A gender perspective on the structure of adolescents' interest in science

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Abstract

It has repeatedly been documented that there are cross-sectional gender differences in adolescents' science interest, and these differences are often considered the main factor behind the gap in enrolment rates in higher education STEM programmes. Based on expectancy-value theory and interest theory, this study models interest and tests how self-efficacy and utility value predict science interest among male and female adolescents based on the PISA 2015 data set for Denmark. The results suggest that self-efficacy and utility value had a large predictive effect on science interest for both males and females. Despite the frequently pointed out gender differences in science interest, the multi-group analysis results only show a significant difference between males and females in the path through utility value. These findings indicate that beliefs about the utility value of science are more important for female adolescents' development of an interest in science than for their male peers. This implies a need for strategies for enhancing students' perceptions of utility value in science education.

Keywords: Interest, Motivation, Gender, PISA, Structural equation modelling

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Science interest drives lifelong learning in the sciences, prompting ongoing, voluntary, and self-motivated engagement, such as reading about science or visiting a science centre. Interest motivates deep engagement in learning tasks, leading to positive educational outcomes and career choices within the sciences (Ainley & Ainley, 2011a; Akkerman & Bakker, 2011). Research into adolescents’ interest in science is especially important in light of the large number of studies finding that students’ science interest declines while at school and identifying a significant gender gap (Archer et al., 2010; Bøe, 2012; Eccles et al., 1983; OECD, 2008; Osborne et al., 2003; Potvin & Hasni, 2014a, 2014b). This has led to concerns regarding the ability to recruit a sufficient number of students to Science, Technology, Engineering, and Mathematics (STEM) programmes in higher education, with a consequent shortage of skilled labour. This trend is often referred to as ‘the leaking STEM pipeline’ (Alper, 1993), although analyses of students’ trajectories have shown that the pipeline metaphor is misleading because it suggests a linear, single-direction movement and does not explain students moving in to as well as out of STEM trajectories (Lykkegaard & Ulriksen, 2019). Furthermore, females are heavily underrepresented in most areas of STEM education in more developed economies despite females having greater freedom in their choice of an educational and career pathway and face fewer constraints, both in terms of cultural norms and socioeconomic factors (OECD, 2008; Soylu Yalcinkaya & Adams, 2020).

In Denmark, the concern regarding students’ lack of interest in science has been prevalent for decades. International studies such as the ROSE study showed more than a decade ago that Danish adolescents do not perceive science as compatible with their interests. Female Danish adolescents, in particular, were more likely to express reservations about science than their peers in many other countries (Sørensen, 2008). However, the situation seems to be improving slightly: PISA 2015 showed that Danish students' interest in science was significantly greater than the average among the participating OECD countries - and considerably greater than in PISA 2006 (KORA, 2015). Moreover, 2021 enrolment figures for higher education STEM programmes show a seven per cent increase since 2017, while overall enrolment in higher education increased by three per cent over the same period. In addition, 16 per cent more females were enrolled in STEM programmes in 2021 compared to 2019. Thus, in the most recent figures, females make up 34 per cent of those admitted to STEM programmes, an increase of four percentage points since 2017 (UFM, 2021). However, these positive trends do not apply equally to all STEM disciplines. An international review by Potvin and Hasni (2014b), for example, found that physics and technology are more popular among males, whereas life and health sciences are often preferred by females.

According to Ainley and Ainley (2011a), science interest should not be considered as an isolated independent motivation variable, but as part of a series of mutually influential motivational processes. It is therefore an oversimplification to measure whether or not students have an interest in science. Expectancy-value theory highlights the importance of the relationship between expectancies for success and subjective task values, as together they predict motivation and performance, as well as future course enrolment and careers choices (Eccles & Wigfield, 2020). The literature suggests that one way to facilitate students' interest is to increase their perceived expectancy of success (Chen et al., 2016; Lent et al., 1994; Lent et al., 1993). One powerful way to enhance students' perceived expectancy of success is the use of feedback, as it is leads to further engagement with the task (Hattie & Timperley, 2007). However, even if students are certain they can master a science task, they may have no convincing reason to do so.

This is reflected by the fact that an average mathematics achiever with a science-related career interest is more likely to gain a bachelor's degree in the physical sciences or engineering than a high mathematics achiever with a non-science career interest (Tai et al., 2006). Where expectation of success is predictive of persistence and academic achievement, task value strongly predicts educational choices and enrolment decisions. Thus, another way to facilitate interest in science is to help students find meaning and value in such activities (Dewey, 1913; Harackiewicz et al., 2016; Hulleman & Harackiewicz, 2009). The individual's perception of a science task as useful in accomplishing future goals relevant to their life can promote deeper interest in the field, and interest may be a proximal motivator of career decisions (Harackiewicz et al., 2014). For example, a student might take a chemistry course to fulfil an admission requirement for a medical or a veterinary degree, with the experience of usefulness leading the student to develop an interest in chemistry.

This study seeks to build on previous analyses of the structure of science interest by Ainley and Ainley (2011a, 2011b). Based on PISA 2006 data, Ainley and Ainley modelled the relations between students' science knowledge, personal value of science and enjoyment of science as predictors of science interest in alignment with the four-phase model of interest development proposed by Hidi and Renninger (2006). According to Hidi and Renninger (2006), individual interest in a domain such as science involves having knowledge of and valuing science, and experiencing positive affect when engaged in science activities. Meanwhile, the analyses by Ainley and Ainley did not include perceived expectancy of success despite it being a strong predictor of interest (cf. Fryer & Ainley, 2019; Nuutila et al., 2020). This study, therefore, investigates how perceived expectancy of success and personal value of science predict adolescents' science interest. The approach is grounded in two supposedly complementary theories; expectancy-value theory (Eccles & Wigfield, 2020) and interest theory (Hidi & Renninger, 2006). Ainley and Ainley (2011a, 2011b) used structural equation modelling (SEM) to test a path model, which was run separately for four countries in order to test socioeconomic background influence on interest. For the current study, I have instead focused on gender differences regarding the structure of science interest among Danish adolescents, based on PISA 2015 data and using SEM multi-group analyses by gender to test the hypothesized model.

Adolescents' interest in science

Interest refers to the relation between a person and an object of interest, including positive feelings, a desire to explore and engage with the object of interest, and a sense that this object has personal meaning and value. Interest has both been conceptualised as a psychological state in terms of situational interest and as a motivation to reengage in a content-related activity in terms of individual interest (Renninger & Hidi, 2011). Situational interest refers to focused attention triggered by particular content or activities at a particular moment. By contrast, individual interest is a relatively enduring predisposition to actively reengage with particular forms of content. The four-phase model of interest development proposes that if situational interest is triggered repeatedly, the person can develop a more persistent disposition (Hidi & Renninger, 2006). From an educational perspective, it is therefore important that students repeatedly experience exciting, fun, challenging and meaningful learning activities in science lessons because such experiences can trigger situational interest, which over time can develop into an individual interest in science and thus motivate continued self-directed engagement with science (Palmer et al., 2017).

This study is concerned with individual interest, i.e. adolescents' more persistent dispositions towards science. The PISA 2015 framework operationalises science interest through two scales, *enjoyment of science* and *interest in broad science topics*. Additionally, the scale *out-of-school science-related activities* could also indicate students' interest because it concerns voluntary self-directed engagement with science content.

Enjoyment and interest are separate and complementary constructs (Ainley & Ainley, 2011b; Krapp & Prenzel, 2011). Interest is a multidimensional construct whose operational definition requires both cognitive and affective categories. The affective component of a person's interest is a positive valence and is related to feelings of enjoyment (Krapp, 2002). According to Krapp and Prenzel (2011), enjoyment can be felt for many reasons and is not in itself a sufficient condition for interest. For example, a student might experience enjoyment during a fun learning activity in a science lesson without being interested in the content. On the other hand, enjoyment can trigger situational interest if the topic or activity is simultaneously attributed personal significance (Deci, 1992). Enjoyment is frequently used as a proxy for interest and intrinsic motivation, due to the operational definitions. PISA operationalises the variable *enjoyment of science* in terms of 'have fun', 'like', 'happy', and 'enjoy', which is in alignment with the operational definition of interest and the affective dimension of validated scales for measuring individual interest (Linnenbrink-Garcia et al., 2010). It should be noted, however, that the scale term 'science' is a broad category with heterogeneous sub-disciplines in which adolescents may have different levels of interest. This is an obvious limitation of content validity which means that nuance differences are lost.

The second interest scale measures interest in broad science topics. As stated by Krapp and Prenzel (2011), an important aspect of the interest construct is its domain specificity. A number of studies have examined students' interest in a wide range of science topics. The ROSE study investigated 15-year-olds' attitudes towards science topics in 40 countries (Schreiner &

Sjøberg, 2004). Hoffmann (2002) and colleagues assessed students' perception of the interestingness of eight topics that were part of physics curricula in German schools. Such studies have provided insight into which topics students generally find interesting and which they find less interesting. Interest in a topic has been conceptualised as 'topic interest', i.e. an individual interest composed of positive feelings and the attribution of personal significance to a particular topic. However, topic interest and individual interest should not be conflated. Rather, topic interest is a subcategory of individual interest. Individual interest may refer not only to topics, but also to particular contexts (e.g. a science museum) and activities (e.g. inquiry-based laboratory work) (Hoffmann, 2002; Krapp & Prenzel, 2011).

The PISA scale *science activities* measures how often adolescents estimate they engage in various out-of-school science-related activities. Engagement is a multifaceted construct that includes observable behaviours, internal cognition, and emotions (Fredricks et al., 2004). Cognitive engagement is closely related to self-regulation, and individuals may regulate their activities by engaging in interest-enhancing actions (Sansone et al., 1992). Moreover, a state of flow includes the affective elements of such engagement (Shernoff et al., 2016). Adolescents who have an individual interest in science and enjoy participating in science-related activities are likely to seek to reengage with the interest domain at every opportunity. The scale *science activities* is therefore proposed as a measure of individual interest *in action* because it reflects the extent to which adolescents estimate they engage in such activities (watching TV programmes about science, for example).

Individuals' beliefs about their perceived expectancy of success have been conceptualised from a variety of theoretical perspectives, including but not limited to self-efficacy, self-concept, self-esteem, and outcome expectations (Marsh et al., 2019). The PISA 2015 framework operationalises expectancy of success as *science self-efficacy*, i.e. the strength of adolescents' belief in their ability to solve a science task based on their skills and circumstances. It is suggested that self-efficacy influences the goals that individuals set for themselves and their effort and task persistence (Bandura, 1998). In the PISA questionnaire, participants were asked 'How easy do you think it would be for you to perform the following tasks on your own?', followed by items such as 'Explain why earthquakes occur more frequently in some areas than in others'. Here, it is not a matter of assessing whether one is competent in geoscience in general, but how strongly an individual believes that they can successfully solve a specific task regarding earthquakes. According to Bandura (1998), self-efficacy has two dimensions: efficacy expectations, which are beliefs about whether one can effectively solve a task (as used by PISA); and outcome expectations, which refer to beliefs that a given behaviour will lead to a particular outcome. It has been argued that self-efficacy predicts interest development (Lent et al., 1994), and recent empirical studies suggest reciprocal links between self-efficacy and interest (Fryer & Ainley, 2019; Fryer et al., 2021). A meta-study has showed that interest and self-efficacy correlate more strongly in science and mathematics than in other subject areas (Rottinghaus et al., 2003), a finding that was more recently supposed by Bong, Lee, and Woo (2015). It therefore seems obvious to include science self-efficacy in the analysis of adolescents' science interest.

Personal value of science refers in broad terms to individuals' beliefs about their possible reasons for engaging in science-related tasks and activities. According to contemporary expectancy-value theory (Eccles & Wigfield, 2020), value beliefs comprise four distinct constructs: intrinsic value (perceived worth of a task due to enjoyment or interest); attainment value (perceived importance of a task for an individual's identity and self-worth); utility value (perceived usefulness of a task for accomplishing future goals relevant to an individual's life);

and cost value (negative aspects of engaging in a task, e.g., time costs). Based on expectancy-value theory, PISA operationalises personal value of science as utility value, i.e. as the extent to which science is perceived as relevant and useful for achieving an individual's current or future goals. Utility value can be characterised as extrinsic value beliefs, whereas the value-related valences of interest are intrinsic and directly related to the object of interest (Deci, 1992; Eccles & Wigfield, 2020). For example, if a student engages in science lessons not out of interest but in order to get good marks, then this student holds extrinsic value beliefs, which appear as extrinsic motivation because the distant goal is separable from the activity itself.

The four-phased model of interest development suggests that personal value may lead to a deeper interest (Hidi & Renninger, 2006), and a number of interventions focused on utility value have targeted students' interest development in science. These interventions seek to support students in connecting course topics to their lives in an intrinsically regulated way that promotes the development of interest. Utility-value interventions have been shown to have the greatest impact among students with low expectancy of success. For example, Hulleman and Harackiewicz (2009) randomly allocated high school science students to either write short essays about the usefulness of the course content for their own lives (intervention group) or write summaries of the course content (control group). Intervention group students reported greater interest in science and attained higher marks at the end of the term than students in the control group, but only if they began the intervention with low expectations of success. In a more recent study, however, Canning, Priniski, and Harackiewicz (2019) found negative interest development among biology students with low initial expectations of success, indicating utility-value interventions may be linked to increased perceived task difficulty and thus lower levels of perceived utility value.

In their analyses, Ainley and Ainley (2011b) found that personal value is an important predictor of students' interest in science, participation in science and motivation to participate in science in the future. Thus, utility value was included in the article's modelling of adolescents' science interest.

A gender perspective on adolescents' individual interest in science

Over the last four decades, cross-sectional gender differences have been repeatedly documented in mean levels of science interest. These differences are often considered the main factor behind the gender gap in enrolment rates in higher education STEM programmes (Ceci & Williams, 2011). However, these gender differences in mean levels of science interest are largely domain-dependent. While adolescents' individual interest in life and health science topics is equally (or more) pronounced among females as males, this is not the case for physics (Krapp & Prenzel, 2011; Potvin & Hasni, 2014a). In the ROSE survey, students were asked which science topics they want to learn more about. The findings showed that females would like to learn about health aspects and the human body, whereas males want to learn about the dramatic aspects of physics and technology (Schreiner & Sjøberg, 2004). According to Hoffmann (2002), females attribute value to references to mankind, social involvement, and the practical applications of theoretical concepts in physics. Hoffmann and her colleagues found that females are highly sensitive to context. This aspect has recently been conceptualised in terms of communal utility value, which refers to the degree to which a domain or activity is perceived as involving working with others, helping others, or serving humanity (Brown et al., 2015; Diekman et al., 2011). Thus, utility value can be either personal (self-oriented) or communal (other-oriented). Interventions have demonstrated that highlighting the inherent communal utility value of science, such as how science careers can serve humanity, develops interest in science among both male and female students (Brown et al., 2015; Shin et al., 2019). The findings suggests that female students' identification with science may be enhanced when the communal utility value of science is made explicit.

Although the causes of gender differences in science interest are complex, two overarching reasons are highlighted in the literature. The first regards gender-based stereotypes and bias. The so-called 'hard' sciences are characterised by a masculine culture in terms of beliefs, norms, and values, which interferes with the development of female gender identity and can lead females to feel less of a sense of belonging and thus interest (Carlone et al., 2014; Le & Robbins, 2016; Soylu Yalcinkaya & Adams, 2020; Su et al., 2009). Low communal utility value is likely a barrier to female science identity (Smith et al., 2015). The second reason relies on gender gaps between females' and males' perceptions of their own abilities and expectancy of success, suggesting that females consistently underestimate their science ability (Cheryan et al., 2017; Sikora, 2019). Evidence indicates that male students have greater belief in their ability in chemistry and physics than their female peers, even after controlling for achievement, whereas female students' perceptions of own ability in physics, and to a lesser degree, chemistry do not correspond with their ability as measured by marks and test scores (Jansen et al., 2014).

Research questions

Based on the reviewed literature, this study models interest and tests how self-efficacy and utility value predict interest for male and female adolescents, thus providing a more in-depth understanding of the variations and nuances between male and female adolescents' perceived expectancy of success, perceived usefulness of science, and interest in science. The research questions were: (1) To what extend does utility value and self-efficacy predict students' enjoyment of science, interest in broad science topics, and engagement in science-related activities? (2) Are there gender differences in how utility value and self-efficacy predict interest?

Materials and methods

Data source and sample

PISA measures 15-year-olds' ability to use their reading, mathematics and science knowledge and skills to meet real-life challenges - regardless of specific curricula. This study used the PISA 2015 student questionnaire data set for Denmark. The Danish part of the PISA assessment took place in schools and was not conducted by teachers, but under the supervision and guidance of trained test administrators from Statistics Denmark's interview corps. In each country, schools and students were selected using a two-stage sampling design. First, a fixed number of schools were drawn from among all the country's schools with 15-years-old students enrolled. The schools were drawn with a probability that is proportional to the number of students in the target group. A fixed number of students from each school were subsequently selected at random. This analysis is based on a sample of 4,869 Danish students, of which 2,539 were females and 2,330 were males.

Procedure and measures

The cognitive assessment was conducted in half-hour bundles of, which were organised and rotated such that each student completed a two-hour PISA test. In addition, each student completed a contextual questionnaire that featured 54 derived variables, both simple questionnaire indices and scaled variables dealing with a range of attitudinal measures including enjoyment of science and science interest. Scales were designed in collaboration with a number of international expert groups and reviewed by national project managers from all participating countries. The validation process included field trials in each country. Field trials and main survey data were analysed within each country to examine dimensionality of scales, as well as to identify differential item functioning (DIF) among countries. Cronbach's alpha was used to check the internal consistency of each scale, and invariance measures of item parameters across countries and languages within a country were conducted (for details, refer to the 'Technical report' from PISA 2015). For further validation of this study, I used Rasch models to validate each latent variable, sometimes showing that an item had to be deleted. Rasch analyses were performed with the statistical package Test Analysis Modules (TAM) in R.

Variables

Five latent variables and two observed variables were investigated in this study. The items can be seen in Table 1. The variables are delineated as follows:

Enjoyment of science (ST94).

Enjoyment of science is a five-item scale, asking students to respond on a four-point Likert scale with the categories 'strongly agree', 'agree', 'disagree', and 'strongly disagree'.. The reliability (Crobach's alpha) was 0.96.

Interest in broad science topics (ST95).

The measure of interest in science asked participants 'To what extent are you interested in the following <broad science> topics?' The listed topics were the biosphere, motion and forces, energy and its transformation, the universe and its history, and how science can help prevent disease. Students declared their interest on a five-point Likert scale with the categories 'not interested', 'hardly interested', 'interested', 'highly interested', and 'I don't know what this is'. The last category was recoded as missing. The item regarding preventing disease did not fit the expectations of a Rasch model and was excluded from further analysis. The reliability for the four-item scale was then 0.79.

Science activities (ST146).

Students´ science activities is a measure of science-related dispositions. Students were asked how often they engaged in science-related activities on a four-point scale with the response categories ‘very often’, ‘regularly’, ‘sometimes’, and ‘never or hardly ever’. Responses were recoded so that higher engagement corresponded to higher value. Four items were removed as they did not fit the expectations of a Rasch model. The reliability for the five-item scale was 0.85. It should be noted that the variable measures participants’ assessment of how often they engage in science - not their actual engagement.

Utility value (ST113).

Four items were used to measure utility value expressing ways that science had personal utility value for the respondent, with the response options ‘strongly disagree’, ‘disagree’, ‘agree’, and ‘strongly agree’. The responses were recoded so that high scores represent higher levels of utility value. The reliability of the scale was 0.93.

Science self-efficacy (ST129).

The measure of science self-efficacy asked participants to rate how they would perform in different science tasks, using a four-point scale with the categories ‘I could do this easily’, ‘I could do this with a bit of effort’, ‘I would struggle to do this on my own’, and ‘I couldn’t do this’. Responses were recoded so that high scores correspond to higher levels of science self-efficacy. The reliability of this eight-item scale was 0.88.

Socio-economic status (ST013).

The PISA 2015 index of social, economic and cultural status consists of indicators of parental education, highest parental occupation, and home possessions (for details, refer to the ‘Technical report’ for PISA 2015). For Denmark, however, reliability for this index was not acceptable. This can be largely attributed to the many dichotomous variables or variables with few outcomes. Thus, the single item on students' self-reported number of books in the family home was used as a proxy for social, cultural, and economic background (Engzell, 2019). Students responded on a six-point scale with the response categories '0-10 books', '11-25 books', '26-100 books', '101-200 books', '201-500 books', and 'more than 500 books'.

Gender (ST004).

This item asked participants whether they are a girl or a boy. PISA does not provide the opportunity to identify oneself as non-binary, nor the opportunity to respond 'would rather not disclose'. For the Danish PISA data set, missing answers to the gender item were imputed by data provided from Statistics Denmark, based on civil registration number data.

Analysis

First step in the analysis was descriptive statistics. The non-parametric Wilcoxon signed-rank test was used to compare the median of males' and females' responses to the individual items. The aim was to reveal gender differences for each item and variable. Then I calculated zero-order correlations for the latent variables for males and females. Zero-order correlation refers to the correlation between two variables without controlling for the possible influence of other variables. The purpose was to confirm the relationship between the five latent variables on which the structural model was to be built.

Structural equation modelling is a multivariate method used to test hypotheses regarding the influences among interacting variables. The model assumption is based on the theoretical relations between the latent motivational constructs, as previously described. Socio-economic status is at a different causal level than the motivational variables, as the influence can only go one way. Thus, the number of books in the family home will be predictive of science self-efficacy and utility value, which in turn will be predictive of enjoyment of science, science interest and engagement in science activities.

All modelling was done with AMOS 27, using the maximum-likelihood algorithm. The first step was confirmatory factor analysis (CFA) to confirm the five latent variables and develop an acceptable measurement model. Next, I developed a structural model to examine directional interrelations among the five latent constructs and the observable background variable. A multi-group SEM approach was applied in order to examine invariance of specific structural path coefficients between males and females.

Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA) examined the models' goodness-of-fit along with the χ^2 statistic. For an acceptable fit of the model to the data, and to satisfy construct validity, cut-off values of 0.95 (CFI), 0.95 (TLI), and 0.06 (RMSEA) were used in the analysis (Hu & Bentler, 1998). Interpretations of the ß-coefficient results followed Keith's (2014) recommendations: betas below 0.05 are considered 'too small to be considered meaningful'; those between 0.05 and 0.10 as 'small but meaningful'; those between 0.10 and 0.25 as 'moderate' and those above 0.25 as 'large'.

Results

The Wilcoxon Signed Rank test for gender differences on scales and items is shown in Table 1. Whereas females report significantly more books in their home compared to males, males report significantly more science self-efficacy, enjoyment of science, interest in broad science topics, and science activities than females. The mean levels of utility value were equal among males and females.

Correlations between each of the five latent variables for males and females are presented in Table 2. As shown, all variables are positively correlated with one another.

[Insert Table 1 around here]

[Insert Table 2 around here]

To answer the first research question, standardised regression weights from the structural equation model were analysed. The resulting model showed a good fit to the data ($\chi^2 = 3433.93$, $p < .000$, $df = 614$, CFI = .97, TLI = .96, RMSEA = .03). Because the sample size is large, the chi-square statistic provides a poor measure of fit and may be regarded as of limited importance. Taking the main paths in the model separately (Table 3), it is evident that socio-economic status had a small direct effect on adolescents' utility value but a large effect on their science self-efficacy. Both self-efficacy and utility value had a large predictive effect on science interest in terms of enjoyment of science, interest in broad science topics, and science activities. The strongest path in the model links science self-efficacy with enjoyment, which in turn is linked to science activities through interest in broad science topics. The strength of the paths can be seen in the size of the squared multiple-correlation coefficients. The model explains between 17 and 50 percent of the variance in the respective science interest scores for males and females.

[Insert Table 3 around here]

To answer the second research question, critical ratio for difference (C.R.) was calculated among all pairs of free parameters between female and male data sets. The critical ratio is the difference between the parameters divided by the estimated standard error of the difference. Under appropriate assumptions and with a sufficient sample size, the critical ratio resembles a standard normal distribution. Thus, a value of 1.96 or higher indicates two-sided significance at the .05 level. Table 3 shows no significant gender-based differences in the measured parameters

– except for a significant difference between males and females in how utility value predicted enjoyment of science (C.R. = 2.03, $p < .05$).

Discussion

The aim of this study was to complement Ainley and Ainley's (2011a, 2011b) analyses and thus contribute to the growing understanding of the structure of adolescents' science interest. Even though this study was limited to a single-country sample, the findings have general cogency for practice as they complement previous research from a number of countries (Ainley & Ainley, 2011b; Bong et al., 2015; Hulleman & Harackiewicz, 2009; Shin et al., 2019).

It is intriguing that despite small mean-level differences in science self-efficacy between males and females, as shown in Table 1, the predictive impact on interest is not biased against females. Thus, when males and females experience that they master the subject matter, there is an equally high probability that they enjoy and are interested in the topic and will reengage with the content (Bong et al., 2015). This is illustrated by the strong path that connects science self-efficacy through enjoyment of science to interest in broad science topics and science activities. However, since enjoyment of science is not specified in domains, it is possible that males and females have imagined different subject areas. As the literature suggests, females have a preference for biology and it seems obvious that they may have thought about biology rather than physics when they were prompted with the terms 'have fun', 'like', 'happy', and 'enjoy' science. The strong direct effect of socio-economic status on this path feeds into ongoing discussions about the impact of science capital on science interest, efficacy beliefs, and educational success (Archer et al., 2015; Turnbull et al., 2020). Through capital and habitus, families may foster values, attitudes, expectations, and behaviours in children that promote academic achievement and efficacy beliefs (Jæger & Møllegaard, 2017).

Perhaps the study's most important finding is the gender difference in how utility value predicts interest. This difference suggests that beliefs about the utility value of science are more critical for female adolescents' interest development than for that of males. This finding is consistent with evidence from utility-value interventions and research in science classrooms (e.g. Hulleman & Harackiewicz, 2009; Shin et al., 2019). It should be noted that the PISA items regarding utility value are clearly self-oriented (cf. Brown et al., 2015; Diekman et al., 2011) as they target individuals' future career goals (e.g. 'making an effort in my <school science> subject(s) is worth it because this will help me in the work I want to do later on'). It is conceivable that respondents, especially females, have attributed communal utility value to these items if they consider upper secondary science as a necessary prerequisite for their aspirations of a health career, such as medicine or pharmacy, as reported by Bøe (2012) and Miller, Slawinski, and Schwartz (2006).

This article's jumping-off point was adolescents' declining interest in science. As Ainley and Ainley (2011a) point out, it is too narrow to consider interest as an isolated motivational variable. This study shows that self-efficacy and utility value have a powerful effect on science interest. At the same time, the findings also indicate that students with low science self-efficacy may experience less enjoyment of and interest in science – even if they regard science as important for their lives. Thus, the implications for practice involves strategies for enhancing students' self-efficacy and perceptions of utility value. Bandura (1998) has proposed that self-efficacy cues are mastery experiences, vicarious experiences, verbal persuasion, and physiological cues. The most influential of these is mastery experiences, which refer to pervious performances and interpretations of performance outcomes as successful or not. If successful, the individual will develop efficacy beliefs when performing similar activities in the future. Science curricula are usually designed to develop students' self-efficacy through mastery experiences, and science teachers can apply principles of mastery experiences by presenting content in ways students understand, tailoring instructional presentations to individual differences in learning, and providing feedback on learning progress and linking rewards with progress (Britner & Pajares, 2006). However, it can be challenging for teachers to match the academic level of each student within every science lesson. Another important principle of motivated learning is therefore to point out the relevance and usefulness of science content for students' lives. Utility value is an extrinsic belief and thus highly amenable to external influence and initiatives. Thus, teachers may influence students' perceptions of utility value through simple initiatives, and these perceptions of utility may in turn stimulate interest development. In upper secondary physics, for example, applications and social issues concerning radioactivity can be discussed, such as nuclear medicine, in order to illustrate how radioactivity can help humanity. The perhaps most important message to teachers is to help students find meaning and relevance of science content for life and human society.

Limitations

This study has certain limitations, meaning that the conclusion should be considered tentative. Importantly, this study was limited to a single-country sample. As illustrated by Ainley and Ainley (2011a, 2011b), country-specific differences may exist regarding predictors of science interest. The PISA data were entirely self-reported, and the findings are limited to cross-sectional data. Furthermore, the analytical approach has some methodological limitations, as predictions are not the same as causal relationships. Interpretation of standardised regression coefficients is dependent on an accurately specified model because changing a single predictor could affect all other coefficients and thus their interpretations (Courville & Thompson, 2001). In addition, specific critiques of the PISA scales can be highlighted. First, despite representing a similar range of socioeconomic backgrounds, females tend to report a greater numbers of books in the family home in PISA (Engzell, 2019). This suggests a risk of endogeneity and bias in the model. Second, the omitted item preventing disease was the only item where females expressed significantly more interest than males. The analysis showed that if this item were retained, mean values of the variable interest in broad science topics would have been equal in males and females. The removal, however, had no effect on the paths in the structural model nor the critical ratio for difference between female and male data sets. Nevertheless, the removal constitutes loss of diversity. Third, regarding the measure of enjoyment of science, the term 'science' is a broad category with heterogeneous sub-disciplines in which adolescents may have different levels of interest. We cannot know for sure if the adolescents have thought of all the sub-disciplines or if they just assess what they like best. The result must therefore be regarded as a generalization. However, the strong correlation between this variable and specific sub-domains in the interest in broad science topics variable indicate that the loss of nuances may not be critical.

Conclusion

Consistent with evidence from utility-value interventions and research on self-efficacy, the findings emphasise the strong power of science self-efficacy and utility value for adolescents' science interest. The results provide information to practitioners about the importance of female adolescents in particular being able to see the usefulness of science in order to develop an enjoyment of and interest in science. This information contributes to the growing insight into how relevance and utility are important for interest development and can be used to design intervention programmes for adolescents.

Data availability statement

The data that support the findings of this study are openly available in in the OECD PISA 2015 Database: http://www.oecd.org/pisa/data/2015database/

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Tables

Table 1

Descriptive statistics with Wilcoxon Signed Rank test for gender differences on scales and items

Item	Female: *M* (SD)	Male: *M* (SD)	Z-value
Utility value (ST113)	2.71 (.83)	2.70 (.83)	-0.75
Making an effort in my <school science> subject(s) is worth it because this will help me in the work I want to do later on	2.76 (.93)	2.71 (.93)	-1.780
What I learn in my <school science> subject(s) is important for me because I need this for what I want to do later on	2.75 (.94)	2.75 (.93)	-.118
Studying my <school science> subject(s) is worthwhile for me because what I learn will improve my career prospects	2.76 (.90)	2.74 (.90)	-.737
Many things I learn in my <school science> subject(s) will help me to get a job	2.59 (.89)	2.59 (.91)	-.034
Science self-efficacy (ST129)	2.68 (.70)	2.89 (.67)	-10.63***
Recognise the science question that underlies a newspaper report on a health issue	2.90 (.83)	3.01 (.80)	-4.238***
Explain why earthquakes occur more frequently in some areas than in others	3.20 (.84)	3.33 (.80)	-5.625***
Describe the role of antibiotics in the treatment of disease	2.53 (.94)	2.70 (.91)	-6.309***
Identify the science question associated with the disposal of garbage	2.47 (.94)	2.76 (.87)	-10.857***
Predict how changes to an environment will affect the survival of certain species	2.76 (.98)	2.92 (.90)	-5.372***
Interpret the scientific information provided on the labelling of food items	2.81 (.93)	2.95 (.88)	-5.372***
Discuss how new evidence can lead you to change your understanding about the possibility of life on Mars	2.50 (.98)	2.84 (.93)	-11.785***
Identify the better of two explanations for the formation of acid rain	2.27 (.99)	2.61 (.96)	-12.153***
Enjoyment of science (ST94)	2.68 (.79)	2.74 (.83)	-2.67**
I generally have fun when I am learning <broad science> topics	2.71 (.86)	2.77 (.91)	-2.238*
I like reading about <broad science>	2.54 (.85)	2.60 (.89)	-2.434*
I am happy working on <broad science> topics	2.66 (.85)	2.74 (.88)	-3.213**
I enjoy acquiring new knowledge in <broad science>	2.70 (.86)	2.77 (.89)	-3.142**
I am interested in learning about <broad science>	2.79 (.85)	2.81 (.89)	-1.062
Interest in broad science topics (ST95)	2.56 (.71)	2.76 (.75)	-10.01***
Biosphere (e.g. ecosystem services, sustainability)	2.33 (.90)	2.36 (.90)	-1.258
Motion and forces (e.g. velocity, friction, magnetic and gravitational forces)	2.42 (.90)	2.83 (.95)	-14.439***
Energy and its transformation (e.g. conservation, chemical reactions)	2.44 (.95)	2.76 (.95)	-11.562***
The Universe and its history	3.04 (.95)	3.08 (.97)	-1.383
Science activities (ST146)	1.60 (.57)	1.78 (.68)	-9.27***
Watch TV programmes about <broad science>	1.86 (.76)	2.13 (.86)	-10.799***
Borrow or buy books on <broad science> topics	1.31 (.62)	1.39 (.72)	-4.691***
Visit web sites about <broad science> topics	1.76 (.80)	1.96 (.90)	-8.111***
Read <broad science> magazines or science articles in newspapers	1.54 (.76)	1.75 (.88)	-8.603***
Follow news of science, environmental, or ecology organizations via blogs and microblogging	1.53 (.80)	1.66 (.89)	-5.306***

Note: *$p < .05$. **$p < .01$. ***$p < .001$.

Tables

Table 2

Descriptives and correlations between scales used to test the model of the structure of interest for females and males.

		1	2	3	4	5
Females:						
1	Utility value					
2	Science self-efficacy	.27**				
3	Enjoyment of science	.44**	.43**			
4	Interest in broad science topics	.37**	.47**	.62**		
5	Science activities	.31**	.44**	.45**	.43**	
	M	2.71	2.68	2.68	2.56	1.60
	SD	.83	.70	.79	.71	.57
Males						
1	Utility value					
2	Science self-efficacy	.26**				
3	Enjoyment of science	.34**	.38**			
4	Interest in broad science topics	.31**	.42**	.63**		
5	Science activities	.31**	.41**	.38**	.36**	
	M	2.70	2.89	2.74	2.76	1.78
	SD	.83	.67	.83	.75	.68

Note: $^{**}p<.01$

Tables

Table 3

SEM multi-group comparisons between female and male data sets for pathway strengths (ß)

Independent variables		Dependent variables	Female	Male	C.R.
Number of books	→	Utility value	.08	.10	-.58
Number of books	→	Science self-efficacy	.27	.26	-.22
Science self-efficacy	→	Enjoyment of science	.38	.35	.70
Utility value	→	Enjoyment of science	.36	.27	2.03*
Enjoyment of science	→	Interest in broad science topics	.69	.67	.29
Interest in broad science topics	→	Science activities	.51	.42	.75
		Enjoyment of science R^2	.35	.24	
		Interest in broad science topics R^2	.47	.50	
		Science activities R^2	.26	.17	

Note: All beta-weights were significant at the .001 level. C.R. = critical ratio for difference between female and male data sets. *$p<.05$