Role of Interest and Self-Concept in Predicting Science Aspirations: Gender Study

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Abstract

According to previous theories and studies, interest and self-concept at an early age have played a pivotal role in occupational choices, especially in the fields of science, technology, engineering, and mathematics. However, a causal relationship between interest, self-concept, and aspirations in science is still under debate. In addition, few studies have focused on gender differences in these relationships. Therefore, this study aimed to explore the relationships between interest and self-concept in predicting science aspirations between ages 13 and 16 at lower-secondary school, considering gender differences. For the analyses, we conducted cross-lagged modeling and multi-group structural equation modeling in order to examine interrelationships between interest, self-concept, and science aspirations. According to the results, students' self-concept was high and stable, while interest was low but increased significantly during the lower-secondary school phases. However, there were no reciprocal relationships between interest and self-concept in predicting students' science aspirations. Interestingly, while girls' interest was indicated as a sound predictor of aspirations in science, girls' self-concept had no predictive influence on aspirations. Possible interpretations and implications of the study for lower-secondary science education are discussed.

Introduction

Students' declining interest in pursuing science-related careers has been highlighted in the science education community, since this may weaken the science, technology, engineering, and mathematics (STEM)–related workforce (e.g., Subotnik et al. 2009). In addition, students' lack of science interest has been discussed in terms of the future population being equipped with scientific literacy (e.g., Choi et al. 2011). Recent studies repeatedly reported that this negative trend of interest and aspirations in science has occurred during the lower-secondary school years (Hong and Lin 2011; Potvin and Hasni 2014a; Sorge 2007), especially among

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girls (Barmby et al. 2008). Although no clear mechanism has been revealed explaining influential factors on students' career decisions, several theories and studies point to two constructs that may play pivotal roles in students' future aspirations in science: *interest* and *self-concept* (Bong et al. 2015). According to the expectancy-value theory (EVT), for instance, a person's choice of career is affected by expectancies of success (self-concept) and subjective values, and the latter part is made up of four constructs, including interest as an intrinsic value (Eccles et al. 1983; Wigfield and Eccles 2000). Similarly, the social cognitive career theory (SCCT) (Lent et al. 1994) suggests that one's competency belief in certain tasks influences task-related interest, and eventually one chooses a profession in which one has relatively high competence and interest in a specific field. Accordingly, these two constructs have gained much attention and have been used in predicting students' educational and career choices in science education (Kang and Keinonen 2017; Tytler 2014). Although a lot of research and theories have revealed interdependence between interest and self-concept, the causal relationship between interest and self-concept is still under debate (Bong et al. 2015). For instance, some longitudinal cross-lagged modeling studies indicate that competency beliefs result in interest development (e.g., Marsh et al. 2005), while other studies reveal that both are heavily dependent on each other (e.g., Bong et al. 2015) or that a relationship between the two constructs is absent (e.g., Potvin et al. 2018). In addition, the role of gender has not been rigorously discussed in exploring the relationship between interest and self-concept, which may play a significant role in predicting science aspirations (Potvin et al. 2018). Therefore, this study aimed to explore the causal relationship between interest and self-concept in predicting students' science aspirations, taking gender differences into account using a longitudinal data set.

Role of Self-Concept and Interest in Promoting Science Aspirations

Young learners start to think of their future careers at around the age of 11 or 12 (Nurmi 2005). While growing up, they measure the probabilities of their success in future careers based on their sense of self, such as the self-concept, in order to select careers that are suited for their success (Marsh and Yeung 1997). Self-concept in broad terms refers to students' perceptions of themselves, and it generally consists of two components: *academic* and *nonacademic* (Shavelson et al. 1976). While the *academic* component covers one's self-concepts specific to general school subjects, *nonacademic* self-concepts include social, emotional, and physical self-concepts (Marsh and Craven 2006). These multiple dimensions of self-concept somehow correlate with each other, but the mean correlation among them is weak, at less than 0.10 (Marsh and Shavelson 1985). In addition, a lot of research has shown that students' achievements in particular school subjects such as science or mathematics were greatly affected by academic rather than nonacademic self-concept (e.g., Marsh 1992; Kang and Keinonen 2017). Furthermore, other studies indicated that students' self-concept of, for instance, science ability increased the aspiration for student engagements in further study or work in that field (Guo et al. 2017; Kang and Keinonen 2017; Sahin et al., 2017). Thus, in this study, we focus on students' *academic* self-concept in science and its relationship to interest and future aspirations in science.

Self-concept is influenced by environmental reinforcement or a significant other (Shavelson et al. 1976); that is, self-concept "is heavily influenced by social comparison" (Bong and Clark 1999, p. 139). At school, for instance, self-concept is likely to be acquired by successful learning experiences such as high marks in science subjects compared to other students (Lent et al. 1994). Interestingly, recent studies indicate that one's perceived competence plays a

stronger role than actual abilities in pursuing a science career (Bong and Skaalvik 2003; Bong et al. 2015; Sax et al. 2015). That is, students are likely to choose science careers based more on their perceived academic ability than on actual academic achievement, although the perception is derived mainly from achievement. The latest international studies, such as PISA (Programme for International Student Assessment) or TIMSS (Trends in Mathematics and Science Study), have reported that the performance gap between girls and boys has decreased to a negligible level, and in some countries like Finland, girls outperformed boys (Martin et al. 2016; OECD [The Organisation for Economic Co-operation and Development] 2016). However, boys are more likely than girls to have a high self-concept in science, while self-concept indicated a positive association with a science-related career expectation (OECD 2016). Therefore, the lower number of women in science-related occupations is likely to be more related to perceived competence in science rather than actual competence or high marks (Sax et al. 2015). One reason that may explain the superiority of perception to actual ability in predicting career aspiration is that this self-belief is related not only to past achievement but also to personal and cultural backgrounds and inputs such as gender, race, and predisposition (Lent et al. 1994). For instance, Britner (2008) reported that although students' performance was one of the sound predictors of self-concept, "social persuasions, vicarious experiences, and physiological states were better predictors of science self-efficacy" (p. 955).

Accordingly, several social psychology and cognitive theories point out the importance of self-concept in one's occupational development and choice. Eccles' EVT (Eccles et al. 1983), founded in social psychology, explains factors affecting people's motivational behavior such as occupational choices. The EVT model emphasizes the role of social, psychological, and cultural factors in (trans)forming individuals' expectation of success and subjective task value that, eventually, predict choice, persistence, and performance. Subject task value is subdivided into attainment value, utility value, relative cost, and interest which will be discussed in the following section. On the other hand, expectation of success refers to students' beliefs about how well they will do on upcoming tasks. The EVT model is based upon a premise that belief in one's own ability influences achievement choices directly (Wigfield and Eccles 2000). This explains why students with a high self-concept in science aspire more to science-related coursework (Guo et al. 2017), STEM majors in college (Sahin et al. 2017), and science careers (Kang and Keinonen 2017). Bandura's Social Cognitive Theory (SCT) (Bandura 1986) and Lent and his colleagues' SCCT (Lent et al. 1994) also highlight the role of self-concept in future goal-setting and action. The core components of the SCT and SCCT are self-efficacy, outcome expectations, and goals that are intricately linked with contextual factors and personal inputs. For instance, self-efficacy is assumed to derive from performance accomplishments, vicarious experiences, verbal persuasion, and physiological and emotional states (Bandura 1986). Also, both theories posit that one's goals and actions are strongly tied to self-efficacy. That is, students tend to set goals based on their perceptions of their capabilities. Using the SCCT model, Lent et al. (1994) suggested a causal relationship among learning experience, self-concept, interest, and goals. For instance, a student who gets a good grade in science will have a belief in their ability to master science tasks. This positive self-concept in science will then affect their interest in and aspiration toward a science career.

In addition to self-concept, interest is one of the key affective components in educational research, for it has been indicated as a sound predictor of student achievement in the topic area, further engagement in advanced subject courses, and future career aspirations (Ainley & Ainley 2011; Kang and Keinonen 2017; Kang and Keinonen 2018; Fouad et al. 2010;

Simon and Osborne 2010). Thus, the relationship between interest and science aspiration has been well documented, and a lot of research has found "interest to be among the most important factors for choices of education and occupations in STEM subjects" (Bøe and Henriksen 2015, p. 23). According to a review by Kang and Keinonen (2018), the construct of interest in educational studies is always content-specific, such as "a particular science content, subject, area of knowledge, or activity" (p. 5) that increases one's attention, concentration, and affect during engagement. Furthermore, interest is often studied using three general characteristics: *cognitive*, *emotional*, and *value related* (Krapp 2007; Hidi and Renninger 2006). The meaning of interest in science can vary depending on the context of research. In our study, we define interest in science as students' attitudes toward doing science at school, in line with Archer et al. (2010), which shows a strong correlation with science aspirations at age 10 to 14. Regarding the development of interest in science at school, recent research often emphasizes that student-centered approaches such as inquiry- or context-based science education increase students' interest in science (e.g., Bennett et al. 2007; Kang and Keinonen 2018). Interestingly, Potvin et al. (2018) reported that teachers' pedagogical novelty, such as using inquiry-based approaches in science, indicated the most powerful predictor of science interest, whereas self-concept was not affected by the teaching approaches. On the other hand, self-concept was highly correlated to students' achievement while interest was not. Accordingly, they concluded that "while interest appears to be driven by class experiences … self-concept seems to be essentially caused by achievement" (p. 15). Eccles' EVT and Bandura's SCT distinguish interest as an intrinsic value that arises from within, while self-concept is developed by social comparison. Thus, it is plausible that student-centered approaches focusing on students' individual needs and interests may not change such a relative perception (Potvin et al. 2018).

Although many studies have indicated the significant relationships between interest, self-concept, and career goals, the causal relationship among them is still under debate (Bong et al. 2015). Accordingly, in order to measure the causal relationships, a few studies have been done using longitudinal data. Potvin et al. (2018) explored the interactions between self-concept, interest, and the intention to pursue science and technology education, based on 2 years of longitudinal data on students in grades seven (age 12) and eight (age 13) in Canada. According to the results, interest and self-concept were not mutually dependent; no significant correlations were indicated between the two constructs during the 2 years. However, perceived easiness indicated high correlations with interest and self-concept. In addition, the educational aspiration toward science and technology was not predicted by interest and self-concept. Rather, contrary to expectations, past aspiration predicted students' future interest in science. However, as the authors noted, two constructs, easiness and self-concept, are likely to be overlapping concepts, which complicates interpretation of the results. The findings also confirmed gender differences in interest and self-perception in science. Specifically, boys presented slightly higher interest and self-concept than girls at the time of the first measurements, and no significant changes were noted during the 2 years. However, while Potvin and his colleagues examined gender differences, they did not study how the patterns between genders were different in terms of the relationships between interest, self-concept, and future aspirations.

On the other hand, there are studies indicating causal relationships between interest and self-concept, but the results of these studies conflict with each other. For instance, the study by Marsh et al. (2005) revealed that prior academic self-concept had a large effect on subsequent academic interest, while prior interest indicated only a small effect on subsequent self-concept.

That is, higher self-concept is likely to result in higher interest, not vice versa. In addition, they found that the patterns of the relationships between interest and self-concept were remarkably similar for male and female students, although males indicated substantially higher math self-concept and interest than females. In contrast, based on a 4-year, longitudinal, large-scale dataset, Bong et al. (2015) reported that academic self-concept and interest went hand in hand with learning science and mathematics, but prior interest predicting subsequent self-concept was larger than the effect in the opposite direction. Thus, they concluded that "interest, therefore, appears to be causally predominant to … self-efficacy" (p. 39). They also reported that interest was more stable over time than self-concept, during the 4 years from grade 7 (age 13) to grade 11 (age 17) in Korea. However, although the studies by Marsh et al. and Bong et al. investigated the relationships between interest and self-concept, one particular limitation of both studies is that they did not involve future study or career motivation as a dependent variable in their models; rather, they merely explored the longitudinal relationships between two constructs.

Early Aspirations toward Science Education and Careers

Young students' views on careers in and from science and the range of jobs that science can lead to are still narrow at age 13 (Archer et al. 2014). However, this early-career expectation in science increases the probability of earning a higher degree in science and engineering at university (Tai et al. 2006). In the early stage, constructs of aspirations of studying advanced science and pursuing science careers are not separable, since many students choose their science subjects with career choices in mind (Reiss and Mujtaba 2017); that is, young students understand that their subject choices at school are important steps on the path to achieving their career aspirations in future. Thus, science aspirations at this age are "understood as students' desire to pursue science further in their schooling and as a potential career path" (DeWitt et al. 2013, p. 1038). Particularly, this early aspiration to study advanced science may play a pivotal role in achieving future career goals, since a STEM education at university often requires someone to have studied science subjects at upper-secondary school. Similarly, a science career often requires an academic degree in STEM fields; thus, study aspiration in advanced science subjects at lower-secondary school "may potentially enhance or restrict future career options" (Sheldrake 2018, p.3).

For this reason, Archer and her colleagues studied influential factors on student science aspirations between the ages of 10 and 14 in the UK. Their first study regarding students aged 10 (year 6) presented an interesting finding that although both boys and girls were highly interested in doing science, their aspirations to be scientists were low and varied by gender (Archer et al., 2010). One reason for this gender difference stemmed from young students' perceptions of science as being hard and scientists as "boffins" (clever) or "geeks" (nerds), which was not seen as a desirable identity, especially by girls, who defined themselves as "girly" (Archer et al. 2013a). In follow-up studies, similar results showed that from age 10 to age 14, students' interest in science was stable and high, but aspirations to science careers were very low (Archer et al. 2013b). However, young students' views of scientists improved from 10 to 14, in that only a few students agreed that scientists are "geeks" or "odd." Rather, 14-year-old students held broadly positive views of scientists, such as scientists can benefit society through advanced technologies and medical breakthroughs. In addition, interest in doing science at school was still the most significant predictor of students' science aspirations, followed by parental attitudes to science, self-concept in science, and gender.

Barmby et al. (2008) also reported that students' attitudes toward future participation in science declined from year 7 (age 11) to year 9 (age 13) in the UK, and this negative trend was much clearer for females. A similar pattern has been indicated in terms of students' self-concept in science, indicating that although both genders' self-concept decreased during the school years, the decline was more severe in females. In the study by Barmby et al., the correlation between future participation and self-concept was high and, interestingly, the coefficient of the correlation had increased as the students advanced into a higher grade. That is, self-concept works as a more important agent in predicting future career aspiration as students mature. Sheldrake et al. (2017) also pointed out that interest and self-concept in physics in year 8 (age 12) were key predictors of students' intentions to study non-compulsory physics in year 10 (age 14) in the UK. They also reported that students with higher interest and self-concept in year 8 remained in the higher interest and self-concept group in year 10, although the trends for both self-concept and interest were negative. In addition, gender was a significant predictor of the students' intention, both in year 8 and in year 10, as boys presented higher aspirations to study physics than girls. In the Finnish context, Kang and Keinonen (2017) examined the effect of self-concept and interest as well as outcome expectation on science career aspiration at age 15 and found that high self-concept and interest led to high career aspiration. Interestingly, although boys indicated higher self-concept, girls presented greater intentions to pursue science careers. They attributed this result to girls' higher outcome expectations toward science learning, which predicted career goals much more than self-concept did in Finland. In line with Kang and Keinonen (2017), Reiss and Mujtaba (2017) also reported that extrinsic motivation in physics was the most important predictor of students' intention to study physics after the age of 16, more than any other factors such as interest or self-concept.

According to the recent PISA study (OECD 2016), the shares of girls' and boys' expectations of a science-related career at age 30 are well balanced, but the fields of science that they prefer are different. In all 72 countries participating in PISA, "girls envisage themselves as health professionals more than boys do; and in almost all countries, boys see themselves as becoming ICT professionals, scientists or engineers more than girls do" (p. 116). This imbalance of science career preferences is reflected in real study choices at university level. According to the recent National Science Foundation [NSF] (2017), women received about half of all bachelor's degrees in science and engineering in 2016 in the USA. However, only about 20% of computer science, engineering, and physics degrees were awarded to women, whereas they held a majority of the degrees in psychology and biological sciences. The report also indicated that a similar pattern continued in STEM occupations, in that men were more likely to work in a STEM occupation than women, while women were more likely than men to work in a STEM-related occupation, such as a health occupation.

Research Aims and Hypotheses

As reviewed, a lot of research has been done on exploring how interest and self-concept affect students' science aspirations during the early years, but the causal relationship between self-concept and interest in predicting science aspirations is inconclusive. In addition, although a few studies have looked into gender differences in that causal relationship, to our best knowledge, no

studies have explored how the patterns differed by gender in these relationships. Hence, this study aimed to investigate the causal relationships of interest and self-concept at age 13 with interest, self-concept, and science aspirations at age 16, during the lower-secondary years in Finland. In particular, we examined the gender differences in those relationships between ages 13 and 16. Based on the review of the literature, we hypothesized that interest and self-concept for both girls and boys would decrease during secondary school (first hypothesis [H1]). Consistent with the literature, we also hypothesized that boys would have higher interest and self-concept than girls [H2]. Hill et al. (2018) emphasized that although the gender difference in science already emerges in primary school, lower-secondary school seems much more impor-tant than during the primary school years, since the gender difference may widen for several reasons, such as more diverse student backgrounds, science subjects and male science teachers, or the influence of the peer group. In addition, since a lot of research shows that being male is a significant factor in retaining positive attitudes to science, we can expect that while interest and self-concept decrease during the lower-secondary phases, boys may attain and retain higher values of interest and self-concept in science than girls. Finally, we hypothesized that there would be significant interdependence between interest and self-concept in predicting science aspirations [H3], and that the patterns of the relationship would be similar between genders [H4]. Although a few studies have explored gender differences in the relationship between interest and self-concept, we found no studies that extended the relationship to science aspira-tions. Thus, we had no solid grounds for this hypothesis, but since a lot of research has indicated significant cross-sectional correlations among these constructs, it seemed plausible that interest, self-concept, and science aspirations would be interdependent on each other. Furthermore, as Marsh et al. (2015) reported similar patterns of relationships between interest and self-concept among boys and girls, we anticipated that the relationships between the three constructs—interest, self-concept, and aspirations—would be similar between genders. The results of this study may extend the current understanding of the roles of interest and self-concept in increasing students' science aspirations and how they are related to each other by gender.

Methods

Sample and Procedures

The present study was conducted based on the survey data from a 3-year longitudinal study "Promoting Youth Scientific Career Awareness and Its Attractiveness through Multi-Stakeholder Co-operation" (MultiCO) in Finland. A total of 472 students (school 1: 206, school 2: 115, school 3: 151) were recruited in three public comprehensive schools in Eastern Finland, which may represent other schools in the province. Consent forms were sent out to all students' parents and tutors at the three schools, and participation in the study was voluntary. The same questions in measuring self-concept and interest were used for the pre- and post-survey two times, and students' science aspiration in science only was measured using the post-survey. The first data collection took place at the beginning of lower-secondary school at age 13, in September 2015, and the second set of data was gathered in May 2018, when the students completed lower-secondary school at age 16 in Finland. Of the total sample, only 312 students (school 1: 145, school 2: 82, school 3: 85, 49% girls) completed both the pre- and post-questionnaires.

Measures

For this study, three constructs—self-concept, interest, and aspiration in science—were measured. All the items were derived from previously well-studied questionnaires (e.g., OECD 2007) and were coded on a 4-point Likert scale from strongly disagree (1) to strongly agree (4). One of six questions measuring self-concept was on the negative scale (see SC4 in Table 1), so it was recoded on the positive scale so that the positive score could indicate a higher level of agreement with the asked construct. Detailed information on the core constructs of this study is listed in Table 1.

Self-Concept The questions related to self-concept, asking about students' confidence in science, were derived from the study by Marsh (1990). Some items on the questionnaire asked students to compare themselves to other students using statements such as, "Compared to others of my age, I am good at science classes," since this self-confidence in science at school stems not only from reflecting on one's own ability (e.g., I learn things quickly in science), but also from comparing oneself to others (e.g., I get good marks in science) (Cronbach's $\alpha = 0.89$ and 0.89 for pre- and post-questionnaire, respectively).

Table 1 Description of the science attitude measures

Measure	Item label	Statement	Time 1, M (SD)	Time 2, M (SD)	Time 1, α	Time 2, α
Self-concept	SC1	Compared to others of my age, I am good at science classes.	1.86 (0.89)	2.12 (0.92)	.89	.89
	SC2	I get good marks in science.	2.83 (0.80)	2.74 (0.88)		
	SC3	Work in science classes is easy for me.	2.74 (0.81)	2.62 (0.84)		
	SC4	I'm hopeless when it comes to science.	3.47 (0.81)	3.33 (0.82)		
	SC5	I learn things quickly in science classes.	2.75 (0.78)	2.63 (0.78)		
	SC6	I have always done well in science.	2.55 (0.87)	2.47 (0.88)		
Interest	INT1	Doing science is one of my favorite activities.	2.16 (0.89)	2.25 (0.8)	0.88	0.90
	INT2	I would like to find out much more about some of the things we deal with in our science class.	2.39 (0.91)	2.52 (0.85)		
	INT3	I really like science.	1.79 (0.78)	2.4 (0.86)		
	INT4	I enjoy science courses.	2.16 (0.84)	2.46 (0.84)		
	INT5	Science is very relevant to me.	2.20 (0.80)	2.32 (0.83)		
Science Aspiration	SA1	I would like to work in a career involving science (biology, chemistry, geology, and physics).	N/A	2.29 (1.01)	N/A	.90
	SA2	I would like to study science after secondary school.	N/A	2.01 (0.95)		
	SA3	I would like to spend my life doing advanced science.	N/A	1.71 (0.82)		
	SA4	I would like to work on science projects as an adult.	N/A	1.86 (0.84)		

N/A, not applicable; *SC*, self-concept; *INT*, interest; *SA*, science aspiration

Interest Students' interest in science was measured with four items derived from Frenzel et al. (2012) and Owen et al. (2008). This construct of interest asked about all three characteristics of interest: cognitive (e.g., I'd like to find out more about science), emotional (e.g., I really like and enjoy science), and value-related characteristics (e.g., science is relevant to me) (Cronbach's $\alpha = 0.88$ and 0.90 for pre- and post-questionnaire, respectively).

Science Aspiration Students' future-oriented motivation for studying and working in a science field was derived from the PISA study (OECD 2007) measures with four items, such as "I would like to work in a career involving science" or "I would like to study science after secondary school" (Cronbach's $\alpha = 0.90$).

Although the reliability and validity of the three measures we used in this study have been confirmed by several studies, we briefly conducted the exploratory factor analysis (EFA) again for our own dataset. As Table 4 in Appendix 1 indicates, 26 variables were gathered into the expected five factors with sufficient factor loadings greater than 0.4 (Muijs 2011).

Statistical Analyses

Preliminary analyses were conducted to access the normal distribution and percentage of missing items over time. According to the results, all the items were normally distributed across two time points, and there were negligible rates of missing items. The highest percentage missing was 2.9% (T1SC5) and 1% (T2SC3) for time 1 and time 2, respectively. We also checked an Intra-class Correlation Coefficient (ICC) measuring "the proportion of the total variance in the outcome variable that is explained by differences between groups" (Bowen and Guo 2011, p. 67). However, we found that the highest ICC was 2.9% (T1INT4), which means most of all observations are so independent that the analysis of clustered data such as multilevel modeling is needless (see Table 5 in Appendix 2). Missing data were estimated using full information maximum likelihood estimation throughout the analysis processes.

We then measured measurement invariance (MI) in terms of interest and self-concept across time and gender, based on the model presented in Fig. 1. In order to take the longitudinal nature of the data into account, items corresponding to the same measure could be correlated across time intervals (Moreira et al. 2018). First, we examined the longitudinal MI across time in three steps, by comparing nested models. Specifically, we measured configural (pattern), metric (weak measurement), and scalar (strong measurement) invariances of the model. The configural invariance is a base-line model of all measurement invariance tests. This model assumes the same number of factors with the same number of items between groups without equality restrictions on other parameters. That is, the result of the configural invariance measurement indicates that the variables under study measure the same constructs across the two time points. After this, we tested metric invariance by constraining factor loadings across time intervals. If the result indicates factor loading invariance across time intervals, the measures are considered to be on the same scale. Finally, we tested scalar invariance by constraining factor loadings and item intercepts across time
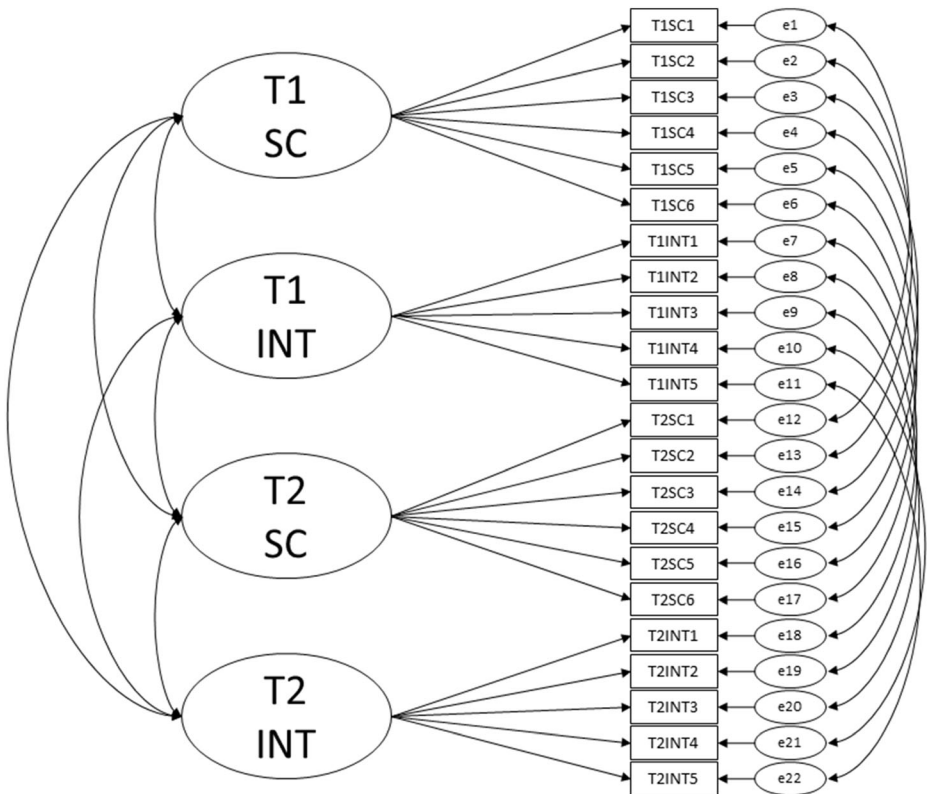
Fig. 1 Measurement invariance model. (T1) First-time measurement. (T2) Second-time measurement. (SC) Self-concept. (INT) Interest. (e) Measurement error. Latent variables are shown as ovals and observed variables as rectangles

intervals. If no significant differences are found between time points in terms of scalar invariance, factor means can be compared across time. For the model comparison, we checked the change in CFI (Comparative Fit Index) and RMSEA (The Root Mean Square Error of Approximation), since a value of ΔCFI smaller than or equal to − 0.01 and a value of ΔRMSEA less than or equal to 0.015 are considered acceptable to establish MI (Cheung and Rensvold 2002). In addition, a multiple group confirmatory factor analysis (MG-CFA) was used to examine measurement invariance between genders following the same steps comparing configural, metric, and scalar invariances.

After confirming MI, we compared means between two time points and gender to test H1 and H2, respectively. We then explored the latent interactions between self-concept, interest, and science aspiration, to examine H3 using a cross-lagged panel analysis, as Fig. 3 shows. Cross-lagged modeling is often used to examine the reciprocal and autoregressive relationships among latent constructs across time (Kearney 2017). The path that connects the same constructs at time 1 and time 2 (for instance, the path between T1SC and T2SC in Fig. 3) is called an autoregressive path, identifying stabilities in the same constructs across time. The cross-time linkages between different constructs are referred to as cross-lagged effects (for instance, the path between T1SC and

T2INT in Fig. 3). Since the aim is to examine predictive regression relations over time, within-time relations remain as covariance estimates (for instance, the path between T1SC and T1INT) (Little 2013). Finally, to test H4, we measured coefficients of each path for each group, and compared them between genders to examine statistical differences. For this, we used the Wald test, examining the invariance of specific structural path coefficients across groups. For instance, in order to test the group difference in the path between T1INT and T2SC in Fig. 3, two models are compared: the unrestricted model (all paths are set free across groups) and the restricted model (all paths are freed except the path T1INT and T2SC). If there is a significant difference between two models ($p < .05$), the path is a variant across groups.

Mplus 8.2 was used with the maximum likelihood with robust standard errors and a chi-squared estimator. In measuring the goodness of model fit, traditional cutoff values were applied: RMSEA below 0.08; CFI above 0.90; and TLI (Tucker Lewis Index) above 0.90 (Wang and Wang 2012).

Results

Measurement Invariance Test

Regarding the longitudinal MI, we compared three models—configural, metric, and scalar invariance models—as presented in the upper part of Table 2. All the longitudinal MI models indicated a satisfactory fit (CFI > 0.9, RMSEA < 0.08) and there was no significant fit change between configural and metric models (ΔCFI ≤ 0.1 and ΔRMSEA ≤ 0.015). Hence, we showed configural and metric invariance. In addition, although the decrease in CFI and RMSEA indicated a lack of scalar invariance, we could easily obtain partial invariance by releasing only two thresholds of items from the equality constraint across time (T1SC1 and T1INT3). Although there is no agreement about an acceptable level of partial invariance, in general, a factor can be considered invariant if the majority, or more than half of items, in the factor are invariant from the full scalar invariance model (Steenkamp and Baumgartner 1998; Vandenberg and Lance 2000). Regarding MI between genders, all the configural, metric, and scalar invariance models indicated good model fit, and the changes in CFI and RMSEA did not worsen substantially. Thus, the tests for MI across gender and time confirmed that the model measured the same phenomenon in different groups.

Mean Differences across Time and Gender

After confirming MI, we examined the mean differences across time by gender, based on the paired-samples *t* test, to examine H1. As expected, although the trend was negative, there were no statistical differences in students' self-concept in science during lower-secondary school for either males or females (see Fig. 2). On the other hand, students' interest in science increased and the degree of the change was significant for both females and males. That is, while self-concept was stable, interest indicated a substantial change during secondary school for both genders. However, considering that 2.5

Table 2 Measurement invariance models across time and gender

| Model	χ^2 (df)	CFI	RMSEA (90% C.I.)	SB-$\Delta\chi^2$ (Δdf)	Reference model	ΔCFI	ΔRMSEA
Time							
Configural	317.82* (192)	0.964	0.046 (0.037, 0.055)				
Metric	361.69* (201)	0.954	0.051 (0.043, 0.060)	36.14 (9) ***	Configural	− 0.010	0.005
Scalar	505.97* (210)	0.915	0.068 (0.060, 0.075)	108.51 (9) ***	Metric	− 0.039	0.017
Scalar partial	381.30* (208)	0.950	0.052 (0.044, 0.060)	17.59 (7) $p = 0.01$	Metric	− 0.004	0.001
Gender							
Configural	583.59* (384)	0.945	0.058 (0.049, 0.068)				
Metric	602.88* (402)	0.945	0.057 (0.048, 0.066)	18.36 (18) $p = 0.43$	Configural	0.000	0.001
Scalar	632.16* (420)	0.942	0.057 (0.048, 0.066)	29.36 (18) $p = 0.04$	Metric	− 0.003	0.000

***> 0.001
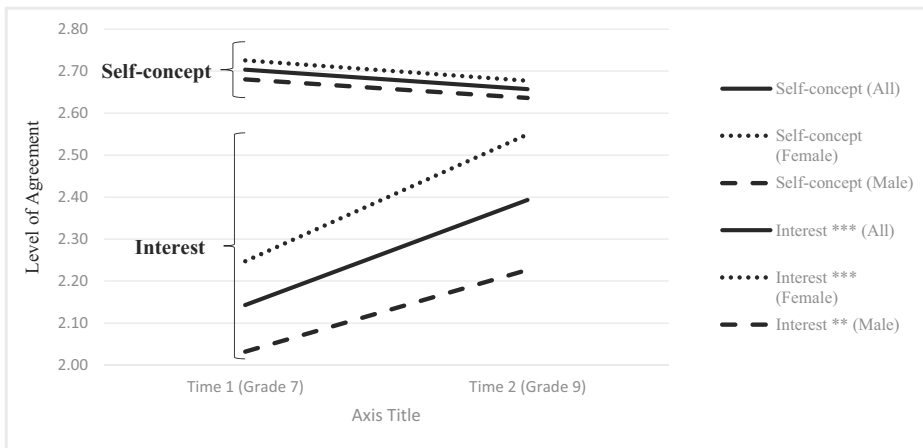
Fig. 2 Mean differences across time. *** < 0.001, ** < 0.005

was the threshold between negative and positive, males' interest was still lower, and females' interest was marginally higher than the threshold. Therefore, we consider that H1 is partially confirmed as the decrease in self-concept is in line with H1 while the increase in interest is opposed to H1.

Next, we explored the mean differences between genders at each measurement point, to test H2 based on independent-samples t test. As shown in Table 3, both female and male students indicated high self-concept (2.73 and 2.68 for girls and boys, respectively) but low interest in science (2.25 and 2.03 for girls and boys, respectively) at the first-time measurement. Although both indicated low interest, females' interest was higher than males', and the difference was statistically significant. At the second measurement, self-concept for both genders remained high, without statistical differences between genders (2.68 and 2.64 for girls and boys, respectively), while the level of interest for both increased compared with the first-time measurement. However, the gender difference in interest still showed that girls had higher interest than boys. That is, when students graduated from lower-secondary school, their interest in science was different, as girls were more interested in science than boys, whereas their self-concept in science was similar in Finland. We therefore consider that H2 is rejected.

Table 3 Mean differences across gender

	Female Mean (SD)	Male Mean (SD)	t (df)
T1 SC	2.73 (0.66)	2.68 (0.67)	0.598 (304) [p = 0.55]
T1 INT	2.25 (0.72)	2.03 (0.68)	2.70 (304) **
T2 SC	2.68 (0.71)	2.64 (0.65)	0.523 (303) [p = 0.60]
T2 INT	2.55 (0.68)	2.23 (0.69)	4.10 (304) ***

T1, time 1; *T2*, time 2; *SC*, self-concept; *INT*, interest

** < 0.01, *** < 0.001.

Longitudinal Interaction between Self-Concept, Interest, and Science Aspiration

To examine H3 and H4, we explored the hypothesized model indicating relationships between self-concept and interest in predicting science aspiration, as presented in Fig. 3. The fit of the research model was satisfactory for all criteria (CFI > 0.9, TLI > 0.9, RMSEA < 0.08).

Regarding the relationships between self-concept and interest, time 1 self-concept was highly correlated to time 2 self-concept for both genders. In addition, time 1 interest and time 2 interest indicated a significant correlation for both genders. Thus, this confirmed the autoregressive effect for both self-concept and interest, indicating that those constructs are stable across time. However, we found that there were no reciprocal effects between self-concept and interest in the overall model for both genders ($p > 0.05$). Thus, the result showed that interest and self-concept were developed independently between the ages of 13 and 16 without interaction (H3 rejected).

Regarding science aspiration for females, time 2 interest predicted science aspiration significantly in addition to time 1 interest. However, no relationship has been found between self-concept and aspiration for females. On the other hand, in the case of males, all the latent variables indicated moderate correlations with science aspiration, except for time 1 interest. We further examined the paths on which females and males presented statistical differences using Wald tests, and we found that one path from T2INT to T2CA indicated a statistical difference between genders ($\chi 2 = 4.79$, $df = 1$, $p < 0.05$). Thus, we confirmed that the relationships between interest and self-concept in predicting science aspirations differ by gender (H4 rejected).
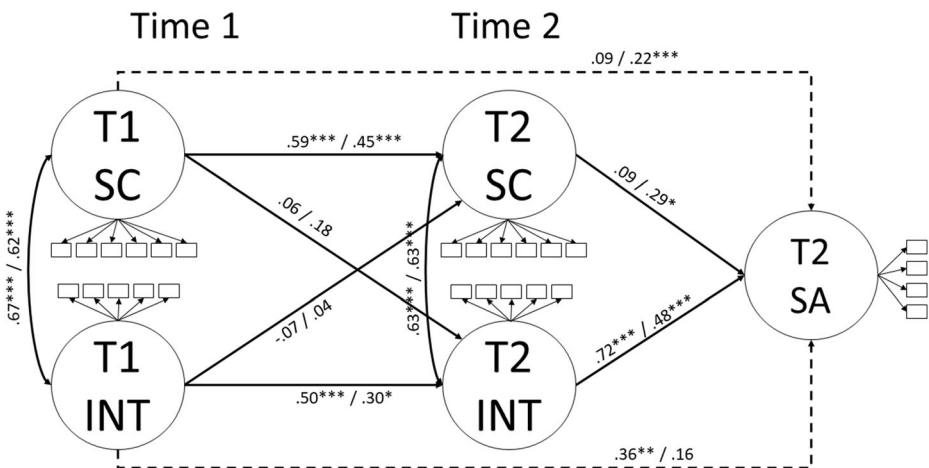

Fig. 3 Structural equation model paths relating to time 1 and time 2 constructs. The first standardized coefficient in each arrow indicates a value for females and the second is for males. Indirect effects are marked with dashed lines. T1 = time 1, T2 = time 2, SC = self-concept, INT = interest, SA = science aspiration. *** < 0.001, ** < 0.005. Model fit: chi-square = 931.79 (0.000), $df = 624$, CFI = 0.93, TLI = 0.93, RMSEA = 0.057 (90% C.I. = 0.049, 0.064)

Discussion

Interest and self-concept are two important factors influencing one's science aspiration, especially during the lower-secondary school phase. Therefore, it is important to measure the trends in interest and self-concept and to explore the relationships of interest and self-concept with science aspirations at these moments. Although several theories and studies indicated interdependency of interest and self-concept in predicting science aspiration, there is a lack of empirical evidence supporting these causal relationships. In addition, while a lot of research points out that gender is one of the most influential factors affecting science aspirations, to our best knowledge, no studies have explored how these causal relationships between interest, self-concept, and science aspiration differ by gender. Therefore, this study aimed to explore the reciprocal relationships between interest and self-concept and how they differ in predicting science aspiration by gender. We also measured the trends in students' interest and self-concept in science between the ages of 13 and 16 in Finland.

Trends in Self-Concept and Interest during Secondary School Years

According to the results, students' self-concept remained high and stable (with little decline), and there were no gender differences during the 3 years of lower-secondary education in Finland. This result is in line with the PISA study (OECD 2016), reporting negligible gender differences in science self-concept in Finland. It is also partially consistent with recent studies by Sheldrake et al. (2017) and Potvin et al. (2018), which indicated a more stable trend of self-concept than interest during secondary school years.

On the other hand, in contrast to previous theories and studies, our result showed that students' interest increased during the lower-secondary phase for both females and males in Finland. This result gives a positive glimpse of Finnish education, showing that students were more interested in science when they completed lower-secondary school than when they started. We assume two reasons that may explain this unique and positive outcome in Finland. First, the newly launched national core curriculum may lead Finnish science teachers' teaching practices toward more student-centered approaches in lower-secondary school. The national core curriculum for basic education has been reformed since 2014, and the local curricula reflect the national curriculum developed between 2014 and 2016. During this developmental period, teachers were provided with an opportunity to discuss the changes and to develop their teaching, because in Finland "local authorities are given substantial flexibility and a great deal of freedom" and "are responsible for creating and carrying out the execution of the new curriculum" by schools themselves (Vahtivuori-Hänninen et al. 2014, p. 21). Compared with the previous version, the new Finnish curriculum puts great emphasis on raising students' interest and motivation toward science subjects by means of inquiry and multidisciplinary project-based learning, showing the relevance of science much better than individual subject teaching and traditional science lessons. Specifically, the new Finnish curriculum points out pedagogical approaches using practical work, inquiries, problem-solving, critical thinking, and, moreover, integration of subjects. Furthermore, the new Finnish curriculum also highlights collaboration and the relevance of studies. These required pedagogical approaches are similar to context-based approaches, which have been shown to result in improvement in students' attitudes toward school science (Bennett et al. 2007). Potvin and Hasni (b) also note that inquiry-based or problem-based interventions have a positive effect on students' interest,

motivation, and attitudes. As Finnish science teachers may have implemented more context-based and collaborative approaches following the renewed core curriculum, this might have increased students' interest during the last 3 years. Second, in Finland, the large-scale national STEM program, aiming to promote primary and secondary school (6- to 16-year-old) students' interest in science through extensive in-service projects, has been implemented between 2014 and 2019 by the LUMA Centre Finland.[1] During the program, Finnish teachers have engaged actively in in-service training focusing on the implementation of the latest methods and activities in STEM education, and specifically the new 2014 curriculum, and this might have an impact on their practices. Professional development focusing on specific instructional practices increases teachers' use of those practices and specific features, such as active learning opportunities (Desimone et al. 2002), in the classroom. During the last three-school-year period, when the data were collected for this study, it was observed that teachers in the three participating schools worked in close collaboration to implement the new curriculum, and this might have influenced teacher practice and student interest. Before the curriculum change, it had been reported that students' interest in science had decreased continuously from 2006 to 2015 (OECD 2016, p. 123), and the teachers used less engaging teaching approaches in teaching science in Finland (Juuti et al. 2010). Therefore, it is plausible to attribute this change in Finland to school science approaches and teachers, which are considered important factors in determining students' views (Christidou 2011).

However, one critical issue with the result is that, although the trend was positive, the average level of interest still remained low in Finland. That is, since Finnish students had a very low interest at the beginning of lower-secondary school, and although their interest significantly increased during 3 years at lower-secondary school, the level of interest still remained low. Previous longitudinal studies, in contrast, indicated that although the trend was negative, the level of interest was still high during the lower-secondary years in other countries (e.g., Potvin et al. 2018; Sheldrake et al. 2017). Therefore, it is important to explore the factors that are associated with low interest at the beginning of the lower-secondary school years and that may be related to students' elementary school experiences in Finland. According to the recent TIMSS 2015 report, the science achievement for Finnish 10-year-olds (grade 4) decreased during the 4 years from 2011 to 2015 (Martin et al. 2016). Moreover, Finnish grade 4 students indicated the lowest interest among the 47 participating countries, and they felt that science teaching at school was not engaging. Thus, we assume that the participating students' very low initial interest in science was attributed to Finnish elementary teachers' less-than-engaging teaching in science lessons. As is known, lessons become more attractive and students are more engaged when teachers use student-centered approaches rather than traditional teacher-directed lectures (Shernoff et al. 2003). Especially in science learning, inquiry-based instruction, linking science content to students' daily life, collaborative learning strategies, and involving students in discussion indicate a positive correlation with interest and achievement (Kang and Keinonen 2018; Schroeder et al. 2007). As mentioned above, the new Finnish curriculum emphasizes these student-centered approaches in science education, and the newly launched LUMA Program focuses on training primary school teachers to implement the new science curriculum at school. Therefore, we expect that, in the future TIMSS 2019

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[1] LU is abbreviated from "luonnontieteet," which means natural sciences, and MA from "matematiikka," which means mathematics. The LUMA Centre is a network of Finnish universities aiming to inspire and motivate students into STEM by using novel and innovative tools and approaches. See Vartiainen and Aksela (2012) for more information.

study, Finnish elementary students' attitudes toward science may be more positive than the previous result, due to better school science approaches and teachers' efforts to implement these approaches in their science classes.

Relationships between Interest, Self-Concept, and Science Aspiration

One of the most interesting findings of this study is that there is no reciprocal relationship between interest and self-concept, although the same constructs are highly associated with each other between two time points. This result is in line with Potvin et al. (2018), who showed the absence of a relationship between interest and self-concept at secondary school, but it is contrary to the findings of Marsh et al. (2005), who indicated interdependent connections between the two constructs in their longitudinal studies. However, although Marsh et al. supported the reciprocal effects of self-concept and interest, this was only marginally significant at the standardized coefficient level of 0.04 (T1 SC with T2 INT) and 0.07 (T1 INT with T2 SC). Therefore, in summary, based on these three empirical studies, we may be able to conclude that in lower-secondary school phases, students' interest and self-concept are likely to be distinct and not coordinated.

In terms of science aspiration, boys' and especially girls' interest was highly associated with their future science aspiration, while girls' self-concept had no effects on science aspiration. Given that the participating students' self-concept was high and stable for 3 years, this contradictory finding between girls and boys is interesting. This finding broadly supports the work of other studies in this area, linking interest with career intention (Barmby et al. 2008; Bøe and Henriksen 2015; Fouad et al. 2010; Kang and Keinonen 2017; Sheldrake et al. 2017; Simon and Osborne 2010). However, while this result is in line with Potvin et al. (2018) in the sense that self-concept has no association with career intention, it is contrary to previous studies that have suggested that self-concept plays a pivotal role in one's occupational development and choice (Eccles et al. 1983; Guo et al. 2017; Lent et al. 1994; Sahin et al., 2017). In one sense, this can be explained by focusing on the fundamental and psychological difference between the two constructs, as self-concept is more about comparing oneself to others, while interest is more about one's inner motivation. Thus, the girls in our sample were likely to consider their future careers not by comparing their abilities with others, but by taking their internal satisfaction, such as enjoyment, into account. Kang and Keinonen (2017) also reported that Finnish girls' high intentions in pursuing science careers were more related to girls' value of science rather than self-concept. The study by Sax et al. (2015) examining the relationship between math self-concept (MSC) and STEM career aspirations between 1971 and 2011 also argued that "the salience of MSC in predicting STEM major selection has generally become weaker over time for women (but not for men). Ultimately, this suggests that women's lower math confidence has become a less powerful explanation for their underrepresentation in STEM fields" (p. 813). Therefore, considering the important predictive role of students' science aspirations at an early stage, we argue that the lower number of women in science-related occupations such as physics or engineering is more likely to be related to girls' interest at lower-secondary or primary school levels, rather than their competency belief at an early stage.

Implications and Limitations

Regarding the gender differences in science aspiration at an early stage, this study has important implications for lower-secondary science education. As discussed, while girls' self-concept was stable and indicated a less predictive power, their interest in science significantly increased during lower-secondary school and was indicated to be a powerful predictor of science aspiration. In particular, interest at the second time measurement, when the students were about to complete lower-secondary school at age 16, indicated a much higher impact on making career decisions compared with the first-time interest at age 13. That is, by participating in science education at lower-secondary school, the probability for girls to choose science-related careers increased in Finland. Therefore, this study emphasizes the role of lower-secondary science education with regard to the gender difference in science aspiration at an early stage, and it encourages science teachers to play a pivotal role in this regard. However, this role may not be accomplished without proper support, such as nation-wide STEM programs like LUMA in Finland and the governmental support for the program. Thus, we recommend and request collaborative work between policymakers, teacher educators, and science teachers in initiating and implementing such national STEM education. In addition, our results recommend further research and practice, focusing more on how to increase girls' interest rather than self-concept, since girls may consider their future careers based on the inner satisfaction that arises from within. According to Kang and Keinonen (2018), several student-centered approaches, such as inquiry-based learning and discussion-oriented lessons, increase Finnish students' interest in science at lower-secondary school. Thus, these student-centered instructions should be considered in order to foster better environments in which girls can engage in science-related activities, advanced studies, and careers.

However, this study is not without limitations. First, since we only used the Finnish sample, the results cannot be generalized to other cultures or countries. In addition, the sample was only from one of the five provinces in Finland. However, as repeatedly reported from several international studies, Finland is known for equity and equality in education throughout the nation; the differences in science achievement between regions across Finland are minimal. Thus, we expect that similar results may be found in the other four provinces of Finland, if we could conduct the same study there. Another limitation is that, although we take gender into account in this study, there can be other social factors, such as cultural stereotypes of occupational characteristics, family demographics (Eccles et al. 1983), ethnicity, or social class (Archer et al. 2013b), that affect students' science aspiration. Therefore, for further research, it would be interesting to explore how each of these social factors makes our suggested model different.

Compliance with Ethical Standards

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

Appendix 1

Table 4 Preliminary EFA results for the five factors

	Time 1			Time 2	
	SC	INT	SC	INT	CA
Factor loadings					
T1SC1	0.594				
T1SC2	0.750				
T1SC3	0.779				
T1SC4	0.610				
T1SC5	0.811				
T1SC6	0.758				
T1INT1		0.817			
T1INT2		0.762			
T1INT3		0.793			
T1INT4		0.766			
T1INT5		0.713			
T2SC1	0.458		0.416		
T2SC2			0.743		
T2SC3			0.801		
T2SC4			0.772		
T2SC5			0.692		
T2SC6			0.704		
T2INT1				0.717	
T2INT2				0.673	
T2INT3				0.792	
T2INT4				0.755	
T2INT5				0.741	
T2SA1					0.769
T2SA2					0.781
T2SA3					0.807
T2SA4					0.817

T1, time 1; *T2*, time 2; *SC*, self-concept; *INT*, interest; *SA*, science aspiration

Appendix 2

Table 5 Missing value, normal distribution, and intra-class correlation coefficient

Measure	Item	Number	Missing		Skewness	Kurtosis	ICC
			Count	Percent			
Self-concept	T1SC1	304	2	0.65	0.72	− 0.44	.019
	T1SC2	303	3	0.98	− 0.28	− 0.40	.005
	T1SC3	304	2	0.65	− 0.24	− 0.40	.006
	T1SC4	303	3	0.98	− 1.47	1.29	.009
	T1SC5	297	9	2.94	− 0.12	− 0.47	.007
	T1SC6	303	3	0.98	0.01	− 0.69	.022
Interest	T1INT1	303	3	0.98	0.33	− 0.67	.005
	T1INT2	302	4	1.31	0.02	− 0.83	.015
	T1INT3	305	1	0.33	0.72	− 0.06	.010
	T1INT4	302	4	1.31	0.37	− 0.42	.029
	T1INT5	302	4	1.31	0.29	− 0.35	.016
Self-concept	T2SC1	305	1	0.33	0.36	− 0.79	.009

Table 5 (continued)

Measure	Item	Number	Missing		Skewness	Kurtosis	ICC
			Count	Percent			
	T2SC2	305	1	0.33	− 0.28	− 0.64	.012
	T2SC3	303	3	0.98	− 0.20	− 0.51	.009
	T2SC4	304	2	0.65	− 1.06	0.29	.009
	T2SC5	305	1	0.33	0.05	− 0.49	.002
	T2SC6	305	1	0.33	0.09	− 0.72	.002
Interest	T2INT1	306	0	0.00	0.07	− 0.59	.003
	T2INT2	305	1	0.33	0.13	− 0.64	.008
	T2INT3	306	0	0.00	0.08	− 0.65	.003
	T2INT4	305	1	0.33	− 0.08	− 0.60	.013
	T2INT5	304	2	0.65	0.20	− 0.49	.006
Science aspiration	T2SA1	306	0	0.00	0.24	− 1.04	.013
	T2SA2	305	1	0.33	0.61	− 0.57	.004
	T2SA3	306	0	0.00	0.96	0.19	.000
	T2SA4	306	0	0.00	0.68	− 0.29	.002

T1, time 1; *T2*, time 2; *SC*, self-concept; *INT*, interest; *SA*, science aspiration; *ICC*, intra-class correlation coefficient

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