JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

EXPLORING EFFECT ON PRIMARY SCHOOL STUDENTS' STEM ATTITUDE DETERMINED VIA STRUCTURAL EQUATION MODELING

Si-Jia Liu, Shao-Na Zhou, Shao-Rui Xu, Hua Xiao

Abstract. *As STEM (Science, Technology, Engineering and Mathematics) education gets more and more attention from society, students' attitudes towards STEM are increasingly concerned. However, there was scant research that has empirically documented the relations among STEM attitude, learning motivation and metacognition. This research used Structural Equation Modeling to examine the above relations. Data were collected from 845 primary school students from grade 4 to 6, regarding their STEM attitude, learning motivation, metacognition, and their sociodemographic characteristics (family socioeconomic status). The results showed that metacognition played a mediating role in the effect of learning motivation on STEM attitude. The family socioeconomic status played a moderating role in the effect of metacognition on STEM attitude, and students with higher family socioeconomic status had a stronger effect on STEM attitude. This research also suggested that it is worth considering the improvement of students' learning motivation to facilitate STEM attitude through promoting their metacognitive skills, meanwhile balancing the gap between students under the difference of socioeconomic level in STEM education.*

Keywords: *learning motivation, metacognition, STEM attitude, Structural Equation Modeling*

Si-Jia Liu, Shao-Na Zhou
South China Normal University, China
Shao-Rui Xu
Guangdong Mechanical and Electrical Polytechnic, China
Hua Xiao
South China Normal University, China

Introduction

Driven by the complex policy, economic, social, and environmental issues today, STEM (Science, Technology, Engineering and Mathematics) education is a comprehensive and interdisciplinary solution. STEM education aims to equip students with 21st-century skills such as problem-solving, critical thinking, logical thinking, communication (Bybee, 2010; NRC, 2010). In STEM teaching activities, students' positive attitude towards STEM plays an important role in the achievement of STEM educational goals and acquisition of skills (Tseng et al., 2013). Studies have attributed active engagement in STEM activities to positive STEM attitude which has a significant effect on students' skill development for the 21st century (Luo et al., 2019).

In recent years, several countries around the world have reported the leakage problem of the current STEM pipeline, and many students in these countries do not like STEM related disciplines or do not choose the STEM related career after graduation (Ball et al., 2017; Doerschuk et al., 2016). The STEM pipeline is a commonly used metaphor for articulating the flow of students through the education system, culminating in a STEM-based career (Allen-Ramdial & Campbell, 2014). Specifically, in the pipeline students enter primary school at the beginning and then flow through various intersections (for example, graduating from high school or choosing a STEM major in college). However, students often flee the STEM pipeline for various reasons. To maintain and increase the flow of young students through the STEM pipeline, the potential means is to enhance students' positive STEM attitude and active participation in STEM activities (Ball et al., 2017). Therefore, it is important to study the effect on STEM attitude.

Previous studies (Mujtaba et al., 2018; Sheldrake, 2016) provided evidence for the important role of learning motivation to STEM attitude. The findings highlighted the strong correlation between students' motivation to learn, especially intrinsic value and self-belief, and STEM attitudes. Several researchers have pointed out that students maintained a negative STEM attitude, which is associated with inadequate metacognition (Akerson &

https://doi.org/10.33225/jbse/22.21.1052

Donnelly, 2008). Many studies focused on the effect of different sociodemographic characteristics on students' STEM attitude, including family economic level (Martin et al., 2016), and parental education level (Alexander et al., 2012). As students' STEM attitude may be complicated and affected by multiple factors, the present study aimed to clarify the effect on students' STEM attitude and their pathways.

Literature Review

General social-cognition model of motivation

Motivation works by motivating human beings to initiate and sustain their goal-directed activities (Lasagabaster, 2016; Pintrich & Schunk, 2002). Students' motivation to learn is mainly reflected in their engagement and contribution to the learning environment (Skinner & Belmont, 1993). Positively motivated students always instinctively participate in activities without expecting external encouragement to complete a challenging task. In contrast, negative motivation indicates that the behavior is motivated by expectation and fear of failing to achieve the goal. Research showed that there is a high correlation between learning motivation and learning attitude, and learning attitude is conditioned by learning motivation (Chang & Chang, 2013). It means that better learning motivation would lead to a more positive learning attitude.

Based on Pintrich's general social-cognition model of motivation, the structure of motivation generally includes three components: (1) expectancy, (2) value, and (3) affect (Pintrich et al., 1994). The first component of motivational beliefs is expectancy. Expectation value theory (EVT) suggests that individuals are motivated to engage in various tasks and activities by their expectation of the possibility of success and the value assigned to the task (Wigfield & Eccles, 2000). Expectation is related to self-efficacy, which is defined as an individual's belief in their ability to perform learning tasks (Rittmayer & Beier, 2008). Rittmayer and Beier (2008) stated that students with a high sense of self-efficacy in science would motivate themselves to set challenging goals and strive to achieve them. Sheldrake (2016) proposed that the science self-efficacy belief of students with high self-confidence had significantly affected their STEM career expectations (Sheldrake, 2016). The second component of the motivational structure is the value. Value is specifically considered as intrinsic value, including students' identification of scientific values and judgment of scientific self-ability in Pintrich's model (Pintrich, 1989). Research stated that the intrinsic value beliefs had a significant predictive effect on students' scientific career expectations (Mujtaba et al., 2018). The third motivational component in the model is the effect. Of the effect in the field of learning and teaching, anxiety is the most widely studied form, which illustrates the feeling of uneasiness and anxiousness when facing the situation, especially in the uncertainty of outcome situation (Jackson, 2018). Learning motivation is closely related to students' test anxiety (Eccles & Wigfield, 2002). Therefore, the present study is to consider self-efficacy, intrinsic value, and test anxiety collectively as motivational indicators.

The association of motivation with STEM attitude

There may be some association between learning motivation and attitude. Attitude is a set of beliefs while motivation is a reason for performing a task or achieving a goal (Tadayon, 2012). The Self-Determination Theory (SDT) refines the relation between motivation and attitudes by suggesting that students can undergo a process of internalizing motivation into attitudes (Deci & Ryan, 1985). Some researchers have demonstrated that motivation has an effect on attitudinal outcomes such as future behavioral intentions and persistence (Deci & Ryan, 2000; Vallerand & Ratelle, 2002). The more motivated the students were, the more positive their adherence to STEM course participation and their willingness to learn STEM in the future (Vallerand et al., 1997). Highly motivated students not only have positive attitudes towards STEM courses and are more inclined to choose a STEM related field in the future (Eccles et al., 1983; Meece et al., 1990). Therefore, it is assumed that learning motivation affects students' attitude towards STEM to some extent.

The metacognition and its associations to STEM attitude and learning motivation

Metacognition is the process of cognition about thought. Flavell (1979) described it as follows: Metacognition focuses on one's knowledge concerning his cognitive processes, or anything related to them (Flavell, 1979). Flavell argued that metacognition explained why children of different ages dealt with learning tasks in different

https://doi.org/10.33225/jbse/22.21.1052

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

ways. Other researchers stated that metacognition refers to a person's thought processes, and the monitoring or control of thought (Bogdanovic et al., 2015). There are two frameworks that previous study usually used for studying children's metacognition. Flavell initiated the first framework which included metacognitive knowledge and metacognitive experience (Flavell, 1979). The second framework, proposed by Brown (1978), includes cognitive knowledge and self-regulation (Brown, 1977). Cognitive knowledge focuses on students' cognitive skills that students possess and their cognitive strategies for solving problems in different contexts (Flavell, 1979). Self-regulation, on the other hand, is the process of using cognitive knowledge to regulate and control cognitive behavior, which can help control and regulate an individual's thinking and learning activities (Bandura, 1986; Özsoy et al., 2017). The framework of Brown was chosen for the present study, as metacognition was more inclined to rely on an individual's self-awareness, including the knowledge and control of individual students in the cognitive field. Also, the framework of Brown includes both static knowledge and dynamic regulation, and students' learning process should be a combination of static knowledge and dynamic regulation.

The association of metacognition with STEM attitude

Studies have shown that the level of metacognition was significantly correlated with learning attitude (Akerson & Donnelly, 2008). Students may encounter negative academic emotions and even end up in an attitude of refusal towards the decline or block thinking processes, causing them to have a negative STEM attitude (Buxton, 1981). It was reported that some students who experience more severe anxiety during the learning process tend to put in less effort, their learning strategies tend to be more superficial, which makes them more likely to give up in the face of difficulties (Pintrich & Schunk, 2002). Meanwhile, students with high self-regulation ability can locate and correct their mistakes in the learning process by combining their learning content, learning objectives, and tasks performance. That is, they express a positive attitude towards STEM and participate in the learning of STEM contents actively. Sungur (2007) suggested that students with high metacognitive ability tend to approach difficult tasks as challenges to master rather than threats to avoid and exhibit a more positive STEM attitude in the face of difficulties and distractions (Sungur, 2007). Therefore, it is assumed that metacognition affects students' attitude towards STEM to some extent.

The association of metacognition with learning motivation

The Social Cognitive Learning Theory (SCLT) which was put forward by Bandura (1986) points out that behavior is directed towards particular goals and eventually becomes self-regulated (Bandura, 1986). Metacognition is considered as one component of self-regulation (Schraw et al., 2006). Hong and O'Neil (2001) made a three-order factor model, which further proved the relation between self-regulated metacognition and motivation (Hong & O'Neil, 2001). Students with high metacognitive ability were more willing to use their efforts and adopt effective strategies (Zimmerman & Risemberg, 1997). Also, previous studies showed that learning motivational beliefs significantly affected the effectiveness of metacognition (Al-Ansari, 2005; Neber & Schommer-Aikins, 2002). Hoy (2004) pointed out that students with strong learning motivation and belief would find other new strategies and make more efforts when faced with problems (Hoy, 2004). It is necessary to further explore the specific relation between learning motivation and metacognition and how they affect STEM attitude through their interaction.

The association of family socioeconomic status with STEM attitude

Regarding socioeconomic status of the family, studies take family income and parental education level as the main measurement criteria (Bradley & Corwyn, 2002). According to the data from TIMSS 2015, students whose families have more financial resources (such as books, private rooms, and Internet connections) are likely to exhibit a better attitude to science (Martin et al., 2016). Bronfenbrenner (1994) reported that students' home environment (such as resource availability) might play a role in their development and learning (Bronfenbrenner, 1994). The researchers found that the availability and number of household resources played an essential role in students' attitude towards science learning (Beck, 2010). Moreover, family habits directly affect students' recognition of the practical value of STEM subjects (Archer et al., 2012). Also, parental educational levels may have direct or indirect effects on students' STEM attitude. Studies showed that parental ability to answer children's science questions at home will affect children's attitude towards science (Alexander et al., 2012). Parental help with children's home-

https://doi.org/10.33225/jbse/22.21.1052

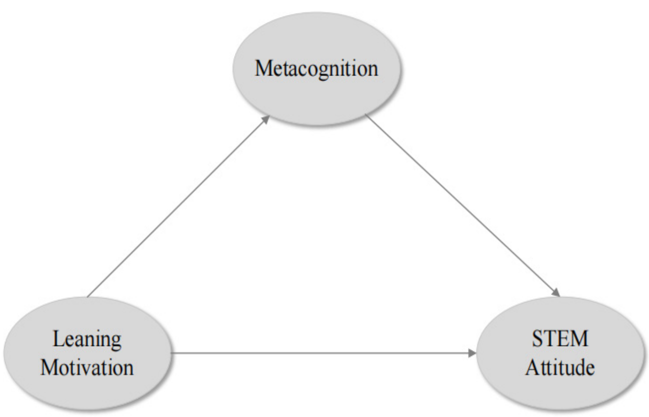
ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

work is associated with children's metacognitive ability (Pomerantz et al., 2007). As seen in the literature, family socioeconomic status seems to affect students' learning attitude (Ali et al., 2013). Based on the above literature, the present study took family economic resources and parental educational level as moderating variables to analyze their effects on students' STEM attitude.

Research Hypotheses

STEM attitude generally has a significant and direct impact on students' future STEM pipeline choices. Based on social psychology, there may be some associations among learning motivation, metacognition, and STEM attitude. According to the above review, the first two research questions are proposed in this study: What is the effect of motivation to learn on attitudes towards STEM? Whether learning motivation affects STEM attitude not only directly, but also indirectly affects STEM attitude through the mediating role of metacognition? In addition, the study considered taking family economic resources and parental educational level of family socioeconomic status as moderating variables to analyze their effects among learning motivation, metacognition, and students' STEM attitude. The third research question in this study was: How motivation and metacognition affect STEM attitudes with the moderating role of Family Socioeconomic Status. Then, the following hypotheses were listed.

Figure 1
The Hypothesized Model of Effect on STEM Attitude



H1: Learning motivation directly and positively affects STEM attitude.
H2: Metacognition plays a positive mediating role between learning motivation and STEM attitude.
H3: Family Socioeconomic Status plays significant moderating roles in the pathway of H1 and H2.

Research Methodology

Research Design

To explore the effect of learning motivation and metacognition on STEM attitudes, and the moderating roles of the family socioeconomic status in the pathway, the structural equation model was conducted for the analysis. First, instruments were carefully chosen, including scales measuring students' STEM attitudes, learning motivation, metacognition, as well as the socioeconomic status of their family. Second, the instruments were distributed in primary schools and data were obtained for the study. Third, the structural equation model was applied to analyze the data and test the hypothesized model in Figure 1. In this section, the fit of the measurement model and the reliability of the indicators of students' STEM attitudes, metacognition, and learning motivation were verified. The relations among the above variables in the model were examined. In addition, the moderating effect of family socioeconomic status was also tested in the pathways of hypothesis 1 and hypothesis 2 in the hypothesized model.

https://doi.org/10.33225/jbse/22.21.1052

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Instruments

Student Attitudes toward Science, Technology, Engineering, and Math (S-STEM) The S-STEM chosen in the present study was developed by Faber et al. (2013) and verified by Unfried et al. (2015) (Faber et al., 2013; Unfried et al., 2015). The S-STEM was used to determine junior students' STEM attitude. It is a 5-point Likert-type scale that consists of 37 items in the 4-factor theoretical structure covering 4 dimensions (mathematics, science, engineering, and technology, twenty-first century skills).

Junior Metacognitive Awareness inventory (Jr. MAI) The most commonly used metacognitive measure for adults with 52 items is the Metacognitive Awareness Inventory (MAI), which was first developed by Schraw and Dennison (1994). Building on the MAI, Sperling et al. (2002) developed the Junior Metacognitive (Jr. MAI) specifically for a younger sample of students (Sperling et al., 2002). Then, version B (Jr. MAI version B) with 18 items was modified for the minimum age of 11 years old (Ning, 2019). Therefore, Jr. MAI version B was selected in the present study. Sperling's model structure covers 2 dimensions, respectively. They are cognitive knowledge and cognitive regulation.

Motivated for Learning Questionnaire (MLQ) The motivational strategies for learning questionnaire (MSLQ) used in this study were developed by Pintrich et al. (1994). It is a self-reported 44 item inventory with a 7-point Likert form designed to assess students' motivational orientations for the course. The MSLQ was adapted to Chinese by Lee et al. (2010). The researchers reported the item response characteristic curves indicating that the items discriminated well. The principal component analysis of each scale showed that the dominant eigenvalues for the Self-efficacy (9 items, alpha value was .88), Intrinsic value (9 items, alpha value was .81), and Test anxiety (4 items, alpha value was .77), accounted for 44.70%, 34.90% and 46.14%, respectively (Lee et al., 2010). Initially, MSLQ was initially developed for college students, but it has proven suitable for use in primary and secondary schools, high schools, college students or adult learners in various countries to determine learning motivation (Jackson, 2018; Jakesova & Hrbáčková, 2014). In this study, the translation and slight rewording of the MSLQ were made to make it suitable for the present participants of upper primary students. Since the inventory was used among younger learners, the first part of the inventory (namely MLQ) was selected with 22 items and 3 factors in the form of a 5-point Likert scale.

Family Socioeconomic Status Regarding the socioeconomic status of the family, studies usually take family income and the education level of the parents as the main measure (Bradley & Corwyn, 2002). Since family income is considered relatively private and students cannot accurately estimate, family income is often chosen to reflect the family's economic situation to some extent. In the present study, family income was used as one of the indicators of family socioeconomic status. It was divided into five categories, including (1) cell phones, (2) TVs, (3) computers, (4) cars, and (5) bathrooms. Besides, parental education level was used as another indicator to evaluate students' family socioeconomic status.

The above questionnaires were distributed to students by research assistants in students' self-study class. One questionnaire was carried out per day, but the total time range was not more than four days. Each questionnaire took a student about 30 minutes to complete and was tagged with the student ID. At the beginning of each questionnaire, students were required to read an informed consent to understand that the questionnaire was for study purposes only, and their names and personal responses would not be disclosed. Students who could accept the informed consent form confirmed with their signature and completed the questionnaire.

Participants and Procedure

This study took the 4th, 5th, and 6th grade students as the participants under the background of senior primary school in People's Republic of China. The participants were selected based on the following considerations. In primary school, students are not under much learning pressure and have fundamental interests in STEM content. Students at upper primary school start to have relatively stable self-knowledge and can make relatively independent judgments on the present survey items. The participant sample consisted of 900 primary school students from 3 different public primary schools. After carefully sorting out and deleting the invalid questionnaires, 845 were effective. Of the participants 43.8% were girl students (N=370) and the other 56.2% were boy students (N=475). They were 23.6% in the 4th grade, 49.0% in the 5th grade, and 27.5% in the 6th grade. The detailed information is given in Table 1.

https://doi.org/10.33225/jbse/22.21.1052

Table 1
The Detailed Information of Participants

Grade	*N*		Totally	The percent (%)
	Girl	Boy		
4th grader	123	76	199	23.6
5th grader	212	202	414	49.0
6th grader	140	92	232	27.5
Totally	475	370	845	-

The data were collected from December 2021 to February 2022. The questionnaires were distributed by the research assistant with the help of teachers in the primary school. The research assistant read out the instructions to explain the aims of the test. Students are informed that their names will not appear in the study and their privacy will be protected. Then, students were given 30 minutes to fill out the questionnaires. Those who did not complete the test or failed the polygraph question were not included in the following analysis.

Data Analysis

The relational screening model can be used to determine the variation between two or more variables and the extent of this change (if any) (Karasar, 2012). In this study, the model was tested with Structural Equation Modeling (SEM) with Mplus 8.0 software. The maximum likelihood estimation technique (ML) was used for parameter estimation analysis, in which CFI, TLI, RMSEA, and SRMR fit indices were used to evaluate the model's fit. According to the standardized path coefficient in the Structural Equation Model, the study analyzed the direct effect of learning motivation and metacognition on STEM attitude. Then, with the help of the Bootstrap mediating test, the study also confirmed the mediating effect of metacognition in the model through the scope of 95% confidence interval. In addition, the maximum likelihood robust estimator (MLR) was used to test the moderating effect with the convergence of .01.

Research Results

Descriptive Statistics for the Variables

Table 2 presents descriptive statistics including skewness values (-1.237 ~ .889) and kurtosis values (-1.283 ~ 1.315), which indicate that the model satisfies the univariate normality assumption (Kline, 2015).

Table 2
Descriptive Statistics of Measurement Items

Item	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
Mathematics	1.000	5.000	3.215~3.712	1.229~1.69	-.585~.011	-1.009~-.42
Science	1.000	5.000	2.789~3.309	.641~1.402	-.188~.257	-.623~.811
Engineering & Technology	1.000	5.000	3.143~3.641	1.011~1.37	-.644~.012	-.921~.003
21st century skills	1.000	5.000	3.575~4.06	1.014~1.185	-.952~-.246	-.658~.239
Self-efficacy	1.000	5.000	3.334~4.207	.86~1.095	-1.223~-.176	-.482~1.315
Intrinsic Value	1.000	5.000	3.574~4.18	.982~1.385	-1.237~-.449	-.483~1.087
Exam anxiety	1.000	5.000	2.179~2.77	1.764~2.128	.255~.889	-1.283~-.474

https://doi.org/10.33225/jbse/22.21.1052

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Item	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
Cognitive knowledge	1.000	5.000	3.651~4.039	.861~1.37	-1.076~-.208	-.867~.397
Cognitive regulation	1.000	5.000	3.464~3.979	1.008~1.574	-.988~-.388	-.822~.268

Measurement Models

CFA established the fit of the measurement model and the reliability of the indicators. Figures 2 and Figure 3 present the results of CFA performed to determine whether the original factor structures of the S-STEM, Jr.MAI (version B) and MLQ were validated in the context of this study. As shown in Figure 2, the original four dimensions of S-STEM were well maintained, and the factor loading values of the topics in each dimension in the sub-dimensions were greater than 0.55. Although there were some items with lower factor loading values, they were still retained in order to keep the original structure of the scale. For instance, the factor loading values of item 7 of science dimension and item 11 of twenty-first century skills dimension were lower than 0.6, but the deletion process is not adopted in the analysis. The CFA results of the Jr. MAI (version B) and MLQ are displayed in Figure 3 (a) and (b). The scale was well structured with each question having factor loading values greater than 0.6 on its respective dimension. Thus, the structure of the three scales was demonstrated to support the next step of the analysis.

Table 3 shows the goodness-of-fit values obtained by the CFA regarding the validity of the scales. The goodness-of-fit values obtained by the CFA regarding the S-STEM, Jr.MAI (version B), and MLQ suggest that all the theoretical structures were acceptable (Hu & Bentler, 1999; Kline, 2015).

Table 3
Goodness of Fit Values for Variables to be Included in Mode

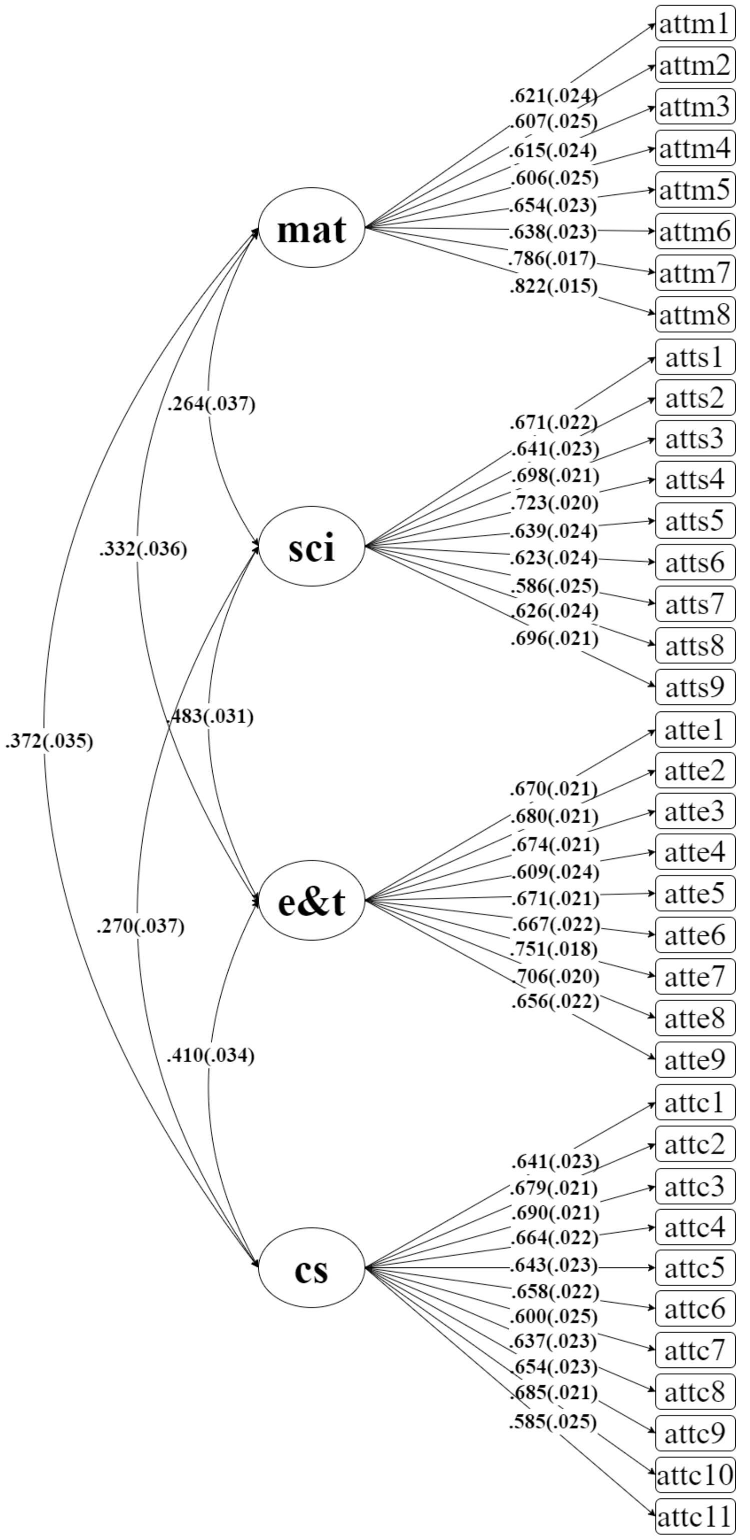
	χ^2	df	χ^2/df	SRMR	CFI	TLI	RMSEA
S-STEM	1591.968	615	2.588	.043	.926	.920	.052
Jr.MAI	379.068	130	2.916	.048	.960	.953	.033
MLQ	619.106	202	3.065	.049	.943	.935	.049

Table 4 illustrates the composite reliability, convergence validity and discriminate validity for measurement models. As shown in Table 4, almost all factor loadings approached or exceeded .6 and are significant in the model, indicating the correspondence with excellent quality (loading >.6). Reliability was examined by applying Cronbach's alpha, and the values of S-STEM, Jr.MAI and MLQ were .911, .923, and .880. After testing the overall fit between the variables, the composite reliability (CR) and average variance extracted (AVE) of the model were validated. The results indicated a good convergence of the multi-indicator potential constructs. However, the AVE was not greater than 0.50 for most dimensions, suggesting variance among their indicators in excess of residual variance.

Additionally, the square roots of AVE value were used to measure the discriminant validity among the dimensions of the scales. It was to ensure that each dimension had independent validity. If the marked number is larger than its adjacent number, it can prove that the dimension discrimination validity is good. As shown in Table 4, the square roots of all AVE in the S-STEM, ranging from .650 to .678, were greater than the correlations between each pair of two latent constructs (.264 to .483). The square root values of the mean number of extracted variances among the constructs were greater than the correlation coefficients between different constructs measured, indicating good discriminant validity in four dimensions. In the Jr.MAI, the two square roots of AVE were .657 and .663, and the correlation between each pair of two latent constructs was .847. It indicated that the questionnaire had general discriminate validity. In the MLQ, the square roots of AVE (.635 to .774), were below the correlations between the self-efficacy and intrinsic value. It indicated that the item distinction validity of these two variables was not significant. In terms of exam anxiety, its correlation value with other variables was negative, indicating that it was contrary to the effect of other variables on the whole.

https://doi.org/10.33225/jbse/22.21.1052

Figure 2
Confirmatory Factor Analysis for STEM Attitude Scale



Note: mat:Mathematics, sci:Science, e&t:Engineering & Technology, cs:21st Century Skills.

https://doi.org/10.33225/jbse/22.21.1052

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 4

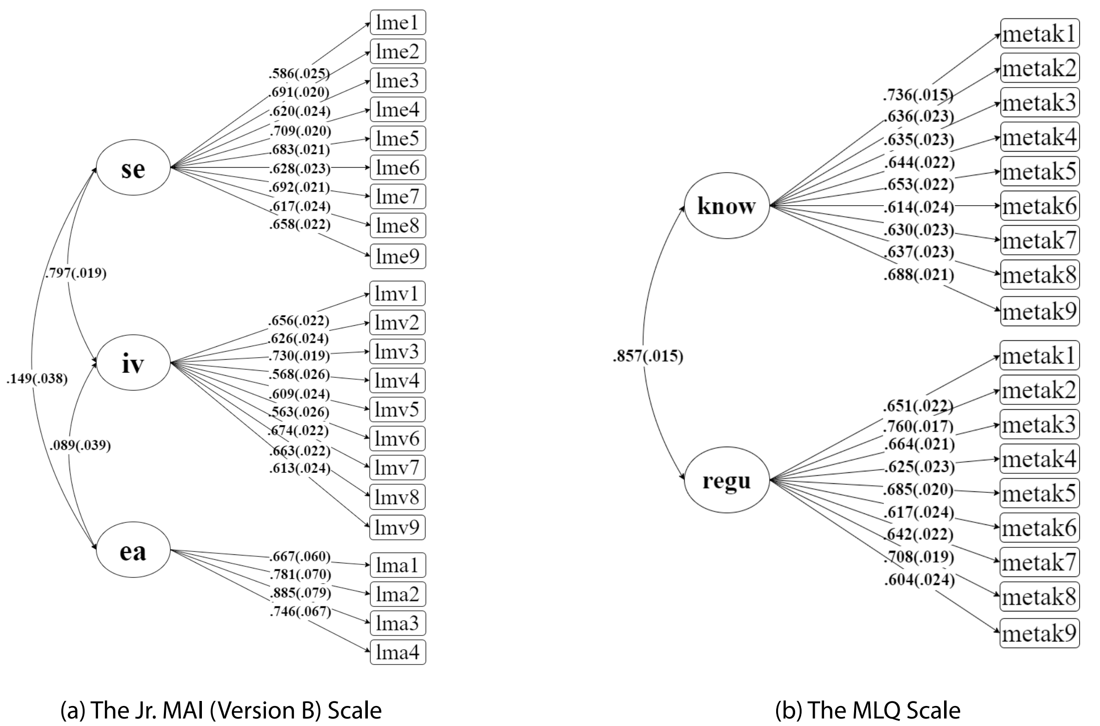
Composite Reliability, Convergence Validity and Discriminate Validity for Measurement Models

	Dimension	ITEM Reliability		Composite Reliability	Convergence Validity	Discriminant			
		Std.Loading	Cronbach's α	CR	AVE	Mat/KNOW/SE	Sci/REGU/IV	Eng/-/EA	CS/-/-
S-STEM	Mat	.604-.831	.877	.868	.454	.674			
	Sci	.581-.728	.872	.872	.432	.264	.657		
	E&T	.623-.747	.886	.884	.460	.332	.483	.678	
	CS	.585-.695	.892	.889	.423	.372	.270	.410	.650
Jr. MAI	KNOW	.632-.734	.874	.872	.431	.657			
	REGU	.604-.760	.873	.876	.440	.847	.663		
MLQ	SE	.586-.709	.872	.871	.429	.655			
	IV	.563-.730	.859	.858	.404	.797	.635		
	EA	.667-.885	.840	.855	.599	-.149	-.089	.774	

Note: Mat:Mathematics, Sci:Science, E&T:Engineering & Technology, Cs:21st Century Skills, KNOW: Cognitive Knowledge, REGU: Cognitive Regulation, SE:Self-Efficacy, IV:Intrinsic Value, EA:Exam Anxiety

Figure 3

Confirmatory Factor Analysis for Junior Metacognitive Awareness Inventory (the Jr. MAI) and Motivated for Learning Questionnaire (the MLQ)



(a) The Jr. MAI (Version B) Scale (b) The MLQ Scale

Note: know: Cognitive Knowledge, regu: Cognitive Regulation, se:Self-Efficacy, iv:Intrinsic Value, ea:Exam Anxiety

https://doi.org/10.33225/jbse/22.21.1052

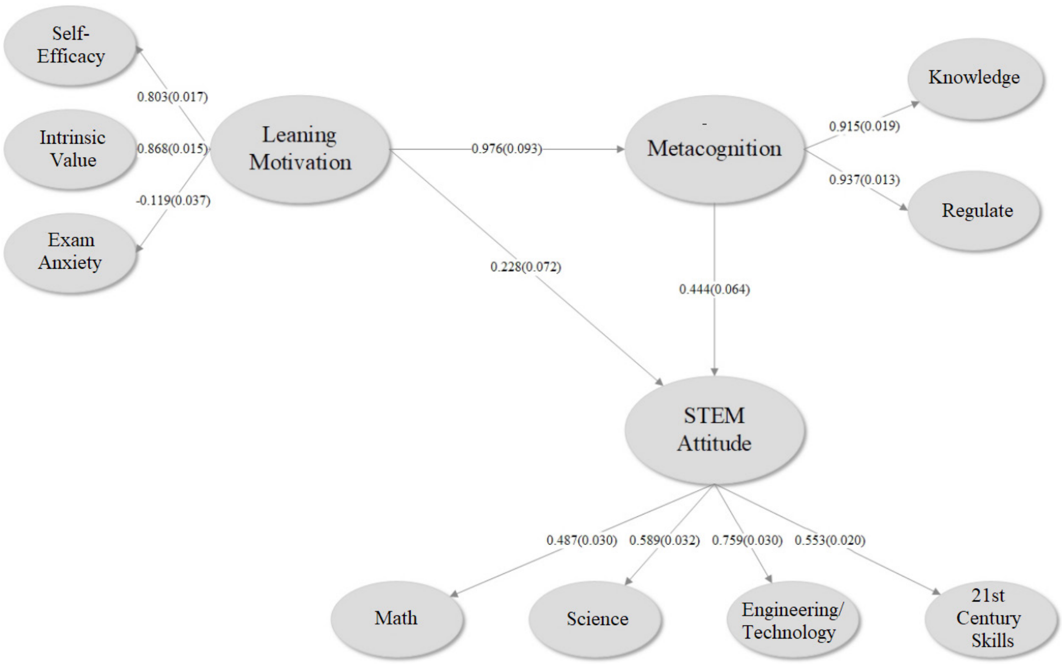
Structural Modeling

In the second stage, the relations among students' STEM attitude, metacognition, and learning motivation in the model were examined. In the present study, there were many latent variables in SEM, and each latent variable was presented by several observation variables. Therefore, this study adopted Item Parceling, taking the average of several indicators as new indicators when modelling. Compared with the method of using a single indicator, Item Parceling had many advantages, such as high reliability and commonality (Little et al., 2002), making data closer to the normal distribution, easier to converge, and better model fitting results. Table 5 shows the values obtained for the confirmatory factor analysis (CFA). The standardized model is represented in Figure 4. The results of CFA of the scale were χ^2/df=2.671 (<3, indicating a good fit), RSMEA=.053 (<.05, indicating a good fit), and the goodness of fit index close to .90 (CFI=.903, TLI=.894). It suggested an adequate fit to the data.

Table 5
Structural Equation Model Fit Indices

Fit index	Structural model values	Criterion
χ^2	1634.457	
df	612	
χ^2/df	2.671	Good below 3.0 Acceptable below 5.0
CFI	.903	Greater than .90
TLI	.894	Greater than .90
SRMR	.044	Below .05
RMSEA	.053	Good below .05 Acceptable below .08

Figure 4
The Structural Model of Effect on STEM Attitude



https://doi.org/10.33225/jbse/22.21.1052

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Direct Effects and Indirect Effects

The path coefficients of the relations among variables were examined and the results for the model are shown in Figure 4. Paths estimated in the model were significant ($p < .05$). Metacognition had high correlations between leaning motivation and STEM attitude. As seen in Figure 4, more favorable learning motivation was significantly associated with stronger STEM attitude and higher metacognition. Higher metacognition was significantly associated with stronger STEM attitude.

Table 6 shows the results for total direct and indirect effects. The results indicated that the learning motivation had a direct effect on the students' STEM attitude. The point estimate and p-value showed that learning motivation had a significant predictive effect on STEM attitude ($\beta_{\text{learning motivation} \rightarrow \text{STEM attitude}} = .228$, $p < .01$), with 95% confidence interval [.098, .382]. Indicators of the direct effect of favorable learning motivation on STEM attitude could be considered: one standard deviation unit increase in favorable learning motivation was associated with a .228 increase in STEM attitude.

Table 6
Direct Effects and Indirect Effects of the Statistical Model

	Point Estimate	Product of Coefficients			BOOTSTRAP 1000 TIMES 95% CI			
					percentile		bias corrected	
		S.E.	Est./*S.E.*	*p*	Lower 2.5%	Upper 2.5%	Lower 2.5%	Upper 2.5%
INDIRECT EFFECT								
Learning Motivation→ Metacognition →STEM Attitude	.433***	.070	6.181	< .001	.313	.587	.357	.679
DIRECT EFFECT								
Learning Motivation→ STEM Attitude	.228**	.072	3.151	.002	.098	.382	.016	.313

**p < .05, **p < .01, ***p < .001;*

Results for indirect effects indicated that students' metacognition level mediated the pathway between their learning motivation and STEM attitude. The nested alternative full mediation model was tested with Chi-square test, the result showed no full mediating effect, and the alternative model was a good fit for the data. The indirect effect of learning motivation on students' STEM attitude through metacognition was .433, and its 95% confidence interval was [.313, .578] without containing zero. The results showed that metacognition played a partial mediating role in the effect of learning motivation on STEM attitude. The positive indirect effects via students' metacognition level could be interpreted as follows: through the positive effect of metacognitive level, increasing favorable learning motivation by one standard deviation unit resulted in a .433 increase in STEM attitude. Therefore, through the mediation of metacognition, the correlation between learning motivation and STEM attitude was strengthened. Compared to the direct effect ($\beta_{\text{Learning Motivation} \rightarrow \text{STEM Attitude}} = .228$,), the indirect effect ($\beta_{\text{Learning Motivation} \rightarrow \text{Metacognition} \rightarrow \text{STEM Attitude}} = .433$) was more significant. Specifically, the effect of learning motivation on STEM attitudes was enhanced through the mediating role of metacognition.

Moderating Effect

Family socioeconomic status, which was used as a moderation variable, included family economic resources and parental educational level. The two variables were packaged together and divided into three groups based on average scores: high, medium, and low in the present study. The moderating effect was tested in relation between Learning motivation and STEM attitude. From Table 7, the result showed that there was no significant difference (pDIFF1 = .334, pDIFF2 = .485, pDIFF3 = .490) in the effect of learning motivation on STEM attitude among students with different family socioeconomic statuses.

https://doi.org/10.33225/jbse/22.21.1052

Table 8 shows the moderating effect of family socioeconomic status between metacognition and STEM attitude. The result suggested that students with higher family socioeconomic status had a stronger effect on their attitude towards STEM (β high = 1.200; β medium = 1.098; β low = .910). Therefore, it was proved that the moderating effect of family socioeconomic status in hypothesis 2 existed. There was a significant difference between highly representative students and low representative students (p < .001), and between medium representative students and low representative students (p < .01). While there was no significant difference between high and medium representative students (p = .101).

Table 7
Moderating Effect of the Statistical Model (Hypotheses 1)

	Point Estimate	Product of Coefficients			BOOTSTRAP 1000 TIMES 95% CI	
		S.E.	Est./*S.E.*	*p*	Lower 2.5%	Upper 2.5%
Moderating Effect						
High	.686*	.080	8.520	.019	.526	.849
Medium	.743***	.048	15.435	< .001	.651	.841
Low	.525***	.223	2.355	< .001	.006	.952
Contrast						
DIFF1 (M-L)	.218	.226	.967	**.334**	-.210	.714
DIFF2 (H-L)	.160	.229	.698	**.485**	-.264	.677
DIFF3 (H-M)	-.058	.084	-.690	**.490**	-.219	.108

*p < .05, **p < .01, ***p < .001

Table 8.
Moderating Effect of the Statistical Model (Hypotheses 2)

	Point Estimate	Product of Coefficients			BOOTSTRAP 1000 TIMES 95% CI	
		S.E.	Est./*S.E.*	*p*	Lower2.5%	Upper2.5%
Moderating Effect						
High	1.200***	.057	15.863	< .001	1.058	1.350
Medium	1.098***	.048	22.784	< .001	1.004	1.190
Low	.910***	.075	16.064	< .001	.811	1.045
Contrast						
DIFF4 (M-L)	.188**	.055	3.439	.007	.066	.287
DIFF5 (H-L)	.289***	.077	3.740	< .001	.132	.434
DIFF6 (H-M)	.102	.062	1.639	.101	-.015	.222

*p < .05, **p < .01, ***p < .001

Discussion

This study explored the relations among students' learning motivation, metacognition, and STEM attitudes, and examined the moderating effect of family socioeconomic status in these relations. The findings have shed light on some interesting insights.

https://doi.org/10.33225/jbse/22.21.1052

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

The Effect of Students' Learning Motivation on STEM Attitude

In the present study, it was found that learning motivation could significantly impact their STEM attitude, which verified previous hypothesis 1 (Lasagabaster, 2016; Wigfield & Eccles, 2000). According to the results of direct effects, students' STEM attitude was primarily affected by self-efficacy, intrinsic worth, and test anxiety. However, many previous studies focused on the impact of motivation on scientific attitude and career expectations (Mujtaba et al., 2018; Sheldrake, 2016), instead of integrating engineering & technology attitude and 21st century skills. The expression and measurement of STEM attitude in this study could easily reflect the situation between primary school students' learning motivation and learning attitude.

When students have a relatively positive learning motivation, they are more willing to participate in STEM courses or related informal course activities. Enrichment activities can spark students' interest in learning STEM and make them gain higher confidence in science and a sense of self-efficacy, leading to a positive emotional experience of STEM. High levels of test anxiety proved to be harmful (Wolf & Smith, 1995). But reasonable treatment of anxiety, which can further optimize students' STEM learning experience and improve their learning motivation, is ultimately manifested as a positive attitude towards STEM. The results of the present study showed that learning motivation has a positive result on students' STEM attitude.

Students' Metacognition Mediated the Pathway between Learning Motivation and STEM Attitude

Based on the research result, the mediating effect value of metacognition was significant in the mechanism between learning motivation on STEM attitude, indicating that metacognition is effective in mediating the effect of learning motivation on STEM attitude. It can be seen that metacognition is an important mechanism that cannot be ignored in affecting students' attitude towards STEM. The result verified Hypothesis 2 of this study. Studies showed that metacognition can strengthen students' learning motivation. If students fail to achieve their learning goals, they will process their cognitive knowledge in the cognitive system and conduct self-regulation (Jackson, 2018), which forms the metacognitive process of students (Schraw et al., 2006). When students have a relatively positive learning motivation, it is more likely for them to find solutions or learning strategies to solve their problems. In this process, students intentionally or unintentionally carry out the process of metacognition. Through multiple cycles, these self-regulation processes will in turn strengthen the level of students' learning motivation.

On the other hand, metacognitive strategies are considered to be related to STEM attitude (Akerson & Donnelly, 2008). Students who have a good command of metacognitive ability can better complete STEM tasks and bring a positive STEM experience. With a high metacognitive level, students will be more confident when facing STEM disciplines, and engage in learning with a positive attitude. Metacognition plays an essential role in enhancing students' STEM learning attitude (Thiede & Anderson, 2003). Therefore, metacognitive should be the key link needed to establish the connection between learning motivation and STEM attitude.

The Considerations Relating to Family Socioeconomic Status Difference

Through multi-group path analysis, it was found that there was no significant difference in the direct effect of learning motivation on STEM attitude among students with different family socioeconomic statuses. While the family socioeconomic status played a moderating role in the effect of metacognition on STEM attitude. Students with higher family socioeconomic status had a stronger effect on STEM attitude. Also, family socioeconomic status significantly promoted metacognitive ability (Maric & Sakac, 2020). The higher family socioeconomic status was, the higher the metacognitive ability was. Researchers have suggested that parental guidance and encouragement to children in family education positively impacted the development of metacognition (Pappas et al., 2003). Higher socioeconomic status was associated with better academic preparation and more opportunities (Alexander et al., 2012; Pomerantz et al., 2007). Family culture and parental expectations are of great significance to the generation and change of students' STEM attitude. Family material and economic investment provide children with various material supports, such as rich learning resources, a comfortable learning environment, and varied learning opportunities. These supports lay the foundation for students to participate in STEM activities and develop positive STEM attitude. The metacognitive transformation of positive STEM attitude has a higher conversion rate among students with rich family resources and parents with higher education levels. Blickenstaff (2005) had linked poor attitude towards STEM to the absence of scientists/engineers as role models. It can be seen that students' family

https://doi.org/10.33225/jbse/22.21.1052

socioeconomic status is an essential factor that moderates metacognition and affects STEM attitude (Blickenstaff, 2005).

Conclusions

In the present study, students' learning motivation affected and could predict their STEM attitude. Students' metacognitive level played a positive mediating role between learning motivation and STEM attitude. Thus, students' metacognition appears to play a more critical role than their learning motivation in improving students' STEM attitude. In addition, family socioeconomic status played a moderating role in the effect of students' metacognition on STEM attitude. It is believed that the support from parents and students' metacognition can be important to enhance their STEM attitude.

This study supported the view that learning motivation and metacognition were related to STEM attitude. When considering the positive effect on students' STEM attitude, appropriate metacognitive intervention objectives should be included in STEM teaching. Prior research literature has illustrated that metacognition does not automatically develop in all students (especially students at the low-end) without support. Identifying students with lower levels of metacognition and targeting them for early intervention efforts may be helpful in increasing students' motivation and STEM learning and thus reducing STEM pipeline leaks. In teaching practice, it is necessary to take metacognition as an important approach to STEM education and ensure that students' metacognitive skills play a role in improving STEM attitude and enhancing STEM learning. In addition, socioeconomic status is also a concern to improve children's STEM attitudes. Although parental educational background is difficult to break through, they can strive to have rich family resources, such as borrowing books from the library and spending more time with their children.

Limitations

There are several limitations that should be considered in the present study. First, as the current study was conducted in two typical types of primary schools, it is difficult to generalize the results to the entire population as the number of learners includes 845 primary school students. Follow-up research would address this limitation to adopt a well-designed sample, such as the two-phase hierarchical cluster design. Second, another limitation is that the survey was conducted by several different research assistants, and the support they provided to primary school students may have been slightly different, even though they had received targeted training. Third, although this study provides static analysis support for understanding the effect on students' STEM attitudes, it does not track the dynamic development and change of STEM attitudes during the growth of students. In order to avoid STEM pipeline leakage to a greater extent, a variety of dynamic comparison designs are needed in further studies.

Acknowledgement

The authors would like to acknowledge the help of the Editor and reviewers. The research is supported in part by the 2022 Guangdong Educational Science Planning Project (Special for Higher education) under the Grant No. 2022GXJK175, and 2020 Guangzhou Philosophy and Social Science Planning Fund of P.R. China under the Grant No. 2020GZQN20.

Declaration of Interest

The authors declare no competing interest.

References

Akerson, V. L., & Donnelly, L. A. (2008). Relationships among learner characteristics and preservice elementary teachers' views of nature of science. *Journal of Elementary Science Education*, *20*(1), 45-58. https://doi.org/10.1007/BF03174702

Al-Ansari, E. M. (2005). The dynamic interplay of student motivation and cognition in the college of education students at Kuwait University. *Social Behavior and Personality*, *33*(4), 341-350. https://doi.org/10.2224/sbp.2005.33.4.341

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education*, *96*(5), 763-786. https://doi.org/10.1002/sce.21018

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Ali, M. M., Yager, R., Hacieminoglu, E., & Caliskan, I. (2013). Changes in student attitudes regarding science when taught by teachers without experience with a model professional development Program. *School Science and Mathematics*, *113*(3), 109-119. https://doi.org/10.1111/ssm.12008

Allen-Ramdial, S. A., & Campbell, A. G. (2014). Reimagining the Pipeline: Advancing STEM Diversity, *Persistence, and Success. Bioscience*, *64*(7), 612-618. https://doi.org/10.1093/biosci/biu076

Archer, L., DeWitt, J.,Osborne, J.,Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habits: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881-908. https://doi.org/10.3102/0002831211433290

Ball, C., Huang, K. T., Cotten, S. R., & Rikard, R. V. (2017). Pressurizing the STEM pipeline: An Expectancy-Value Theory analysis of youths' STEM attitudes. *Journal of Science Education and Technology*, *26*(4), 372-382. https://doi.org/10.1007/s10956-017-9685-1

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory / Albert Bandura.

Beck, C.W. (2010). Home education: The social motivation. *International Electronic Journal of Elementary Education*, *3*, 71-81.

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education*, *17*(4), 369-386. https://doi.org/10.1080/09540250500145072

Bogdanovic, I., Obadović, D. Z., Cvjetićanin, S., Segedinac, M., & Budić, S. (2015). Students' metacognitive awareness and physics learning efficiency and correlation between them. *European Journal of Physics Education*, *6*(2), 18-30. https://doi.org/10.20308/ejpe.96231

Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology*, *53*(1), 371-399. https://doi.org/10.1146/annurev.psych.53.100901.135233

Bronfenbrenner, U. (1994). Ecological models of human development. *International encyclopedia of dducation* (Vol. 3, pp. 1643-1647). Elsevier.

Brown, A. L. (1977). Knowing when, where, and how to remember: A problem of metacognition. *Advances in Instructional Psychology*, *1*, 77-165.

Buxton, L. (1981). Do you panic about maths? *The Mathematical Gazette*, *65*(434), 300-300. https://doi.org/10.2307/3616613

Büyüköztürk Ş., Kılıç-Çakmak E., Akgün Ö. E., Karadeniz Ş., & Demirel F. (2012). Bilimsel araştırma yöntemi [Scientific research method]. https://avesis.medeniyet.edu.tr/yayin/d93be4a3-e3bb-42ae-8635-96946af53ee9/bilimsel-arastirma-yontemleri

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, *70*, 30-35.

Chang, W. Y., & Chang, I. Y. (2013). An investigation of students' motivation to learn and learning attitude affect the learning effect: A case study on tourism management students. *Anthropologist*, *16*(3), 457-463. https://doi-org.uottawa.80599.net/10.1080/09720073.2013.11891371

Deci, E. L., & Ryan, R. M. (1985). Education. *Intrinsic motivation and self-determination in human behavior*(Vol.9, pp.245-271). Springer. https://doi.org/10.1007/978-1-4899-2271-7_9

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, *11*(4), 227-268. https://doi.org/10.1207/S15327965PLI1104-01

Doerschuk, P., Bahrim, C., Daniel, J., Kruger, J., Mann, J., & Martin, C. (2016). Closing the gaps and filling the STEM pipeline: A multidisciplinary approach. *Journal of Science Education and Technology*, *25*(4), 682-695. https://doi.org/10.1007/s10956-016-9622-8

Eccles, J. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motives: Psychological and sociological approaches* (pp. 75-146). Free man.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, *53*, 109-132.

Faber, M., Unfried, A., Wiebe, E. N., Corn, J., Townsend, L. W., & Collins, T. L. (2013). Student attitudes toward STEM: The development of upper elementary school and middle/high school student Surveys. *Paper presented at 2013 ASEE Annual Conference & Exposition*, Atlanta, Georgia. https://doi.org/10.18260/1-2-22479

Flavell, J. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, *34*, 906-911. https://doi.org/10.1037/0003-066X.34.10.906

Hong, E., & O'Neil, H. F. (2001). Construct validation of a trait self-regulation model. *International Journal of Psychology*, *36*(3), 186-194. https://doi.org/10.1080/00207590042000146

Hoy, A. W. (2004). What do teachers know about self-efficacy? Paper presented at the *annual meeting of the American Educational Research Association*, CA.

Hu, L. t., & Bentler, P. M. (2008). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1-55. https://doi.org/10.1080/10705519909540118

Jackson, C. R. (2018). Validating and adapting the motivated strategies for learning questionnaire (MSLQ) for STEM courses at an HBCU. *Aera Open*, *4*(4). https://doi.org/10.1177/2332858418809346

Jakesova, J., & Hrbáčková, K. (2014). The czech adaptation of motivated strategies for learning questionnaire (MSLQ). *Asian Social Science*, *10*(12), 72. https://doi.org/10.5539/ass.v10n12p72

Kline, R. B. (2015). Principles and practice of structural equation modeling: Guilford publications.

Lasagabaster, D. (2016). The relationship between motivation, gender, L1 and possible selves in English-medium instruction. *International Journal of Multilingualism*, *13*(3), 315-332. https://doi.org/10.1080/14790718.2015.1105806

Lee, J. C., Zhang, Z. H., & Yin, H. B. (2010). Using multidimensional Rasch analysis to validate the Chinese version of the Motivated Strategies for Learning Questionnaire (MSLQ-CV). *European Journal of Psychology of Education*, *25*(1), 141-155. https://doi.org/10.1007/s10212-009-0009-6

https://doi.org/10.33225/jbse/22.21.1052

Little, T. D., Cunningham, W. A., Shahar, G., & Widaman, K. F. (2002). To parcel or not to parcel: exploring the question, weighing the merits. *Structural Equation Modeling: A Multidisciplinary Journal*, *9*(2), 151-173. https://doi.org/10.1207/S15328007SEM0902_1
Luo, T., Wang, J., Liu, X. F., & Zhou, J. P. (2019). Development and application of a scale to measure students' STEM continuing motivation. *International Journal of Science Education*, *41*(14), 1885-1904. https://doi.org/10.1080/09500693.2019.1647472
Maric, M., & Sakac, M. J. (2020). Metacognition in preschool children-indicators, developmental and socio-educational differences. *Československá psychologie (Czechoslovak Psychology)*, *64*(1), 1-17. https://yadda.icm.edu.pl/yadda/element/bwmeta1.element.f4e52de1-d9cc-4364-9597-120ac856da54
Martin, M. O., Mullis, I. V., Foy, P., & Stanco, G. M. (2016). TIMES 2015 international results in science. *Chestnut Hill: TIMES &PURLS International Study Center*, Boston College.
Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology*, *82*, 60-70. https://doi.org/10.1037/0022-0663.82.1.60
Mujtaba, T., Sheldrake, R., Reiss, M. J., & Simon, S. (2018). Students' science attitudes, beliefs, and context: associations with science and chemistry aspirations. *International Journal of Science Education*, *40*(6), 644-667. https://doi.org/10.1080/09500693.2018.1433896
National Research Council (NRC). (2010). *Exploring the intersection of science education and 21st century skills: A workshop summary*. National Academies Press.
Neber, H., Schommer-Aikins, M. (2002). Self-regulated science learning with highly gifted students: The role of cognitive, motivational, epistemological, and environmental variables. *High Ability Studies*, *13*(1), 59-74. https://doi.org/10.1080/13598130220132316
Ning, H. K. (2019). The bifactor model of the junior metacognitive awareness inventory (Jr. MAI). *Current Psychology*, *38*(2), 367-375. https://doi.org/10.1007/s12144-017-9619-3
Özsoy, G., Memiş, A., & Temur, T. (2017). Metacognition, study habits and attitudes. *International Electronic Journal of Elementary Education*, *2*(1), 154–166. https://iejee.com/index.php/IEJEE/article/view/263
Pappas, S., Ginsburg, H. P., & Jiang, M. Y. (2003). SES differences in young children's metacognition in the context of mathematical problem solving. *Cognitive Development*. *18*(3), 431-450. https://doi.org/10.1016/S0885-2014(03)00043-1
Pintrich, P. R., Roeser, R. W., & Groot, E. A. (1994). Classroom and individual differences in early adolescents' motivation and self-regulated learning. *Journal of Early Adolescence*, *14*, 139-161. https://doi.org/10.1177/027243169401400204
Pintrich, P. R. (1989). The dynamic interplay of student motivation and cognition in the college classroom. In C. Ames and M. Maehr (Eds.), A*dvances in motivation and achievement: Motivation-enhancing environments* (Vol. 6, pp. 117-160). J AI Press.
Pintrich, P. R., & Schunk, D. H. (2002). Motivation in education: Theory, research, and applications: Prentice Hall.
Pomerantz, E., Moorman, E. A., & Litwack, S. D. (2007). The how, whom, and why of parents' involvement in children's academic lives: More is not always better. *Review of Educational Research*, *77*, 373-410. https://doi.org/10.3102/003465430305567
Rittmayer, A. D., & Beier, M. E. (2008). Commitment and success in science, technology, engineering, and mathematics: Exploring gender, self-efficacy, and experiences as predictors. *Poster presented at the 20th Annual Convention of the Association for Psychological Science*, IL.
Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. *Research in Science Education*, *36*(1-2), 111-139. https://doi.org/10.1007/s11165-005-3917-8
Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology*, *19*(4), 460-475. https://doi.org/10.1006/ceps.1994.1033
Sheldrake, R. (2016). Students' intentions towards studying science at upper-secondary school: the differential effects of under-confidence and over-confidence. *International Journal of Science Education*, *38*(8), 1256-1277. https://doi.org/10.1080/09500693.2016.1186854
Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom - Reciprocal effects of teacher-behavior and student engagement across the school year. *Journal of Educational Psychology*, *85*(4), 571-581. https://doi.org/10.1037/0022-0663.85.4.571
Sperling, R. A.,Howard, B. C., Miller, L. A., & Murphy, C. (2002). Measures of children's knowledge and regulation of cognition. *Contemporary Educational Psychology*, *27*(1), 51-79. https://doi.org/10.1006/ceps.2001.1091
Sungur, S. (2007). Modeling the relationships among students' motivational beliefs, metacognitive strategy use, and effort regulation. *Scandinavian Journal of Educational Research*, *51*(3), 315-326. https://doi.org/10.1080/00313830701356166
Tadayon, N. R. (2012). Bandura's social learning theory & Social cognitive learning theory. https://doi.org/10.13140/RG.2.2.20172.74887
Thiede, K. W., & Anderson, M. C. (2003). Summarizing can improve metacomprehension accuracy. *Contemporary Educational Psychology*, *28*(2), 129-160. https://doi.org/10.1016/S0361-476X(02)00011-5
Tseng, K. H., Chang, C. C., Lou, S. J., & Chen, W. P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, *23*(1), 87-102. https://doi.org/10.1007/s10798-011-9160-x
Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (s-stem). *Journal of Psychoeducational Assessment*, *33*(7), 622-639. https://doi.org/10.1177/0734282915571160
Vallerand, R., & Ratelle, C. (2002). Intrinsic and extrinsic motivation: A hierarchical model. *Handbook of Self-determination Research*, *128*, 37-63. https://doi.org/10.1177/0098628312437704
Vallerand, R. J., Fortier, M. S., & Guay, F. (1997). Self-determination and persistence in a real-life setting: toward a motivational model of high school dropout. *Journal of Personality and Social Psychology*, *72*(5), 1161-1176. https://doi.org/10.1037/0022-3514.72.5.1161
Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68-81. https://doi.org/10.1006/ceps.1999.1015

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Wolf, L. F., & Smith, J. K. (1995). The consequence of consequence: Motivation, anxiety, and test performance. *8*(3), 227-242. https://doi.org/10.1207/s15324818ame0803-3

Zimmerman, B. J., & Risemberg, R. (1997). Self-regulatory dimensions of academic learning and motivation. In *Handbook of academic learning* (pp. 105-125): Elsevier. https://doi-org.uconn.80599.net/10.1016/B978-012554255-5/50005-3

Received: *September 17, 2022* Revised: *November 04, 2022* Accepted: *December 01, 2022*

Cite as: Liu, S., Xu, S. R., Xiao H., & Zhou, S. (2022). Exploring effect on primary school students' STEM attitude determined via structural equation modeling. *Journal of Baltic Science Education*, *21*(6), 1052-1068. https://doi.org/10.33225/jbse/22.21.1052

Si-Jia Liu PhD, School of Physics and Telecommunication Engineering, South China Normal University, Guangzhou 510006, China.
E-mail: lius.j@outlook.com
ORCID: https://orcid.org/0000-0001-5925-0416

Shao-Na Zhou *(Corresponding author)* Associate Professor, School of Physics and Telecommunication Engineering, South China Normal University, Guangzhou 510006, China.
E-mail: zhou.shaona@m.scnu.edu.cn
ORCID: https://orcid.org/0000-0003-1455-5122

Shao-Rui Xu Researcher, School of Electronics and Communication, Guangdong Mechanical and Electrical Polytechnic, Guangzhou 510550, China.
E-mail: jayxee@hotmail.co.uk

Hua Xiao Professor, School of Physics and Telecommunication Engineering, South China Normal University, Guangzhou 510006, China.
E-mail: xiaoh@scnu.edu.cn