigating whether intended subject selections align with actual subject-selection behaviours, (ii) use school-based recruitment strategies to avoid sampling biases and allow the confirmation of demographic information, and (iii) recruit a larger, possibly international, sample of adolescents, to allow greater generalisability of findings and gender differences to be investigated.

Conclusion

Despite these limitations, there are practical implications for teachers from these findings. It appears important for teachers to build self-efficacy and growth mindsets in science, especially during the middle adolescent years, if girls' enrolments in physics and chemistry are to be increased. While many interventions have been designed to fix the 'leaky' STEM pipeline, the influence of the daily interactions between teachers and their students cannot be understated as an important mechanism to enhance girls' growth mindset in science.

Teaching practices that support the development of growth mindsets, such as emphasising the capacity for each student to improve relative to their existing ability in science (Yaeger & Dweck, 2020), have the potential to support girls' continued participation in chemistry and physics. Also, it is vital that science instruction is structured so that girls experience regular success, as fostering the development of positive self-efficacy is a key factor influencing subject choice across all sciences. Our pilot study provides a timely insight into the role of individual and social factors in girls' intentions to study different science subjects in the senior years of high school, and provides support for continued research focus in this important area.

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Appendix

A scale for measuring student intentions to study science subjects in the senior years of high school

How likely are you to choose to study the following subjects in Year 11?

	Very unlikely	Unlikely	Neutral	Likely	Very likely
Biology	1	2	3	4	5
Chemistry	1	2	3	4	5
Physics	1	2	3	4	5

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