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Exploring students' science motivation across grade levels and the role of inductive reasoning in science motivation

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Abstract
The purpose of this study is to explore students' motivation towards science learning at different grade levels and to investigate whether inductive reasoning can contribute to an explanation of science motivation. The study conducted a cross-sectional assessment in six public schools in Vietnam with a total population of 813 students from the 5th, 7th, 9th, 10th and 11th grades. Students completed instruments in either paper-and-pencil or online administration modes. An adapted science motivation questionnaire comprised five subscales for self-efficacy, active learning strategies, science learning value, achievement goals and learning environment stimulation. An inductive reasoning test consisted of four subtests: figure series completion, figure analogies, number analogies and number series completion. The results of confirmatory factor analyses and Rasch model measurement showed that the instruments were adequate fit models, both the science motivation questionnaire (RMSEA=.054, CFI=.919, SRMR=.055) and inductive reasoning test (RMSEA=.038, CFI=.902, SRMR=.044). We found that students' scores gradually fell grade by grade in science motivation throughout the grade cohorts. Particularly, students' motivation dropped noticeably on the self-efficacy and active learning strategies subscales. No gender difference was found between males and females in science motivation. Although a positive correlation was observed between inductive reasoning and motivation across grade levels, multi-model Bayesian inference suggested that other factors, such as age, science performance and parental involvement, were better predictors of students' science motivation. Furthermore, a path analysis showed that inductive reasoning has an indirect effect on science motivation through a science performance variable. The implications for enhancing science motivation are also discussed.

Keywords Science motivation · Inductive reasoning · Intelligence · Rasch model · Bayesian model averaging

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Introduction

The importance of student motivation in learning has been discussed in numerous studies. Most studies have shown that positive motivation in learning not only promotes students' academic performance during their school years, but is also one of the main prerequisites for their success in future (Duckworth et al., 2011; Eccles & Wigfield, 2002; OECD, 2017b). Enhancing science motivation has therefore become an important goal of formal education, which contributes to promoting science literacy for tomorrow's citizens. Researchers (e.g. Anderman & Dawson, 2011; Pintrich & Schunk, 2002) have agreed that children's academic motivation stems from relative dynamic factors of both dispositional and contextual variables. Some components of motivation arise from individual characteristics, and others emerge from direct and indirect interactions in families, schools and society. Existing studies discuss links between students' motivation and common understudied factors, such as age (e.g. Heckhausen et al., 2010), gender (e.g. Britner, 2008; Cavas, 2011; Chan & Norlizah, 2018), intelligence (e.g. Kriegbaum et al., 2018), parental involvement (e.g. Fan et al., 2012) and academic achievement (Ganzach, 2000; Gonida & Urdan, 2007).

However, inductive reasoning, a core component of fluid intelligence (Kinshuk & Mcnab, 2006), is also closely tied to science achievement (e.g. Csapó, 1997; Díaz-Morales & Escribano, 2013; Mehraj, 2016; Mollohan, 2015; Venville & Oliver, 2015). Whether there is a relation between inductive reasoning and science motivation and to what extent inductive reasoning interacts with other factors in predicting student motivation and performance in schools are still unexplored questions. Additionally, a broad range of measurement data, through longitudinal studies (e.g. Hwang et al., 2016; Robinson et al., 2019) and cross-sectional studies (e.g. Dorfman & Fortus, 2019; Józsa et al., 2017), often offer a deeper understanding of individuals' differences in science motivation, which plays an important role in personalized support in enhancing children's academic motivation in particular contexts.

For that reason, our cross-sectional investigation attempts to explore patterns of science motivation differences and to examine the relationship between science motivation and inductive reasoning across grade levels. Moreover, gender difference in science motivation is examined in different grade cohorts. We also investigate the relevant factors (e.g. age, gender, science achievement, parental involvement in schoolwork and parents' education level) on predictive roles in science motivation in the Vietnamese context. Our efforts are expected to draw a partial picture of science motivation among children at different grade levels and to identify main factors contributing to individuals' motivation.

Theoretical background

Science motivation and its role in learning science

Several theoretical perspectives have been developed to explain why students are engaged in an academic activity. The core aspects of educational motivation are students' goals, the intrinsic and extrinsic nature of motivation, students' beliefs about their competencies and students' perceived evaluation of academic tasks. Garcia and Pintrich (1995) recommended that motivation factors include self-perception, effort, intrinsic goal orientation, task value, self-efficacy, test anxiety, self-regulated learning, task orientation and learning strategies. According to Glynn, Taasoobshirazi, and Brickman (2009), motivation to learn refers to "the disposition of students to find academic activities relevant and worthwhile and to try to derive the intended benefits from them" (p. 128).

Additionally, Anderman and Dawson (2011) summarized four theoretical perspectives on performance of motivation: the goal orientation, socio-cognitive, self-determination and expectancy-value theories. Other scholars have focused on the essential reasons that students choose to engage in tasks, such as mastery goals and performance goals. Meanwhile, socio-cognitive theorists often examine the interactions between the learner, the environment and other relevant factors. Self-efficacy is one of the main factors in determining a person's beliefs about the ability to complete a task, and students with high self-efficacy are able to execute a learning task regardless of its difficulty (Tuan et al., 2005).

Informed by these different approaches, several instruments have been developed to assess science motivation in an educational setting. Glynn et al. (2009) developed the Science Motivation Questionnaire II, covering five subscales: intrinsic motivation, self-determination, self-efficacy, career motivation and grade motivation (Glynn et al., 2011). Józsa (2014) proposed the Subject Specific Mastery Motivation Questionnaire, involving six school subjects (reading, mathematics, science, English as a foreign language, art and music) and school mastery pleasure in 5-point Likert-type items. The students' motivation towards science learning (SMTSL) questionnaire (Tuan et al., 2005) was the first subject-specific assessment tool to assess students' motivation in science learning. The basic theories behind the SMTSL are a combination of constructivist learning and motivation in an educational environment. The questionnaire was composed of 5-point Likert-type questions on self-efficacy, active learning strategies, science learning value, performance goals, achievement goals and learning environment stimulation.

Science motivation plays an important role in learning science and is a major predictor of science performance in schools (e.g. Cavas, 2011; Chan & Norlizah, 2018; Clark et al., 2014; Glynn et al., 2009; Tsai et al., 2015). Several studies (Cavas, 2011; Chan & Norlizah, 2018; Dermitzaki et al., 2013; Tuan et al., 2005) have shown that students with higher motivation are likely to achieve higher performance in learning science, in which self-efficacy is one of the central factors predicting academic achievement at the primary and secondary education levels (Bouffard et al., 2001; Britner, 2008; Peetsma et al., 2005). The 5-year panel analysis study in Korea also found that academic performance and self-efficacy formed a longitudinal causal relationship (Hwang et al., 2016). Additionally, the Programme for International Student Assessment (PISA) reported that 15-year-old students who indicated greater motivation scored higher on PISA school subject tests than their peers within the same country (Mo, 2019).

Difference of age in science motivation

From a socio-cognitive viewpoint, academic motivation is formed from both contextual factors and student cognition (Anderman & Dawson, 2011; Pintrich & Schunk, 2002). Empirical studies (e.g., Dorfman & Fortus, 2019; Józsa et al., 2017) have indicated changing patterns of science motivation across grade levels. The general findings are that students' motivation tends to drop gradually as they move through the school system. A 2-year longitudinal study (Bouffard et al., 2001) showed that students' experience declined in terms of self-efficacy belief and learning strategies on reaching secondary school, while Hoffman (2015) demonstrated that the initial passion for formal learning scatters across the middle school years (the 7th to 9th grades) before plummeting in high school. Furthermore, a 5-year longitudinal study by Gottfried et al. (2001) described academic intrinsic motivation significantly decreasing in a linear trend over the years, but the reduction rates for motivation depended on the particular subject areas, with maths showing the largest decline and social studies seeming unchanged. It appears that the developmental change in students' motivation in schools may be related to biological development.

An effective developmental study requires longitudinal surveys and takes as long as the developmental process that is being observed. Developmental programmes spanning several years are expensive, require stable long-term funding, and are therefore rare. However, if the environmental conditions for development are constant or change relatively slowly compared to the developmental process under observation, these processes may be estimated with cross-sectional assessment. Cross-sectional data are more biased if the period covered is longer and the assessed age groups are influenced by different environmental factors (e.g. Baltes, 1968; Maxwell & Cole, 2007). Cross-sectional surveys of schoolchildren who develop within slowly changing educational systems may provide acceptable estimates of real developmental processes. Longitudinal assessments of motivation usually span less than 2 years (e.g. 2 months in a study by Datu et al. (2018), 3 months in Schwartz and Waterman (2006), 4 months in Bathgate and Schunn (2017) and 21 months in Chapman (1988)), while studies covering 3 or more years are very rare (e.g. 3 years in Becker et al. (2010) and 8 years in Gottfried et al. (2001)). As for inductive reasoning, its development has also been studied both with cross-sectional (Csapó, 1997; Molnár et al., 2013; Vo & Csapó, 2020) and longitudinal assessments (Ifenthaler & Seel, 2011). The present cross-sectional study that assessed five cohorts is equivalent to a 5-year longitudinal assessment, and, although they do not provide intact developmental data, the grade-level differences observed may offer a satisfactory estimate of the main trajectories in the Vietnamese context, where the current national education curricula have been consistently implemented across the country since 2002.

Gender difference in science motivation

As regards gender differences, results from previous studies on science motivation are somewhat inconsistent in different contexts. No significant gender-related differences have been found in motivation towards science scales (e.g., intrinsic and extrinsic motivation, self-determination and self-efficacy) (Britner, 2008; Glynn et al., 2009; Zeyer, 2010; Zeyer & Wolf, 2010), although boys managed slightly higher points in self-efficacy than girls and girls received higher scores on the self-determination scale (Britner, 2008; Glynn et al., 2009). Some studies that implemented the SMTSL questionnaire found that males did not differ from females in science motivation in terms of self-efficacy, learning environment stimulation or active learning strategies (Andressa et al., 2016; Cavas, 2011; Chan & Norlizah, 2018), but females are significantly more motivated as regards science learning values and achievement goal scales (e.g. Cavas, 2011; Chan & Norlizah, 2018) as well as performance goals (Andressa et al., 2016). Other studies have indicated that females score higher on achievement goals (King & Ganotice, 2014) and on self-efficacy scales in Earth science (Britner, 2008).

Inductive reasoning and science motivation

Inductive reasoning, one of the core components of fluid intelligence (Kinshuk & Mcnab, 2006), is a cognitive process in which a general conclusion is drawn from individual cases or particular facts (Adey & Csapó, 2012; Sternberg & Sternberg, 2012). There are four main groups of problem tasks to examine inductive reasoning: analogies, series completions, classifications and matrices with element materials, such as verbal, numerical, geometric and figural elements (Adey & Csapó, 2012; Klauer & Phye, 2008; Sternberg, 1986; Sternberg & Sternberg, 2012). Geometric-figural matrix tasks that contain a series of figures or geometries are most frequently found on intelligence tests, such as Raven's Standard Progressive Matrices (McCallum, 2017). These studies have demonstrated that inductive reasoning capacity develops significantly grade by grade, with the most rapid improvement occurring in middle school (e.g. Csapó, 1997; Díaz-Morales & Escribano, 2013; Molnár et al., 2013; Muniz et al., 2012; Vo & Csapó, 2020). Several empirical studies have shown that inductive reasoning is closely tied to problem-solving skills (Csapó, 1997; Molnár et al., 2013; Schweizer et al., 2013) and plays an important role in learning most school subjects, such as mathematics (Nunes & Csapó, 2011), science (Adey & Csapó, 2012; Hamers et al., 1998) and other subjects (Nikolov & Csapó, 2018; Soodmand Afshar et al., 2014).

The relationship between intelligence and motivation has been considered in previous studies (e.g. Gagné & St Père, 2001; Preckel et al., 2008; Spinath et al., 2006). For example, the study by Spinath et al. (2006) demonstrated that children with higher intelligence are likely to achieve higher academic performance in self-concept, self-efficacy and intrinsic values. A meta-analysis drawing from 74 empirical studies (Kriegbaum et al., 2018) also concluded that intelligence and motivation have a positive relationship ($r=0.17$) and estimated 16.6% of the overall explained variance in school attainment. In addition, Chraif and Dumitru (2015) reported that students who perform better on inductive reasoning tests tended to report higher points on motivation surveys than their peers, and an online assessment by Kambeyo (2018) found a statistically significant correlation between inductive reasoning and science motivation, but not a strong one. This suggests that inductive reasoning and motivation may be mutually reinforcing. In other words, the interplay of inductive reasoning and motivation may be an underlying predictor of school achievement, and both constructs can thus contribute to explaining a higher proportion of explained variance in total.

Parental influences on student motivation and school achievement

Interactive activities in school and family environments are likely to impact children's academic motivation and achievement (Pintrich & Schunk, 2002). Experiences in classrooms notably impact student motivation and school performance (Bathgate & Schunn, 2017; Hernesniemi et al., 2020). Students' motivation toward learning is positively tied to parental involvement in schooling (Fan et al., 2012; Gonzalez-DeHass et al., 2005) and parents' education levels (Acharya & Joshi, 2009). There is even a strong link between parental care (warmth and volitional support) and mastery motivation, in which mothers' care was a better predictor of mastery motivation and school achievement (Józsa et al., 2019). Studies on the family-school connection have demonstrated the importance of the relationship between parenting factors and school-related performance (Gonida & Urdan, 2007). As shown in the PISA 2015 results, parental involvement, consisting of parents' participation in school-related activities and parents' interest in their children's school activities, was positively related to not only children's success in learning science, but also to other areas (OECD, 2017a, b). A longitudinal study by Fan and Williams (2010) also confirmed that there was an aggregate impact of interactive variables, including intrinsic motivation, and parental involvement and engagement, on learning maths and English. Moreover, the interactions between parents' education, cognitive ability and achievement motivation in shaping academic achievement were examined in a study by Ganzach (2000). This supposes that the complex relations between parental involvement in children's schooling and academic motivation are reinforced by the parents' education levels variable which is directly linked to cognitive ability, and all of this has an effect on children's academic performance.

The present study

The study context

The national education system in Vietnam has four levels: early childhood education with nursery and kindergarten; general education with primary education, lower secondary education and upper secondary education; professional education with professional secondary education and vocational training; and higher education with college undergraduate, master's and doctoral courses (Vietnam National Assembly, 2006). Primary education is compulsory for all children aged 6 to 10 years. Lower secondary education lasts 4 years (6th to 9th grades) for children aged 11 to 15 years, while students aged 15 to 18 years can enrol in upper secondary education. Ninth graders must pass a provincial selection examination to continue to upper secondary education. After completing the 12th grade, all high school students are required to take the National High School Graduation Examination to earn a diploma called the High School Graduation Certificate before enrolling for university or college.

The present general education curriculum has been introduced throughout the country starting from the 2002 to 2003 school year. Objectives, content, curricula, textbooks and regulations on completion requirements as well as other relevant matters are similar in both non-public and public schools (UNESCO, 2011). Therefore, a cross-sectional assessment of science motivation and reasoning skills can provide useful information on how well encouraging learning science and teaching thinking skills can be integrated into subject-specific areas at different grade levels. This may be meaningful in practice vis-à-vis boosting students' motivation and proposing improved programmes in future.

Research questions

The current study aims to use the adapted SMTSL questionnaire to assess the extent of science motivation among students in the Vietnamese school context. The validity and reliability of the adapted instrument were examined before conducting further analyses. Then, we explored the change in students' motivation and magnitude of the gender effect on science motivation across grade levels. We also examined whether inductive reasoning affects science motivation and which models are appropriate for predicting individual motivation in learning science. Hence, there were five research questions guiding the current study:

1. What evidence is there for the validity and reliability of the adapted SMTSL questionnaire in the Vietnamese context?
2. How does students' motivation towards science learning differ across grade levels?
3. Is there a gender difference between males and females in science motivation?
4. To what extent is inductive reasoning ability related to science motivation?
5. Which factors contribute to explaining individual science motivation among students?

Methods

Participants

The study was conducted with 813 students (375 boys and 438 girls) in the 5th, 7th, 9th, 10th and 11th grades. The study sample was selected randomly from 24 intact classes in six public schools in the southern Vietnamese province of An Giang. Table 1 summarizes the main characteristics of the school grade cohorts in the study population. The mean age of the participants was 13.9 years, ranging from 9.8 to 17.1 years. We assessed more than 100 students in each cohort from at least four classes in two different schools. The study took place between August and September of 2019. The students spent around 45 min completing the questionnaire and test under examination conditions. We administered the instrument during regular school time.

Instruments

Students' motivation towards science learning questionnaire

Our study adapted the SMTSL questionnaire developed by Tuan, Chin, and Shieh in 2005. Tuan et al. (2005) supposed that self-efficacy, science learning value, learning strategies, individual learning goals and learning environment stimulation are foundational elements of motivational factors in assessing students' science learning motivation. The questionnaire was therefore developed based on these foundational components. The *self-efficacy* subscale measures students' beliefs about their own capacity to perform well on science learning tasks (e.g. I am sure that I can do well on science tests). The *active learning strategies* subscale focuses on how students apply the various strategies to acquire new knowledge based on their own experience (e.g. When learning new science concepts, I connect them to my previous experiences). *Science learning value* refers to what students can achieve in their daily lives when they attend science courses, such as scientific reasoning, problem-solving skills and science knowledge (e.g. I think that learning science is important because it stimulates my thinking). *Performance goals* denote students' goals in science learning such that they compete with other students and draw their teacher's attention. The *achievement goals* subscale assesses students' satisfaction with their performance in science learning (e.g., During a science course, I feel most fulfilled when I am able to solve a difficult problem). In the current study, our adapted instrument is focused on achievement goals. The performance goals subscale was not included in this study because we needed to reduce the number of items to match the limited time of the 45-min period suggested by principals at the participating

Table 1 The study samples.

Grade	n	Boy/girl ratio (%)	Mean age (years)	Age range (years)	No. of classes
5	157	49.7/50.3	10.3	9.8–10.8	4
7	222	48.2/51.8	12.2	11.8–13.3	6
9	132	41.0/59.0	14.3	13.8–14.6	5
10	117	39.3/60.7	15.3	14.8–15.5	4
11	185	48.6/51.4	16.3	15.8–17.1	5
Total	813	46.1/53.9	13.9	9.8–17.1	24

schools. The *learning environment stimulation* subscale entails the curriculum, teachers' teaching and the learning environment, which influence students' science learning motivation (e.g., I am willing to participate in this science course because the teacher does not put a lot of pressure on me). A 5-point Likert-type was utilized where participants rate their responses for each statement at 1=strongly disagree, 2=disagree, 3=no opinion, 4=agree and 5=strongly agree.

Various empirical studies (e.g. Cavas, 2011; Chan & Norlizah, 2018; Dermitzaki et al., 2013; Shaakumeni & Csapó, 2018; Tuan et al., 2005) have provided evidence that the instrument we have selected is reliable and valid in cross-cultural contexts. For example, Cronbach's alpha for the entire questionnaire in Taiwan was 0.89 and ranged from 0.70 to 0.89 for each subscale (Tuan et al., 2005); it was 0.87 in Turkey, ranging from 0.54 to 0.85 for the scales (Cavas, 2011); and it was 0.68 to 0.82 in Greece (Dermitzaki et al., 2013), 0.84 in Malaysia (Chan & Norlizah, 2018) and 0.79 in Namibia, ranging from 0.66 to 0.77 (Shaakumeni & Csapó, 2018). In this study, we employed the adapted questionnaire and analysed 18 items on five subscales: self-efficacy, active learning strategies, science learning value, achievement goals and learning environment stimulation.

Inductive reasoning test

An inductive reasoning test was adapted from the item bank developed by the Research Group on the Development of Competencies (University of Szeged). The original test was developed in Hungarian (Csapó, 1997). The verbal analogy subtest was then replaced with figural items (Korom et al., 2017), as it was easier to adapt them to different languages.

Numerous empirical studies in cross-cultural context have established the reliability and predictive validity of this test with school-age populations in Hungary (Molnár & Csapó, 2011), Finland (Csapó et al., 2019), Namibia (Kambeyo & Wu, 2018) and China (Wu & Molnár, 2018). In this study, the test was expected to measure the appropriate abilities of all students in the targeted sample. Finally, we employed 30 adapted items covering four tasks (figure series completion, figure analogies, number series and number analogies) in Vietnamese. A correct answer is assigned a score of 1 point, and an incorrect answer earns 0 points on a raw point scale for all items. Most previous assessments of inductive reasoning were already delivered online, so the validity of the digitized tests has already been established. It seems that the paper-based and computer-based versions are equivalent, and no administration media effect was found (Csapó et al., 2009).

Background questionnaire

The material was adapted and translated into Vietnamese from the student questionnaire used for PISA 2015 (OECD, 2017a, b). The background questionnaire included family background, mother's education level, father's education level and parental involvement. For parental involvement, students were asked their perceptions of parental support, engagement and interest in school activities. In this section, we also added a self-report form to gather information on school performance and science (physics, biology and chemistry) test results in the previous semester. The part was embedded in the instrument in both paper-and-pencil and online formats. The online test instrument was composed in the Electronic Diagnostic Assessment System (eDia) (Csapó & Molnár, 2019) and administered through servers at the University of Szeged (Hungary).

Procedures

For the paper-based assessment, the students were given a test booklet containing a questionnaire section and an answer sheet. The teachers guided the students through the appropriate practice items step by step following our procedures in their regular classrooms under the supervision of their teachers. For online administration, the students accessed the eDia platform and registered for the online instrument with a personal password (see Csapó & Molnár, 2019). The students completed the test and questionnaire in the school labs with computers or other electronic devices (tablet or smartphone). Two teachers observed and provided technology support in the computer labs.

The data were analysed with a one-parameter Rasch model in ACER ConQuest software for polytomous items with partial credit model (PCM) analysis for the SMTSL questionnaire (Adams & Wu, 2010) and dichotomous items for the inductive reasoning test (Adams & August, 2010). Our data results were scaled in maximum likelihood estimation (MLE) output parameters with Rasch model measurement. All the data sets were further manipulated in R software application version 3.5.3 (R Core Team, 2019), including the common package libraries (e.g. psych (Revelle, 2019), sciplot (Morales, 2020), ggplot2 (Wickham, 2016), lavaan (Rosseel, 2012) and equaltestMI (Jiang et al., 2017)).

Results

Validity and reliability of the SMTSL questionnaire

In order to assess the fit of the model to the data, a CFA was conducted with main goodness-of-fit indices, such as root mean square error of approximation (RMSEA), comparative fit index (CFI) and standardized root mean square residual (SRMR). We referred to the cut-off criterion developed by Hu and Bentler (1999) to evaluate model fit: CFI>.90, RMSEA<.06 and SRMR<.08. In the present study, the lavaan package was operated to fit the model. The results showed that the model is satisfactory with the cut-off criteria ($\chi^2(125)=421.352$, $p<.001$, CFI>.919, RMSEA<.054, SRMR<.055). As expected, all the indicators provided significant positive factor loadings, with standardized coefficients ranging from 0.40 to 0.78.

Furthermore, we employed a partial credit analysis to scale the performance of the students on the SMTSL questionnaire. The weighted infit test is more useful to examine the relevance between the model and the data. A fit item is established if its infit value falls within the range of 0.7 and 1.3 (Griffin, 2010). The results of the PCM analysis show that the SMTSL questionnaire fitted the model to the data quite well. The infit for single items (weighted mean squares, MNSQ) ranged from 0.85 to 1.29 ($M = 1.0$, $SD = 0.12$). All in all, these results suggest that the model was well supported with the empirical data. The results are consistent with the characterization of motivational factors proposed in the literature (Cavas, 2011; Chan & Norlizah, 2018; Dermitzaki et al., 2013; Shaakumeni & Csapó, 2018; Tuan et al., 2005).

We used the internal consistency index of McDonald's omega (ω) in R package psych (Revelle, 2019) for reliability estimates, since it seems less biased than Cronbach's alpha in this case (Dunn et al., 2014). As presented in Table 2, internal consistency reliability was generally adequate. There were significant positive correlations between five motivational factors. This indicated that students who showed a high score on one subscale were likely to achieve a high score on the others.

A measurement invariance test was conducted as a prerequisite for comparing measurements in different groups to ensure the same measure construct across subgroups of students.

Table 2 Internal consistency estimates (ω) and intercorrelations (Pearson) for the subscales.

	Omega (ω)	SE	AL	SL	AG
SE	.71				
AL	.79	.417			
LS	.66	.165	.490		
AG	.70	.145	.405	.433	
LE	.74	.213	.461	.486	.480

Note. *SE* self-efficacy, *AL* active learning strategies, *SL* science learning value, *AG* achievement goals, *LE* learning environment stimulation; p<.001 for all coefficients

There are several approaches to measuring invariance (Vandenberg & Lance, 2000). In this study, we employed the measurement invariance in R package equaltestMI (Jiang et al., 2017), which combines equivalence testing (Yuan et al., 2016) and projection-based approaches (Deng & Yuan, 2016). The results showed that the model exhibited an acceptable fit and metric invariance as regards students' gender, $\Delta\chi^2(13)=19.31$, p=.114, and administration modes, $\Delta\chi^2(13)=18.79$, p=.130. Adjusted RMSEA values for these tests of invariance were .056 and .054, respectively (less than .079 as the cut-off for .05). Thus, it was proven that the measurement models were not significantly different in terms of the factor structure for the loadings of all the indicators regardless of either gender or delivery mode. With respect to grade levels, since the study assessed students from five grades, we referred to the 7th grade (the largest sample size) as a reference group, while the other grades were focal groups. We manipulated a series of confirmatory factor analyses with pairs of grades. The model was not metric-invariant, $\Delta\chi^2(12)=34.27$, p=.001, but it was scalar-invariant, $\Delta\chi^2(12)=18.98$, p=.068, as regards the 7th- and 5th-grade pairs. This invariance test had an adjusted RMSEA of .069 (less than .075 as the cut-off for .01). The model exhibited metric non-invariance of $\Delta\chi^2(12)=23.41$, p=.024, for the 7th- and 9th-grade pairs, but the adjusted RMSEA values for the test of invariance were .072 (less than .077 as the cut-off for .01). Simultaneously, the model showed a metric invariance of $\Delta\chi^2(12)=13.51$, p=.333, for the 7th- and 10th-grade pairs with an adjusted RMSEA of .063 (less than .095 as the cut-off for .05), and a metric invariance of $\Delta\chi^2(12)=15.58$, p=.211, for the 7th- and 11th-grade pairs with an adjusted RMSEA=.073 (less than .095 as the cut-off for .05). Overall, although the approach to testing invariance showed some limitations, the results demonstrated that the structure of the instrument was somewhat equivalent to measuring across the grade cohorts.

Differences in science motivation among students between grade levels

Figure 1 illustrates the differences in students' motivation on the subscales between grade cohorts. We plotted the smooth curves (the dotted line) to visualize the patterns of students' science motivation across grade levels (see more at Wickham, 2016). In general, students' motivation gradually decreased across grade levels.

As regards individual scales, the students showed the lowest scores on the learning environment stimulation subscale across the grade groups. The younger grades (5th and 7th) achieved the highest score on active learning strategies. The scores for this subscale fell sharply from 1.52 (digits) in the 5th grade to under 0.70 in the 10th grade and tended to be unchanged at the beginning of upper secondary education. There was a noticeable reduction in the scores for self-efficacy from above 2.17 in the 5th grade to just 0.72 in the 10th grade. Although the scores fluctuated toward the achievement goals and science learning value subscales, the older children scored a little lower than

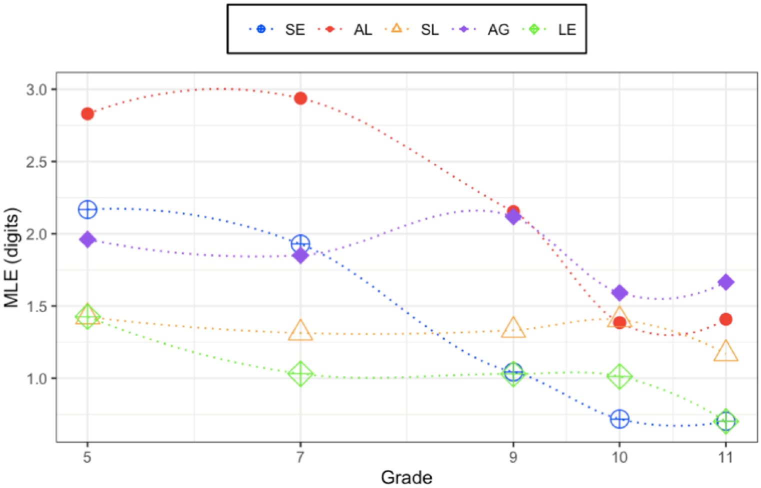

Fig. 1 Changes of science motivation on the subscales across grade cohorts. Note. SE self-efficacy, AL active learning strategies, SL science learning value, AG achievement goals, LE learning environment stimulation.

the younger ones. The younger groups (5th and 7th graders) seemed to achieve higher self-efficacy and motivation scores in learning science, while the older groups tended to be more concerned about the values and aims of learning science.

Overall, the average scores for participant responses on all the subscales were higher in comparison with the average item location parameter of 0 logits, which is the same within three raw points on the 5-point Likert scale. This suggested that the students showed a high positive perceived motivation towards learning science. The highest score was recorded for the active learning strategies (M=2.22, SD=1.96), followed by achievement goals (M=1.84, SD=1.75) and the self-efficacy subscale (M=1.38, SD=1.52). Science learning value had an average score of 1.31 (SD=1.31), while learning environment stimulation had the lowest score (mean=1.03, SD=1.38).

In addition, we manipulated the ANOVA analysis to explore the influence of grade groups on each scale. No significant difference was indicated in any of the cohorts in science learning value [F(4)=0.97, p=.422] and achievement goals [F(4)=2.09, p=.080], while a significant difference was found between grade-level groups for self-efficacy [F(4)=40.39, p<.001], active learning strategy [F(4)=27.66, p<.001] and learning environment stimulation [F(4)=5.92, p<.001]. Tukey's Honest Significant Differences analysis was used to identify which grades showed significant differences statistically. Table 3 provides the results of Tukey's multiple comparisons between grades. Despite the mean score of the older students being lower than that of the younger ones, significant differences occurred in most of the pairs among the middle school student groups.

Gender difference in students' motivation toward science learning

Figure 2 depicts the performance of male and female students on each motivation subscale. It seems that males had higher scores than females on the self-efficacy and active learning strategies subscales, while the females performed better on science learning value, achievement goals and learning environment stimulation. Furthermore, the *t*-test showed a significant difference on the achievement goals subscale, with the girls achieving higher scores (M=1.99, SD=1.65) than the boys (M=1.64, SD=1.83), t(760.5)= −2.85, p=.004.

Table 3 Tukey's multiple comparisons.

Scale	Mean difference									
	7-5	9-5	10-5	11-5	9-7	10-7	11-7	10-9	11-9	11-10
SE	−0.23	−1.12***	−1.45***	−1.46***	−0.89***	−1.21***	−1.12***	−0.33	−0.34	−0.02
AL	−0.11	−0.68*	−1.44***	−1.42***	−0.78**	−1.55***	−1.52***	−0.74**	−0.74**	−0.02
LE	−0.40*	−040*	−0.41*	−0.72***	−0.01	−0.02*	−0.32	−0.18	−0.32	−0.31

Note. *SE* self-efficacy, *AL* active learning strategies, *LE* learning environment stimulation

* p<.05

** p<.01

*** p<.001

Reflecting differences for each subscale among the grade cohorts, Fig. 3 illustrates performance patterns among males and females on each subscale across the grade levels. A fluctuation in motivation level among boys and girls can be observed on each subscale, but the general tendency was that girls reported higher motivation than boys, especially on the achievement goals and learning environment stimulation subscales. The males performed lower than the females on all the subscales, except in the 11th grade, where the boys achieved higher scores than the girls.

Additionally, we continued to examine gender differences with the *t*-test within each subscale across school grade cohorts. No significant gender difference was found between males and females on any subscale across grade levels (p>.05), except in the 11th grade, where boys did better on learning environment stimulation [t(167.2)=2.29, p=.023]. It seems that students' motivation toward science learning is not dependent on gender.

Relationship between inductive reasoning and science motivation

The inductive reasoning test established a satisfactory fit to the current data (CFI=.902, RMSEA=.038, SRMR=.044) with McDonald's omega (ω) at .89. Rasch model analysis suggested the test showed a good fit with the infit for single items (weighted mean squares, MNSQ), ranging from 0.85 to 1.24 (M=0.99, SD=0.09).

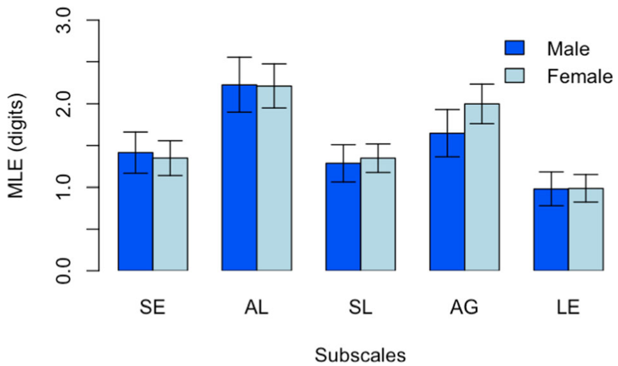

Fig. 2 Comparison of science motivation between males and females on each subscale. Note. SE self-efficacy, AL active learning strategies, SL science learning value, AG achievement goals, LE learning environment stimulation.

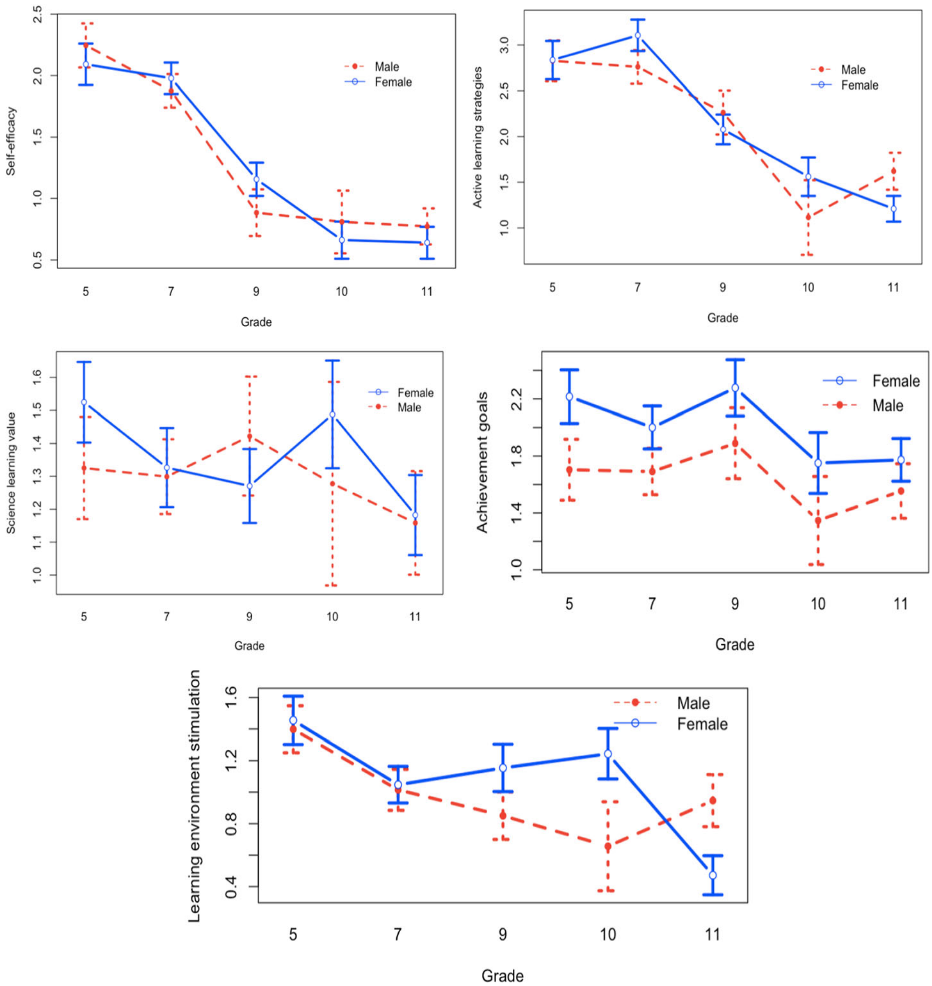

Fig. 3 Performance of males and females on each subscale among grade cohorts.

Pearson's product-moment coefficient was calculated to investigate the relationship between inductive reasoning and science motivation. Table 4 summarizes the correlation between these two variables on the individual subscales. Generally, their relationship was not strong. There was a positive correlation between inductive reasoning and all the subscales across the grades, except in the 11th grade. Inductive reasoning was found to be positively correlated with most of the subscales in the 5th, 7th, 9th and 10th grades. In the 11th-grade cohort, it was negatively related to science motivation on all the subscales. It appears that self-efficacy has a clearer link to it than to the other SMTSL subscales, while achievement goals and learning environment stimulation showed no significant relation to it.

Main factors predicting science motivation

We used Bayesian estimation analysis with Bayesian model averaging (BMA) as a model choice method to ascertain better predictors of science motivation among school-aged children.

Table 4 Correlation between inductive reasoning and science motivation.

Scale	Grade				
	5th	7th	9th	10th	11th
Self-efficacy	.14	.20**	.24**	.22*	−.04
Active learning strategy	.13	.19**	.06	.22*	−.06
Science learning value	.11	.19**	.03	.22*	−.04
Achievement goals	.12	.08	−.01	.12	−.03
Learning environment stimulation	.13	−.06	−.25**	.02	−.15*

Note. * p<.05, ** p<.01

This approach has been noted as a potentially significant improvement over existing methods in terms of both predictive and explanatory ability (Genell et al., 2010; Hair et al., 2010). With the BMA technique, all the possible models were first evaluated according to a model fit measured by the Bayesian information criterion (BIC) and derived posterior model probabilities. Then, for each explanatory variable, the posterior effect probability was computed by averaging the posterior model probabilities for all model fits. Finally, the average mean and standard deviation of each regression coefficient were estimated by weighted averaging of coefficients under each separate model (see more at Raftery et al., 2020). After identifying the main factors, we continued to use the path analysis to examine a suitable model for our investigation.

Science performance was manipulated as an average of three school subjects (physics, chemistry and biology) in the last semester. We included inductive reasoning (IR), student age (AG, a representation of grade level), gender (GE), school difference (SC), science achievement (SA), mother's education level (ME), father's education level (FE) and parental involvement (PA) as the explanatory variables in our exploration.

We employed the BMA analysis for the science motivation scales with linear regression models in R package BMA (Raftery et al., 2020). The best models were recommended based on the Bayesian information criterion for each manipulation. For instance, when exploring predictors for the SE subscale, the best model, which included age, science performance and parental involvement, was suggested, since it had the highest posterior model probability (41.0%) and the lowest BIC index (−85.02) and explained around 19.4% of variance. The next best model, involving IR, AG, SA and PA, was considered a second priority for the models estimating SE, whereas it can only explain 20.3% of variance and its posterior probability is just 29%. It can explain 20.3% of variance but with a posterior probability of just 29%. Similarly, we employed a BMA analysis for the other scales and found that the most frequent variables in these models were IR, AG, SA, ME and PA, while SC and FA were absent in most of the models.

Furthermore, we implemented a path analysis with structural equation modelling to test for direct and indirect effects. After investigating several models, the one with five main explanatory variables of motivation has proven the best. Finally, our results offered a general model illustrated simply in Fig. 4, which presents significant relations between understudied variables. Results also show that the models fit the present data well on all the scales (Table 5).

As regards the role of inductive reasoning in science motivation, it seems that inductive reasoning showed a direct and indirect effect on motivation, in which science achievement was expected as a mediator. The mediated relationship was examined with the Sobel test, and it was determined that the mediating effect was significant on the subscales for SE (Z=3.31, p=.001), AL (Z=1.94, p=.05) and SL (Z=2.67, p=.008). Inductive reasoning has a positive relation with all the science motivation subscales, except the LE subscale, where students who achieved a higher score on IR reported lower motivation. Mother's education level does not directly affect student motivation, but a relationship between the two variables is established through parental involvement. Age has a significant negative relationship with SA, SE and AL factors, but it is positively linked to IR.

Discussion and conclusions

The SMTSL questionnaire represents high criterion-related validity for assessing students from the primary to secondary education levels. CFA and PCM analysis confirmed that the instrument provides an adequate fit to the data and is suited to measuring science motivation in the Vietnamese context. This result seems to be consistent with previous findings in Namibia (Shaakumeni & Csapó, 2018), Malaysia (Chan & Norlizah, 2018), Turkey (Cavas, 2011) and Greece (Dermitzaki et al., 2013). The results also demonstrated that Vietnamese students showed high motivation in learning science and positive attitudes toward science.

This study showed changing patterns of students' motivation in learning science from the 5th to 11th grades. The results were mostly consistent with the literature (e.g. Bouffard et al., 2001; Dorfman & Fortus, 2019; Józsa et al., 2017), indicating that student motivation tended to decrease gradually during secondary school education. The current study also found that students' science motivation dropped from primary to upper secondary education. When reaching upper secondary education, students tend to be less motivated than in the early secondary grades on most of the scales. Nonetheless, the students showed an unchanged motivation toward the values and purpose of learning science, but their positive perspectives on their own abilities and learning environment declined grade by grade from the primary to the secondary education levels. This may be due to their being more concerned about the Matura examination as a general expectation of their parents after they enter high school (Du, 2015). The findings are important for identifying the priority factors in enhancing science motivation in school practice. They signal a potentially alarming picture of change in students' motivation and call for more facilitators of science inspiration and more concern with regard to enriching school environment factors in high schools in Vietnam.

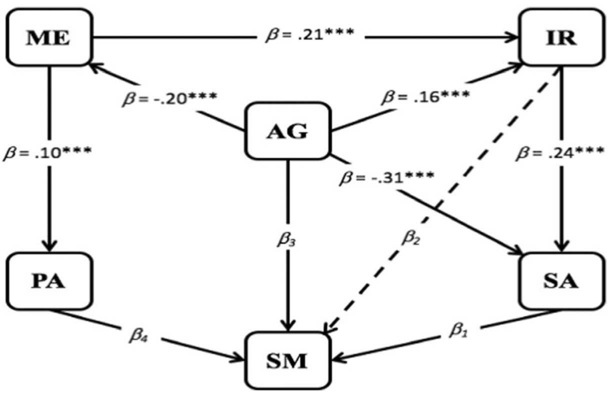

Fig. 4 The general model of relations between explanatory variables predicting motivation. Note. ME mother's education level, IR inductive reasoning, AG student age, PA parental involvement, SA science achievement, SM science motivation in general, β regression coefficient.

Table 5 The model fits and regression coefficients predicting science motivation.

Scale	χ^2 (5)	p	CFI	RMSEA	SRMR	β_1	β_2	β_3	β_4
SE	13.36	.020	.971	.058	.038	.19***	.11*	−.23***	.37***
AL	12.41	.030	.977	.055	.036	.13*	.08	−.28***	1.11***
SL	13.65	.018	.960	.059	.035	.13**	.04	.02	.41***
AG	13.04	.023	.962	.057	.035	.10***	.02	.00	.62***
LE	12.06	.034	.969	.054	.035	.14***	−.17***	.02	.52***

Note. *SE* self-efficacy, *AL* active learning strategy, *SL* science learning value, *AG* student age, *LE* learning environment stimulation; β_1, regression coefficient for science achievement; β_2, regression coefficient for inductive reasoning; β_3, regression coefficient for student age; β_4, regression coefficient for parental involvement

Although boys reported higher scores than girls on the self-efficacy and active learning strategies subscales and the girls achieved better performance in science learning value, achievement goals and learning environment stimulation, no significant gender difference was found on any of the science motivation scales, except for the achievement goals subscale, with the girls attaining higher scores than the boys. This is in line with the results of PISA 2015 that showed that no significant difference was found between boys and girls on science tests in Vietnamese students (OECD, 2016). The findings are consistent with results from existing studies (Andressa et al., 2016; Britner, 2008; Cavas, 2011; Chan & Norlizah, 2018; Glynn et al., 2009; Zeyer, 2010; Zeyer & Wolf, 2010). Nevertheless, they are not in an agreement with the studies in Turkey (Cavas, 2011) and Malaysia (Chan & Norlizah, 2018), according to which females achieved significantly higher scores than males on the science learning values subscale. This may derive from the particular context in Vietnam, where relatively more young women are interested in the science-related sectors (International Labour Organization, 2020). However, more research is called for to explore the effects of gender disparities in science motivation on longer-term science achievement in Vietnamese students.

A positive correlation was found between inductive reasoning and science motivation in most of the grade cohorts, but the former does not directly affect the latter on most subscales. The findings are consistent with existing studies (Chraif & Dumitru, 2015; Spinath et al., 2006) and a meta-analysis reviewed by Kriegbaum et al. (2018). The results of the BMA analysis and path analysis contributed to an increased understanding of relevant factors and models to predict students' science motivation. These analyses demonstrated that inductive reasoning has a direct and indirect effect on science motivation on the self-efficacy, learning environment stimulation, active learning strategy and science learning value scales through the science performance variable as a mediator.

Furthermore, the analyses suggested a simple model, presenting the relations between explanatory variables predicting motivation, in which students' achievement in learning science disciplines in the previous semester meaningfully affected their motivation. The outcomes agree with those of the studies in Taiwan (Tuan et al., 2005) and Malaysia (Chan & Norlizah, 2018). Interestingly, parental involvement was observed as one of the core predictors of science motivation, while parents' education levels seemed not to be linked directly to students' motivation in schools. The mother's and father's education variables are central as students' access to educational resources at home is a strong predictor of science achievement, and ample parental support and engagement as well as interest in school activities play a key role in children's motivation in learning and school, which has been confirmed in previous studies (Fan et al., 2012; Fan & Williams, 2010; Gonzalez-DeHass et al., 2005; OECD, 2017b). The results showed that mother's education level contributed considerably to predicting student motivation through the parental involvement in schoolwork variable. This is due to the typical culture of the traditional family in Vietnam, where parents (especially the mother) are greatly interested in the performance and activities of their children in school (Hoang et al., 2014; Phan, 2004). Additionally, the model provides an interesting relation between student age and mother's education level, in which the mothers of younger student groups seem to have higher education levels than those of older ones. This reflects the current situation of improvement in females' education level in Vietnam in recent years.

However, even though the students reported high motivation toward learning science, this may cause potential risks to external parental pressure on students because the PISA results showed that those who experience high motivation tend to feel anxious about a test, even if they are well-prepared (OECD, 2017a, b). Hence, both schools and families should be concerned about how to inspire students' learning motivation and reduce excessive fear of failure. Teachers, school leaders and school psychologists should be aware of these impacts to create a more supportive learning environment.

Other practical implications are that Bayesian inference may represent a potential approach in educational research. Specifically, BMA analysis can be replicated in evaluating appropriate models. The smooth online data collection indicates that instruments used for assessing motivation can be introduced into regular educational practice. Online delivery reduces the costs and eliminates the human workload and organizational difficulties of paper-and-pencil surveys as well as providing low-cost immediate feedback. Recent studies (e.g., Nikou & Economides, 2016) show that computer-delivered assessment improves motivation.

The study has certain limitations. The instrument may not cover all motivational factors. The next-generation instrument should also be modified continually in the Vietnamese version with a larger sample size. Because this cross-sectional study was conducted in a single province in the south of Vietnam with a limited sample of students, some of the results cannot be generalized to represent the whole Vietnamese context. More research should be done to validate the instrument with a longitudinal assessment on the relation between motivation, reasoning, academic success and other relevant factors. Further investigation is necessary to clearly explain why the upper secondary school students responded less positively than the lower secondary school students. There are several possibilities that could be examined. Further investigations need to take these limitations into account to better understand the interaction between different environmental and social factors.

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Declarations

Conflict of interest The authors declare no competing interests.

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