Research in Science & Technological Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/crst20

How are social context factors related to epistemological beliefs, motivations, and achievement in science? A serial mediation model

Xiaowei Tang

RESEARCH IN SCIENCE & TECHNOLOGICAL EDUCATION
https://doi.org/10.1080/02635143.2024.2355196

How are social context factors related to epistemological beliefs, motivations, and achievement in science? A serial mediation model

Xiaowei Tang

Faculty of Education, University of Macau, Taipa, Macao, China

ABSTRACT

Background: Epistemological beliefs and motivational factors are significant predictors of achievement in science.

Purpose: To understand how social context factors shape epistemological beliefs and motivational factors and how they pass the influences to achievement in science.

Sample: A population of ninth graders in an underdeveloped region of southwest China ($N = 2655$).

Design and Methods: With science achievement test scores and survey data from the sample, we built a structural equation model on how the students' epistemological beliefs and motivational factors mediate the effects of a set of social context factors on their achievement in science. Gender and rural-urban differences are also explored.

Results: Intrinsic motivation and epistemological beliefs significantly predicted achievements in science. Epistemological beliefs directly and indirectly affected achievement in science, with intrinsic motivation mediating its indirect effects. Among the social context factors, teacher influence and informal learning experiences positively predicted epistemological beliefs; family encouragement negatively predicted epistemological beliefs; only informal learning experiences directly affected intrinsic motivation. Significant rural-urban and gender differences were found.

Conclusion: Access to informal science learning experiences can play a crucial role in transforming the social environments in underdeveloped regions, promoting students' epistemological development and intrinsic motivation, and, in turn, their achievement in science. Fostering students' epistemological development may also require identifying and reconciling the conflicts between epistemological messages from home and school.

KEYWORDS
Epistemological belief; intrinsic motivation; social context factor; achievement in science; serial mediation model

Introduction

Epistemological beliefs and motivational factors are widely recognized as having significant effects on students' achievement in science (Chai et al. 2021; Guo et al. 2022; Katsantonis, McLellan, and Torres 2023; Kyriakopoulou and Vosniadou 2020). Recent studies show that epistemological beliefs and intrinsic motivation are the most potent

CONTACT Xiaowei Tang xiaowei.tang@gmail.com; xiaoweitang@um.edu.mo Faculty of Education, University of Macau, Avenida da Universidade, Taipa, Macao E3011, China

global predictors of student performance in the PISA 2015 science test (Guo et al. 2022; Organization for Economic Co-operation and Development ; She, Lin, and Huang 2019). The two also correlate. Motivational factors are often considered more proximal to academic achievement (e.g. Muis 2007). They partially mediate the relationship between epistemological beliefs and achievement in science (Karatas & Erden 2017; Guo et al. 2022). With epistemological beliefs controlled for, students' motivation can still predict their achievement in science (Addabbo, Di Tommaso, and Maccagnan 2016).

Previous scholars modeled the relationships among epistemological beliefs, motivational factors, and achievement in science. To make educational use of the known relationships, we still need to better understand how social contexts shape epistemological beliefs and motivational factors and how they can pass the influences to achievement in science. This study extends the modeling effort to involve student perceptions of potentially relevant *social context factors*. The goal is to explore through structural equation modeling (SEM) what contexts matter and how epistemological beliefs and motivational factors mediate their effects on student achievement in science. Since epistemological beliefs and motivational factors often display gender differences (Kim and Hamdan Alghamdi 2023), and the rural-urban achievement gap is the most significant predicament of Chinese education (Zhao et al. 2016), this study also explores the influences of gender and school location on the network of correlations.

Literature review

Motivation and achievement in science

Motivation refers to the inner state driving a person toward doing something (Deci & Ryan 2012). The construct is often divided into intrinsic and instrumental motivation in studies on learning and achievements (Ho and Liang 2015; She, Lin, and Huang 2019). Intrinsic motivation is characterized by an enjoyment of the learning action itself, while instrumental motivation denotes a pursuit of some associated outcome. According to Self-Determination Theory (SDT, Deci & Ryan, 2012), intrinsic motivation usually catalyzes high-quality learning. The effects of instrumental motivation, however, depend on whether an individual internalizes the value or utility of the pursued outcome, or gets compelled toward it by external forces.

Scholars in science education found that intrinsically motivated students tend to participate more in learning activities (P. Y. Lin and Schunn 2016), be more persistent and active in learning (Augustyniak et al. 2016), and employ more deep learning strategies (Chin and Brown 2000). These features make intrinsic motivation a strong and widely applied predictor of academic performance (Chai et al. 2021; Organization for Economic Co-operation and Development). Instrumental motivation, in contrast, shows weaker and more culturally dependent predicting power (Karakolidis, Pitsia, and Emvalotis 2019; Organization for Economic Co-operation and Development). For instance, Karakolidis et al. (2019) suggested that Greek students' instrumental motivation negatively predicted their achievement in science after controlling for intrinsic motivation. They attributed this to the 'increased anxiety and fear for failure (p.1470)' accompanying the high external incentive triggered by the utilitarian view prevailing in the Greek educational system. Similarly, Chai et al. (2021) found that instrumental motivation positively correlated with students' science achievement in Finland and Canada but not in Hong Kong, and for Singapore, the correlation was negative. They attributed the finding to cultural differences: Western societies usually encourage students to learn science for its future utility, whereas East Asian societies tend to encourage science learning for future test scores and social status. The latter may raise pressure instead of promoting learning for understanding (Liang, Lee, and Tsai 2010).

The complexity of instrumental motivation's effects on achievement can be explained through SDT (Deci & Ryan 2012). This theory considers intrinsic motivation inherent in human nature and central to learning, proposing that social contexts can shape intrinsic motivation by regulating perceived autonomy and competence. Social contexts making people feel more in control or enhancing their perceived competence can positively affect intrinsic motivation and learning outcomes. Contexts thwarting autonomy or promoting perceived incompetence would have the opposite effects. When instrumental motivation represents the drive toward future test scores and social status in a competitive environment, it can lead to reduced perceived autonomy and prompt incompetence, undermining intrinsic motivation. This study targets a Chinese student population in an underdeveloped region of southwestern China. One would expect the social contexts to be more aligned with the East Asian tradition. Based on the above literature, we generate the following hypothesis:

H1: Intrinsic motivation may positively predict student achievement in science, whereas instrumental motivation may not.

Epistemological beliefs and achievement in science

Epistemological beliefs refer to personal takes on the nature of knowledge and knowing (Hofer and Pintrich 1997). Personal epistemology can be conjectured as a unidimensional construct (Kuhn, Cheney, and Weinstock 2000) or manifold resources functioning on multiple layers of contexts (Merk et al. 2018). Studies on how epistemological beliefs predict achievement in science mostly adopt unsynchronized multidimensional conceptualization (Hofer and Pintrich 1997; Schommer 1993).

Schommer's (1993) work and Hofer and Pintrich's (1997) epistemological theories are among the most widely adopted frameworks. The two overlap in attention to the tentativeness and source of scientific knowledge. Schommer's framework also covers beliefs on the speed of learning and innate abilities. Hofer and Pintrich (1997) argue that these two dimensions are more about learning than epistemology. Their framework contains two dimensions of knowing (*source* and justification) and two dimensions of knowledge (*certainty* and *simplicity*). Adopting Hofer and Pintrich's framework, Conley et al. (2004) develop a domain-specific instrument that measures epistemological beliefs in science. This widely-used instrument involves a) *source*, which measures how much scientific knowledge is attributed to external authorities; b) *justification*, which evaluates views on the role of empirical evidence and the process of justifying scientific claims; c) *certainty*, which assesses the belief in the correctness of scientific knowledge; and d) *development*, which assesses the belief in the tentativeness of scientific knowledge.

Accumulated evidence supports the link between epistemological beliefs and achievement in science (Chai et al. 2021; Greene, Cartiff, and Duke 2018; She, Lin, and Huang 2019). Studies suggest that epistemological beliefs can affect achievement in science by regulating cognitive and metacognitive learning strategies, triggering interest, and preparing students for conceptual changes (Chiou, Lee, and Tsai 2013; Muis 2007). According to Muis' (2007) theoretical model, epistemological beliefs condition how an individual defines a task and sets the learning goals and standards. Students with mature epistemological beliefs are more likely to be driven toward deep learning, which leads to better achievement.

The predicting power of epistemological beliefs varies in dimensions. Beliefs in development and justification dimensions best predict students' achievement in science, whereas the other two dimensions sometimes show negative correlations (Greene, Cartiff, and Duke 2018). PISA 2015's epistemological beliefs scale adopts the development and justification dimensions of Conley's et al. (2004) instrument. Studies exploring the PISA 2015 data also show that these two dimensions constitute one of the strongest predictors of students' performance across countries (Guo et al. 2022; She, Lin, and Huang 2019). We conceptualize epistemological beliefs in alignment and generated the following hypothesis:

H2: Epistemological beliefs in the development and justification dimensions could positively predict student achievement in science.

Epistemological beliefs, motivation, and achievement in science

The literature generally suggests a positive relationship between epistemological beliefs and motivational factors (Ho and Liang 2015; Liang, Lee, and Tsai 2010). While some scholars consider the possibility that intrinsic motivation can trigger an effort to understand science in depth and lead to epistemological development (Chen and Pajares 2010; Zhu 2019), most studies interpret such correlations the other way around. As Muis (2007) suggests, epistemological beliefs function by defining the learning task and setting the ground for other learning or motivational factors to come into play. The findings also demonstrate complex messages at the dimensional level. For instance, Liang et al. (2010) and Ho and Liang (2015) show that, for Taiwanese high-schoolers and science-major undergraduates, beliefs in the development and justification dimensions positively predict intrinsic motivation for science learning, as mediated by a constructivist conception of learning. In contrast, beliefs in the certainty dimension negatively predict intrinsic motivation, since a strong belief in the uncertain nature of science may lead to great anxiety in a learning-to-test environment and undermine the learner's perceived competence.

Some researchers attempt to model the relationships among epistemological beliefs, motivational factors, and achievement. In an earlier study, Mason et al. (2013) show that both intrinsic and instrumental motivations could mediate the positive effects of epistemological beliefs on American fifth and eighth-graders achievement in science. Recent modeling efforts in this regard mostly draw on data from PISA 2015. Zhu (2019) suggests that students' intrinsic motivation can both directly and indirectly influence their achievement in science, with epistemological beliefs in development and justification dimensions mediating the indirect effects. Chai et al. (2021) show that intrinsic motivation, epistemological beliefs, and the interactions between the two can positively predict student achievement in science across countries, while the influence of instrumental motivation heavily depends on cultural contexts. Guo et al. (2022) show that students' epistemological beliefs have a stronger influence on their achievement in science than the motivational factors, indicating the involvement of paths beyond those mediated by the motivational factors. In light of the previous findings, the following hypotheses are naturally put forward:

H3: Epistemological beliefs might have direct and indirect effects on student achievement in science.

H4: Intrinsic and instrumental motivations could both mediate epistemological beliefs' indirect effects on achievement in science.

Social context factors that shape epistemological beliefs and motivation

There have been repeated calls to promote student achievement in science by developing their epistemological beliefs and motivations for science learning (Greene, Cartiff, and Duke 2018; T. J. Lin et al. 2013). Since these cognitive and attitude variables cannot be directly controlled from the outside, leveraging their influences on science learning and achievements would require a detailed understanding of how they get shaped by the external contexts and how they can pass the influences from external contexts to student learning and achievement in science.

According to social cognitive theory (Bandura 1986), we observe and learn from others through various social interactions. When students build their beliefs and attitudes toward science, they may imitate the role models set by the adults, align with the views of their parents or the peer group they identify with, or develop personal understandings based on experiences within various settings (Owen et al. 2008; Soltani 2020). Parents, teachers, and peers make up the major social groups learners commonly observe and interact with, while home, classroom, and informal learning contexts constitute the major settings where such interactions unfold. Together they form the major social contexts that shape students' learning behaviors and achievement (Soltani 2020).

Early studies highlight the influences from home, school, and peer on epistemological beliefs (Belenky et al. 1986; Kuhn, Cheney, and Weinstock 2000). Through interactions, parents can convey their personal epistemic stance and mold their children's epistemic behaviors (Luce, Callanan, and Smilovic 2013). Parents' encouragement of independent thinking and decision-making can facilitate the development of more sophisticated epistemological beliefs (Schommer 1993). School curriculum and teaching pedagogy can also convey epistemological messages. A learner used to knowledge transmission tend to believe that knowledge is changeless and coming from authorities. In contrast, students with rich inquiry learning experiences tend to view knowledge as tentative and see themselves as sources of knowing (Conley et al. 2004). Students can also attain epistemological understandings through peer interactions, as those with mature epistemological beliefs tend to play dominant roles in learning activities (Schommer 1995; Windschitl 1997).

Later studies consider students' epistemological beliefs as shaped by their participation in multiple epistemic systems (Greene, Cartiff, and Duke 2018), including informal learning environments such as museums and the Internet (Buehl and Fives 2016). Different systems can vary significantly in epistemological norms, and the learners need to reconcile the differences or make choices when developing their own beliefs (Tabak and Weinstock 2008).

Socioeconomic status (SES) and gender also have roles in this. Students from high SES families are more likely to view science as tentative (Ozkal et al. 2010). While some reported no gender difference (Buehl and Alexander 2005; Conley et al. 2004), others identified varied gender-related patterns. Some suggested that males tend to hold tentative views of knowledge and play active roles in knowing (Ozkal et al. 2010), while others found females more sophisticated in their beliefs about the nature of learning (Hofer 2000; Neber and Schommer-Aikins 2002).

Similar social context factors also shape students' motivations in science learning. Owen et al. (2008) found that science class experience, family inclination, and peer inclination all predict whether students see science as fun. Parents' involvement in schoolwork, interest in science, and encouragement for engagement in science can facilitate students' interest in science (Dabney, Chakraverty, and Tai 2013). Science teachers who encourage students to learn (Aktan 2019) and classroom environments that afford active participation can contribute to their intrinsic motivation (Christidou 2011). The influence of peer attitudes in childhood is less significant than that of teachers and parents but may increase towards middle grades (Vedder-Weiss & Fortus, 2013). Informal learning experiences can also play a significant role, promoting intrinsic motivation by enhancing perceived autonomy in what to learn (Crowley, Pierroux, and Knutson 2014). Besides, male students are often reported as higher in intrinsic motivation (Meece, Glienke, and Burg 2006), while females as higher in instrumental motivation (DeBacker and Nelson 2000).

Lamb et al. (2012) developed an instrument for surveying five contextual dimensions accounting for motivations in science learning: family encouragement, teacher influence, classroom experience, peer influence, and informal learning experience. These dimensions cover what the existing literature identified as the most influential social context factors (see the above review). To maximize our chance of capturing how social contexts shape student epistemological beliefs and motivations, we adopt this instrument as a measure of the social context factors, generating the following hypotheses:

H5: Every social context factor could positively predict student intrinsic motivation and instrumental motivation.

H6: Every social context factor may positively predict epistemological beliefs.

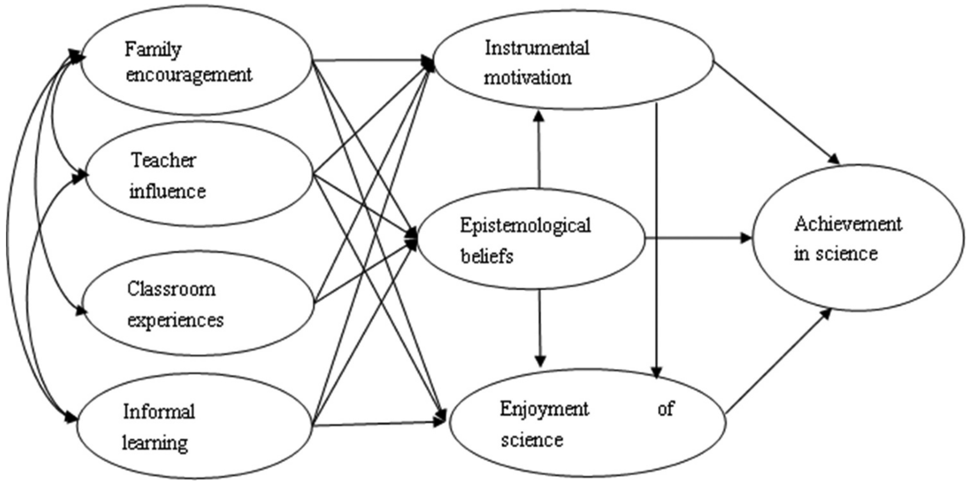


Figure 1. The hypothetical network of correlations.

H7: Epistemological beliefs can mediate social context factors' effects on student achievement in science.

H8: Epistemological beliefs might mediate social context factors' effects on intrinsic and instrumental motivations.

The initial model

The initial model for this exploratory SEM builds upon the hypotheses generated above (see Figure 1). Based on the literature about social context influences (e.g. Soltani 2020), the model sets five major social context factors (Lamb et al. 2012) as correlated independent variables that can directly predict intrinsic motivation, instrumental motivation, and epistemological beliefs. Informed by SDT (Deci & Ryan, 2012) and empirical literature (e.g. Chai et al. 2021), the model sets intrinsic and instrumental motivation as interacting factors directly correlating with achievement in science for the initial model, while keeping in mind that instrumental motivation may have no effect or negative effect in Asian culture (Liang, Lee, and Tsai 2010). Based on Muis' (2007) suggestion that motivational factors are more proximal to academic achievement than epistemological factors, the model set epistemological beliefs as both directly and indirectly correlating with achievement in science (Guo et al. 2022), with the two motivational factors mediating the indirect correlation. The paths that show no significance would be removed in modeling later.

Materials and methods

Participants and procedures

The scientific literacy test and the surveys were administered to all the 9th graders (N = 3170) in a prefecture-level division of a southwestern province in China. The test took 50 minutes, and all three surveys took 10 minutes. The data collection took place at the beginning of the 2021 fall semester, so the results represent the academic achievements of Grade 8 students. After removing cases with missing values in the survey items, the final sample size is 2655 cases (83.8% of the original cases), with 1320 males and 1333 females, 524 from urban schools, and 2116 from rural schools. 15 students did not report their school type. Informed consents were obtained for the data to be used in this study.

Measures

Achievement in Science

The 35-item scientific literacy test was part of an official assessment of the local education quality. It was designed by researchers with experience designing test items for the National Assessment of Compulsory Education Quality in China. In terms of content, the test design followed the science curriculum standards for elementary and middle school at the time, covering the domains of life science (11 items), physical science (12 items), earth and space science (8 items), as well as nature of science (4 items). In terms of scientific competencies, it adopted the categories suggested by PISA 2015, namely explaining phenomena scientifically (EXP, 10 items), evaluating and designing scientific inquiry (INQ, 16 items), and interpreting data and evidence scientifically (INT, 9 items). In terms of cognitive demand, it involved items on low (12 items), medium (14 items), and high (9 items) levels, also as defined by the PISA 2015 framework. The percentage makeup of the categories was determined through two rounds of the Delphi method with a group of 24 experts. After piloted and revised, the final test showed reasonable reliability (Cronbach's $\alpha = 0.704$). In modeling, the three scientific competency categories were used as the components of achievement in science.

Social context factors

We adopted the 19-item Science Interest Survey to measure self-reported contextual features that 'provide the most influence on students' pursuits of science' (Lamb et al. 2012, 645). These contextual features were denoted as extrinsic factors in the original work. In this study, we shifted to the term *social context factors* instead to avoid the potential confusion with extrinsic motivation. The survey contains five subscales, namely family encouragement (5 items, e.g. 'My family has encouraged me to study science'.), peer attitudes (3 items, e.g. 'My friends do not like science'.), teacher influence (4 items, e.g. 'My science teachers have encouraged me to learn about science'.), informal learning experiences (3 items, e.g. 'Visiting science museums and exhibits makes me want to learn more about a science topic'.), and science classroom experiences (4 items, e.g. 'The topics taught in my science class are important in the real world'.). The original survey was on a five-point Likert scale. We changed it to a four-point Likert scale, removing the mid-point to avoid social desirability bias (Garland 1991). The survey generated acceptable reliability and reasonable CFA results when piloted.

Epistemological beliefs

In alignment with the suggestions of previous literature (Greene, Cartiff, and Duke 2018) and PISA 2015, the development (6 items) and justification (9 items) subscales of Conley's et al. (2004) survey were adopted to measure the students' epistemological beliefs. The original five-point Likert scale was changed to a four-point Likert scale.

Intrinsic motivation and instrumental motivation in science

Motivational factors were measured with PISA 2015 scales (OECD 2017) on enjoyment of science (5 items) and instrumental motivation (4 items). Both were on a four-point Likert scale. A higher score on enjoyment of science indicates stronger intrinsic motivation in science learning. A higher score on instrumental motivation suggests stronger motivation by the utility of science.

Demographic variables

Besides the scientific literacy test and the survey items, we also collected student information on gender, school location (urban/rural), parental education levels, and science-related school arrangements, such as whether their science teachers are professional, how often they have lab sessions, whether their science lessons are often occupied by other subjects, and how often their schools organize field trips to museums or science centers. Such information allowed further modeling efforts and helped explain the findings later.

Statistical analysis

SPSS was used for data management, descriptive statistics of key variables, non-rotated factor analysis checking for common method bias, correlational analysis checking for collinearity issues, *t*-tests, and reliability tests. AMOS was used for validity tests through CFA andSEM. All the key variables were nondimensionalized. The significance level of all the tests was set at $\alpha = 0.05$. Path significance is determined based on whether the confidence interval contains 0.

Results

The measurement model

The reliability and validity of all the measures have been tested before the data is incorporated for SEM. The measure of social context factors demonstrated acceptable overall reliability (Cronbach's $\alpha = 0.87$) but a low fit in confirmatory factor analysis (CFA). The model was adjusted by removing the peer attitudes subscale, where all three items have factor loading lower than 0.5. A mismatch between the items and the sociocultural context could have caused this subscale's lack of homogeneity. The item 'My friends love to watch science programs on TV' can be outdated in the new media era; the item 'My friends view science as nerdy' rarely describes the case in China, where students successful in science can also be popular (Händel et al. 2014). The adjusted CFA model had a χ^2/df of 8.698. Following Wheaton's (1987) advice, when χ^2/df is larger than 3, other indicators are used to determine the goodness of fit, including RMSEA = 0.054 (lower than 0.06); SRMR = 0.038 (lower than 0.08); CFI = 0.936; NFI = 0.929; GFI = 0.961; and TLI = 0.920 (all greater than 0.9). The results indicated a good fit (Gefen, Straub, and Boudreau 2000). The same criteria applied to all the model fitness judgments throughout the study.

The measure of epistemological beliefs showed acceptable reliability overall (Cronbach's $\alpha = 0.89$) and on each subscale (Cronbach's $\alpha = 0.74$ for the development dimension; Cronbach's $\alpha = 0.89$ for the justification dimension). The CFA indices ($\chi^2/$

df = 6.587; RMSEA = 0.046; SRMR = 0.031; CFI = 0.964; NFI = 0.958; GFI = 0.970; TLI = 0.958) demonstrated a good fit.

The motivation measures also showed acceptable reliability (Cronbach's $\alpha = 0.87$ for enjoyment of science; Cronbach's $\alpha = 0.81$ for instrumental motivation). Their CFA indices ($\chi^2/df = 4.255$; RMSEA = 0.035; SRMR = 0.017; CFI = 0.992; NFI = 0.990; GFI = 0.991; TLI = 0.989) demonstrated a good fit.

Common method bias test

The common method of bias among the survey variables was investigated through an unrotated factor analysis using all the associated items. The test produced six factors with characteristic roots larger than 1, with the first factor explaining 30.02% of the variation (less than the critical standard of 40%), indicating no serious common method bias among the variables. The correlation coefficients between all the studied variables fell in the range from 0.15 to 0.66 on the significance level of $p < 0.001$ (see Table 1), suggesting no collinearity problem.

Demographic differences

In terms of gender, *t*-tests showed that male students scored significantly higher than female students in achievement in science ($t = 6.18$, $p < 0.001$), enjoyment of science ($t = 3.01$, $p < 0.01$), and instrumental motivation ($t = 2.06$, $p < 0.05$). No significant gender differences were found in epistemological beliefs and social context factors. In terms of rural-urban comparison, urban students scored significantly higher than rural students in all measures. See Table 2 for details. These significant differences signal the necessity of exploring modeling variations based on gender and urban-rural differentiation.

Structural equation model

The initial model resulted in reasonable fit indices ($\chi^2/df = 5.160$; RMSEA = 0.040; SRMR = 0.033; CFI = 0.946; NFI = 0.934; GFI = 0.949; TLI = 0.938), yet with many

Table 1. Descriptive statistics and correlations among the variables.

Var.	*M*	*SD*	DE	JU	ES	IM	FE	TE	SC	IN	INQ	EXP	INT
DE	2.95	0.44	-										
JU	3.22	0.50	0.59	-									
ES	2.94	0.59	0.36	0.51	-								
IM	2.88	0.61	0.34	0.44	0.61	-							
FE	2.81	0.55	0.26	0.40	0.65	0.54	-						
TI	3.25	0.58	0.31	0.49	0.56	0.43	0.55	-					
SC	3.14	0.56	0.28	0.47	0.60	0.44	0.55	0.66	-				
IN	2.91	0.60	0.26	0.41	0.63	0.50	0.58	0.46	0.54	-			
INQ	19.27	6.94	0.22	0.27	0.28	0.20	0.20	0.23	0.24	0.22	-		
EXP	14.20	5.57	0.18	0.22	0.24	0.18	0.15	0.16	0.18	0.19	0.46	-	
INT	11.29	5.21	0.20	0.23	0.26	0.17	0.19	0.21	0.20	0.22	0.47	0.38	-

The correlation coefficients are all significant ($p < 0.001$). M=mean; SD=standard deviation; DE=development; JU=justification; ES=enjoyment of science; IM=instrumental motivation; FE=family encouragement; TI=teacher influence; SC=science classroom experiences; IL=informal learning experiences; INQ=evaluate and design scientific inquiry; EXP= explain phenomena scientifically; INT=interpret data and evidence scientifically. The same abbreviations apply to other tables and figures.

Table 2. Gender differences and rural-urban differences.

	Achievement		Enjoyment of science		Instrumental motivation		Epistemological beliefs		Extrinsic factors	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Male	48.78	15.79	14.87	3.06	11.62	2.47	46.59	6.94	48.21	7.78
Female	45.31	12.95	14.52	2.84	11.42	2.49	46.73	5.88	48.45	7.12
T	6.18***		3.01**		2.06*		−0.56		−0.84	
Urban	51.93	15.20	15.58	3.24	12.00	2.67	48.20	6.80	50.39	8.31
Rural	45.83	14.13	14.47	2.84	11.41	2.37	46.28	6.28	47.82	7.15
T	8.33***		7.16***		4.43***		5.88***		6.51***	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

insignificant path coefficients. The insignificant paths were removed stepwise, starting with the one with the highest *p* value. A variable would be removed if all its associated paths were removed. Through this process, instrumental motivation and the social context factor of science classroom experience were removed, resulting in a final model that fits well with the data (See Figure 2. $\chi^2/df = 5.285$; RMSEA = 0.040; SRMR = 0.031; CFI = 0.957; NFI = 0.948; GFI = 0.963; TLI = 0.951).

This model turned out to be fully mediated. First, enjoyment of science can directly predict achievement in science ($\beta = 0.27$, $p < 0.001$), while epistemological beliefs can either directly ($\beta = 0.24$, $p < 0.001$) or indirectly predict achievement in science through the mediation of enjoyment of science ($\beta = 0.03$, $p < 0.001$). Second, family encouragement negatively predicts epistemological beliefs ($\beta = -0.33$, $p < 0.01$), while teacher influence and informal learning experiences positively predict epistemological beliefs (teacher influence: $\beta = 0.55$, $p < 0.001$; informal learning experience: $\beta = 0.45$, $p < 0.001$). Third, informal learning experience is the only social context factor directly predicting enjoyment of science ($\beta = 0.83$, $p < 0.001$). Put together, there are seven significant mediated paths (see Table 3). Each social context factor's effect on achievement in

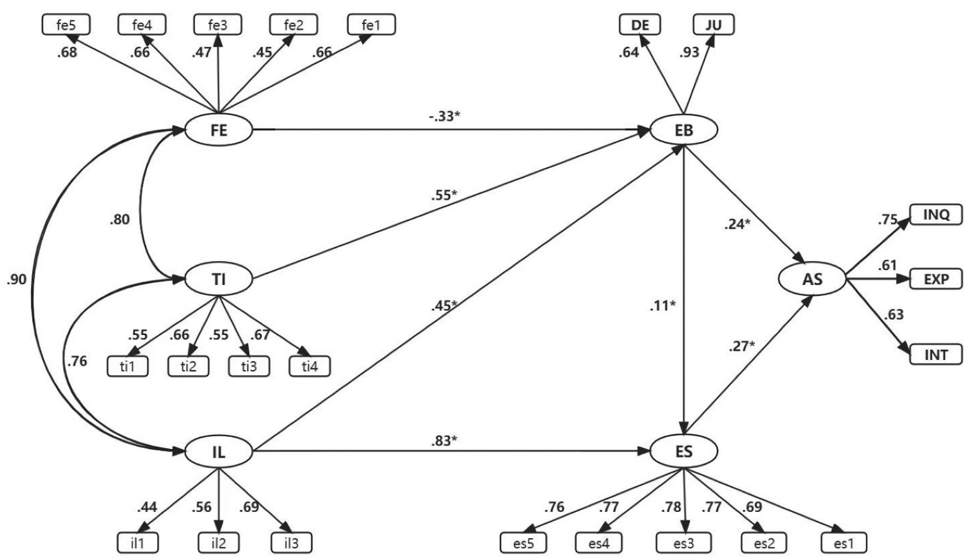


Figure 2. Structural equation model on the mediated relationships between extrinsic factors and achievement in science.

Table 3. Mediating effects with bootstrapping for the whole sample.

Path	Boot SE	Effect value	95% CI	
			Lower limit	Upper limit
FE →EB→AS	0.036	−0.079**	−0.158	−0.013
FE→EB→ES→AS	0.004	−0.006*	−0.017	−0.001
TI→EB→AS	0.023	0.128**	0.087	0.177
TI→EB→ES→AS	0.006	0.013*	0.005	0.030
IL→ES→AS	0.027	0.232**	0.172	0.286
IL→EB→AS	0.034	0.111**	0.052	0.185
IL→EB→ES→AS	0.004	0.011*	0.004	0.023
Total mediation	-	0.411	-	-
Total effect	-	0.411	-	-

*$p < 0.05$, **$p < 0.01$..

science can be mediated either by epistemological beliefs alone or with enjoyment of science as a secondary mediator. Besides, the positive relationship between the informal learning experience and achievement in science was largely mediated by enjoyment of science alone (β = 0.23, $p < 0.01$). In total, the model explained about 21% ($R^2 = 0.21$) of the variation in achievement. The social context factors explained 44% ($R^2 = 0.44$) of the variation in epistemological beliefs and 77% ($R^2 = 0.77$) of the variation in enjoyment of science.

For rural students ($N = 2116$), the model provided good model fit ($\chi^2/df = 4.099$, RMSEA = 0.038; SRMR = 0.031; CFI = 0.958; NFI = 0.945; GFI = 0.964; TLI = 0.951), with all seven paths staying significant and only slight shifts in parameters. For urban students (N = 524), while the χ^2/df value was reduced (mainly due to reduced sample size), most other fit indices were not as good ($\chi^2/df = 2.602$, RMSEA = 0.055; SRMR = 0.042; CFI = 0.936; NFI = 0.901; GFI = 0.918; TLI = 0.926). Family encouragement and informal learning experiences no longer showed significant correlations with epistemological beliefs. The correlation between epistemological beliefs and enjoyment of science dropped in significance (β = 0.13, $p < 0.05$). Only two out of the seven mediated paths remained significant: the positive relationship between teacher influence and achievement in science mediated by epistemological beliefs (β = 0.16, $p < 0.01$), and the positive relationship between informal learning experience and achievement in science mediated by enjoyment of science (β = 0.16, $p < 0.01$). See Table 4 and Figure 3 for details.

All fit index results of the model were at an acceptable level for both the male ($N = 1320$, $\chi^2/df = 3.22$, RMSEA = 0.041; SRMR = 0.033; CFI = 0.958; NFI = 0.940; GFI = 0.956; TLI = 0.951) and the female ($N = 1333$, $\chi^2/df = 3.316$, RMSEA = 0.042; SRMR = 0.034; CFI = 0.952; NFI = 0.933; GFI = 0.955; TLI = 0.944). For the male, the negative correlation between family encouragement and epistemological beliefs was insignificant. The two related mediated paths also became insignificant. For the female, the positive correlation between epistemological beliefs and enjoyment of science was greatly reduced. All paths with enjoyment of science as a secondary mediator became insignificant. The model became a parallel mediation model. See Table 5 and Figure 4 for details.

The positive correlation between epistemological beliefs and enjoyment of science for the male group ($\beta = 0.18$, $p < 0.001$) is significantly higher than that of the female group ($\beta = 0.07$, $p < 0.05$). The model explained 23.9% ($R^2 = 0.239$) of the total variation in male students' achievement in science, which is higher than that of the female group ($R^2 = 0.174$).

Table 4. Mediating effects with bootstrapping for urban and rural groups.

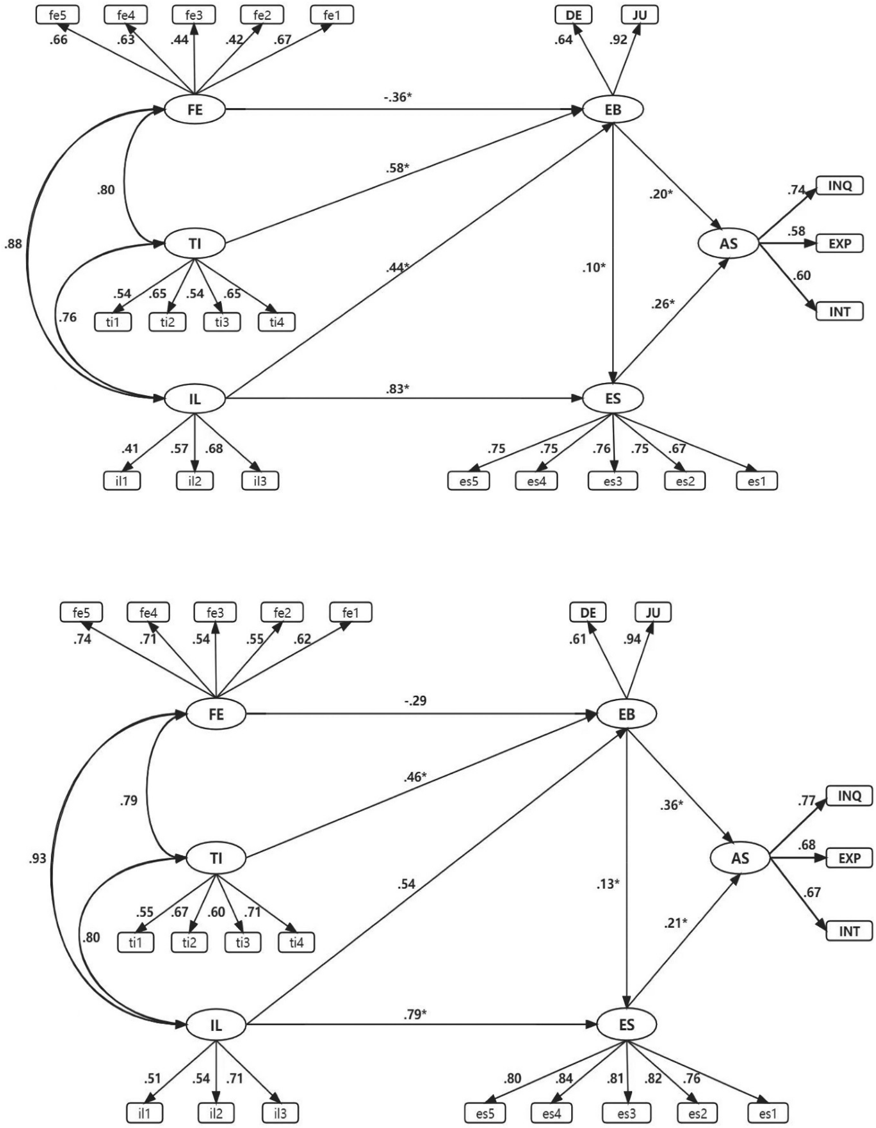
			95% CI	
Path	Boot SE	Effect value	Lower limit	Upper limit
Rural				
FE →EB→AS	0.037	−0.078*	−0.178	−0.026
FE→EB→ES→AS	0.004	−0.008*	−0.019	−0.002
TI→EB→AS	0.030	0.120**	0.069	0.188
TI→EB→ES→AS	0.006	0.015**	0.004	0.031
IL→ES→AS	0.031	0.219**	0.154	0.280
IL→EB→AS	0.034	0.093**	0.035	0.179
IL→EB→ES→AS	0.005	0.011**	0.004	0.023
Total mediation	-	0.372	-	-
Total effect	-	0.372	-	-
Urban				
FE →EB→AS	0.207	−0.190	−0.605	0.129
FE→EB→ES→AS	0.037	−0.024	−0.104	−0.019
TI→EB→AS	0.064	0.164**	0.030	0.279
TI→EB→ES→AS	0.008	0.012	−0.003	0.031
IL→ES→AS	0.066	0.160**	0.044	0.284
IL→EB→AS	0.227	0.289	−0.009	0.814
IL→EB→ES→AS	0.023	0.016	−0.013	0.041
Total mediation	-	0.324	-	-
Total effect	-	0.324	-	-

*$p < 0.05$, **$p < 0.01$.

Discussion

Aligning with previous findings (e.g. Chai et al. 2021; Guo et al. 2022; Katsantonis, McLellan, and Torres 2023), especially those on East Asian students (Chai et al. 2021; Liang, Lee, and Tsai 2010), this study suggested that intrinsic motivation and epistemological beliefs could significantly predict student achievement in science, while instrumental motivation hardly had an impact. It also showed that epistemological beliefs have direct and indirect effects on achievement in science, with intrinsic motivation mediating its indirect effects, which, again, supports previous findings (Guo et al. 2022; She, Lin, and Huang 2019). Beyond that, this study found that teacher influence and informal learning experiences positively predict epistemological beliefs, whereas family encouragement negatively predicts epistemological beliefs. Furthermore, informal learning experiences constitute the only social context factor directly affecting intrinsic motivation, while family encouragement and teacher influence only show indirect effects mediated by epistemological beliefs. The serial mediation model supports Muis' (2007) conjecture that intrinsic motivation is more proximal to academic performance. The model also showed significant rural-urban and gender differences.

Surprisingly, family encouragement, a social context factor initially hypothesized as promoting personal interest in science, showed no direct effects on enjoyment of science and negatively predicted students' epistemological beliefs, especially for female and rural students. This may have to do with the general context of our study. The sample for this study was collected from an underdeveloped southwestern region of China. Only 8.8% of the students have at least one parent with an undergraduate or three-year college diploma. That means most students come from families with relatively low scientific literacy. When their parents showed interest in their science course or encouraged them to learn sciences, participate in related activities, and pursue a career in science, it is more likely that the encouragement would align with the utility view traditional to East



(a)

(b)

Figure 3. Structural equation models for rural group (a) and urban group (b).

Asian society (Liang, Lee, and Tsai 2010), emphasizing the importance of test scores or STEM careers that pay well in the future. According to SDT (Deci & Ryan, 2012), encouragement in that direction may reduce students' perceived autonomy over science learning and thwart their perceived competency in a competitive environment, which may explain why family encouragement has little effect on intrinsic motivation. For the more vulnerable rural group, it may even hinder the development of epistemological beliefs by driving attention toward book knowledge rather than the inquiry process of science. More empirical research on the nature of the encouragement these students get from their families would be needed to bring more insights into the phenomenon.

Table 5. Mediating effects with bootstrapping for male and female groups.

			95% CI	
Path	Boot SE	Effect value	Lower limit	Upper limit
Male				
FE →EB→AS	0.042	−0.056	−0.164	0.006
FE→EB→ES→AS	0.007	−0.010	−0.026	0.001
TI→EB→AS	0.031	0.133**	0.077	0.209
TI→EB→ES→AS	0.010	0.027**	0.011	0.052
IL→ES→AS	0.034	0.216**	0.152	0.280
IL→EB→AS	0.043	0.104**	0.037	0.201
IL→EB→ES→AS	0.008	0.020**	0.008	0.040
Total mediation	-	0.500	-	-
Total effect	-	0.500	-	-
Female				
FE →EB→AS	0.066	−0.131*	−0.298	0.031
FE→EB→ES→AS	0.006	−0.005	−0.016	0.008
TI→EB→AS	0.044	0.148**	0.075	0.253
TI→EB→ES→AS	0.006	0.006	−0.009	0.020
IL→ES→AS	0.041	0.222**	0.146	0.297
IL→EB→AS	0.055	0.132**	0.043	0.255
IL→EB→ES→AS	0.006	0.005	−0.009	0.015
Total mediation	-	0.371	-	-
Total effect	-	0.371	-	-

*$p < 0.05$, **$p < 0.01$.

With little contribution from family contexts, formal and informal learning experiences became the most significant shaping power for epistemological beliefs. While science courses were required in all the schools, only 47.3% of the urban students and 26.5% of the rural students reported that their schools would organize field trips to science museums at least once a year. It makes sense that the more regularly occurring teacher influence has stronger shaping power over student epistemological beliefs than informal learning experiences, which rarely or never took place for the majority.

Informal learning experience, however, is the only social context factor that directly affects students' intrinsic motivation, with a high correlation coefficient (β =0.83). A couple of explanations may fit in here. For one thing, informal learning experiences are not oriented toward formal assessments and usually involve voluntary participation and having fun (Holmes 2011). Such features afford learners greater autonomy while removing the competitive pressure and, therefore, the risk of perceived competence, making it ideal for fostering intrinsic motivation (Deci & Ryan, 2012). For another, students who are intrinsically interested in science may actively engage in more informal learning experiences, which can further feedback into intrinsic motivation through a virtuous cycle. The unique role informal learning experiences play in shaping intrinsic motivation reflects from one side how formal science learning in that region fails to provide comparable social environments in general. Although teacher influence positively affects the formation of a developing view of science and an understanding of how scientific claims get justified, the selection pressure in the test-oriented culture (Zhao, Mu, and Lu 2016) could have constrained the effort of making learning experiences enjoyable for students.

We also find significant gender differences in the correlation between epistemological beliefs and intrinsic motivation. While male students with more sophisticated

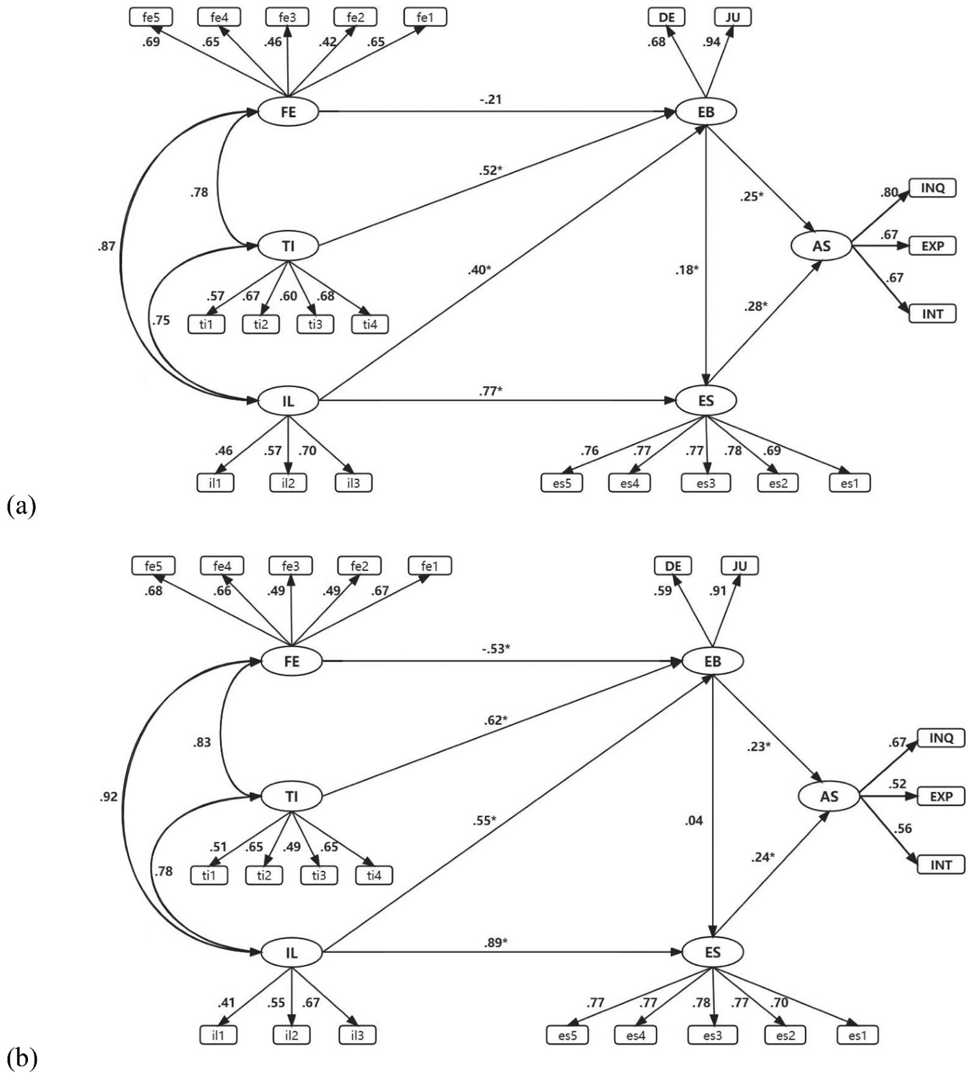


Figure 4. Structural equation models for male group (a) and female group (b).

epistemological beliefs tend to be more intrinsically motivated, this relationship is insignificant for female students. One possible explanation is that for female students, the positive relationship between epistemological beliefs and achievement in science is mediated by factors other than intrinsic motivation. For instance, female students with sophisticated epistemological beliefs may have sophisticated conceptions of learning, adopt deeper approaches when learning sciences, or regulate their cognitive processes more effectively (Ho and Liang 2015; Liang, Lee, and Tsai 2010; Muis 2007), all of which can contribute to their achievement in science. The path mediated by intrinsic motivation is affectively charged and more of a 'hot cognition' in nature (Gupta et al., 2018). In contrast, the potential paths mediated by learning approaches or metacognitive strategies are less and can function regardless of whether the learners enjoy science. The above finding also implies a gender difference in what drives intrinsic motivation in science.

Previous literature suggested that different genders prefer different ways of relating to the world. Female students tend to develop intrinsic motivation for science learning when they perceive it as more humanized (Watts and Bentley 1994) or representing ways of 'helping' or 'caring' (Jones, Howe, and Rua 2000). That could also explain why informal learning experiences have a stronger effect on female students' enjoyment of science. Future studies exploring gender differences in these mediated paths within controlled learning environments may help further our understanding of this topic.

The paths in the serial mediation model also show significant rural-urban differences. The educational gap between rural and urban parents may explain the different effects of family encouragement. Rural parents are significantly lower in their highest degrees ($t = 13.129$, $p < 0.001$) and may be less sophisticated in personal epistemology than urban parents. When encouraging their children to learn science, the epistemological ideas they convey may negatively affect the students' epistemological beliefs. Previous studies in Western contexts suggest that as the students get older, parental influences would decrease while peer influences would increase (Johnston & Viadero, 2000; Luce, Callanan, and Smilovic 2013). Yet a study from Iran shows that family factors continue to serve as a strong predictor for secondary students' science learning (Soltani 2020). More empirical studies are needed to determine if parental involvement and its influences on student epistemological beliefs follow different patterns in Chinese contexts.

Practical implications and limitations

The Chinese students undertaking the PISA2015 test came from more developed and affluent areas of China. In contrast, the sample in our study came from underdeveloped regions lacking family resources for science learning, representing a student population that can differ significantly in their achievement in science and their needs for external support. Our study suggests a potential way to enhance student achievement by transforming their social environments, which may be particularly useful for underdeveloped areas with similar contexts. Considering that informal learning experience can play such a significant role in predicting intrinsic motivation for science learning and that a large proportion of the students (especially rural students) have little opportunity to attend informal learning activities, we strongly recommend that schools in such regions should work on increasing their students' opportunities to visit museums and science centers or to attend other types of informal learning activities. This would be more important for female students than male students, as their intrinsic motivation only relates to this social context factor. Besides, the negative effects of family encouragement and the positive effects of teacher influence on student epistemological beliefs suggest that the students, especially rural students, could have received conflicting epistemological messages from school and family. In that case, fostering their development of epistemological beliefs would require an effort to identify and reconcile the conflicts (Tabak and Weinstock 2008). Parental education may be necessary to accomplish this goal.

There are also some limitations in this work. First, while this research speaks to the interplays between social context factors, epistemological beliefs, motivations, and achievement in science, the achievement test and the survey data are both cross-sectional. Thus, we cannot draw any causality conclusions. Future studies can undertake longitudinal, experimental, or mixed-method research designs to confirm the potential causes indicated in this study. Second, the sample only represents the student population in an underdeveloped region. The conclusions drawn from the study are therefore limited in generalizability. Future studies may consider comparative design between regions of varied levels of economic development within the same culture. Third, the study does not fully address the social context factors of potential importance. In particular, the effects of peer attitudes have not been examined. In future studies, the items in that subscale should be rewritten so that the tool can better cover the range of social context factors. As we mentioned in the earlier discussion, following the findings of this study, there are also a few directions worthy of further exploration, including the nature of family encouragements that have negative effects on student epistemological beliefs, the gender differences in how epistemological beliefs and intrinsic motivation mediate the effects of social context factors on achievement in science, as well as the patterns of parental involvement in children's science learning in Chinese contexts.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the University of Macau under Grant No. SRG2022-00006-FED.

ORCID

Xiaowei Tang http://orcid.org/0000-0002-9363-6248

References

Addabbo, T., M. L. Di Tommaso, and A. Maccagnan. 2016. "Education Capability: A Focus on Gender and Science." *Social Indicators Research* 128 (2): 793–812. https://doi.org/10.1007/s11205-015-1057-8.

Aktan, S. 2019. "Investigation of Classroom Teaching, Selfefficacy and Motivation in Social Studies Classrooms." *International Journal of Research in Education & Science* 5 (2): 639–656.

Augustyniak, R. A., A. Z. Ables, P. Guilford, H. L. Lujan, R. N. Cortright, and S. E. DiCarlo. 2016. "Intrinsic Motivation: An Overlooked Component for Student Success." *Advances in Physiology Education* 40 (4): 465–466. https://doi.org/10.1152/advan.00072.2016.

Bandura, A. 1986. *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice-Hall.

Belenky, M. F., B. M. Clinchy, N. R. Goldberger, and J. M. Tarule. 1986. *Women's Ways of Knowing: The Development of Self, Voice, and Mind*. New York: Basic books. Vol. 15.

Buehl, M. M., and P. A. Alexander. 2005. "Motivation and Performance Differences in students' Domain-Specific Epistemological Belief Profiles." *American Educational Research Journal* 42 (4): 697–726. https://doi.org/10.3102/00028312042004697.

Buehl, M. M., and H. Fives. 2016. "The Role of Epistemic Cognition in Teacher Learning and Praxis." *Handbook of Epistemic Cognition*, edited by J. A. Greene, W. A. Sandoval, and I. Braten, 247–264. Routledge.

Chai, C. S., P. Y. Lin, R. B. King, and M. S. Y. Jong. 2021. “Intrinsic Motivation and Sophisticated Epistemic Beliefs Are Promising Pathways to Science Achievement: Evidence from High Achieving Regions in the East and the West.” *Frontiers in Psychology* 12:1–14. https://doi.org/10.3389/fpsyg.2021.581193.

Chen, J. A., and F. Pajares. 2010. “Implicit Theories of Ability of Grade 6 Science Students: Relation to Epistemological Beliefs and Academic Motivation and Achievement in Science.” *Contemporary Educational Psychology* 35 (1): 75–87. https://doi.org/10.1016/j.cedpsych.2009.10.003.

Chin, C., and D. E. Brown. 2000. “Learning in Science: A Comparison of Deep and Surface Approaches.” *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching* 37 (2): 109–138. https://doi.org/10.1002/(SICI)1098-2736(200002)37:2<109:AID-TEA3>3.0.CO;2-7.

Chiou, G. L., M. H. Lee, and C. C. Tsai. 2013. “High School students’ Approaches to Learning Physics with Relationship to Epistemic Views on Physics and Conceptions of Learning Physics.” *Research in Science & Technological Education* 31 (1): 1–15. https://doi.org/10.1080/02635143.2013.794134.

Christidou, V. 2011. “Interest, Attitudes, and Images Related to Science: Combining Students’ Voices with the Voices of School Science, Teachers, and Popular Science.” *International Journal of Environmental & Science Education* 6 (2): 141–159.

Conley, A. M., P. R. Pintrich, I. Vekiri, and D. Harrison. 2004. “Changes in Epistemological Beliefs in Elementary Science Students.” *Contemporary Educational Psychology* 29 (2): 186–204. https://doi.org/10.1016/j.cedpsych.2004.01.004.

Crowley, K., P. Pierroux, and K. Knutson. 2014. “Informal Learning in Museums.” In *The Cambridge Handbook of the Learning Sciences*, edited by R. K. Sawyer, 461–478. Cambridge University Press. https://doi.org/10.1017/CBO9781139519526.028.

Dabney, K. P., D. Chakraverty, and R. H. Tai. 2013. “The Association of Family Influence and Initial Interest in Science.” *Science Education* 97 (3): 395–409. https://doi.org/10.1002/sce.21060.

DeBacker, T. K., and R. M. Nelson. 2000. “Motivation to Learn Science: Differences Related to Gender, Class Type, and Ability.” *The Journal of Educational Research* 93 (4): 245–254. https://doi.org/10.1080/00220670009598713.

Deci, E. L., and Ryan, R. M. 2012. “Self-determination theory.” In *Handbook of theories of social psychology*, edited by P. A. M. Van Lange, A. W. Kruglanski, and E. T. Higgins, 416–436.

Garland, R. 1991. “The Mid-Point on a Rating Scale: Is it Desirable?” *Marketing Bulletin* 2 (1): 66–70.

Gefen, D., D. Straub, and M. C. Boudreau. 2000. “Structural Equation Modeling and Regression: Guidelines for Research Practice.” *Communications of the Association for Information Systems* 4 (1): 7. https://doi.org/10.17705/1CAIS.00407.

Greene, J. A., B. M. Cartiff, and R. F. Duke. 2018. “A Meta-Analytic Review of the Relationship Between Epistemic Cognition and Academic Achievement.” *Journal of Educational Psychology* 110 (8): 1084. https://doi.org/10.1037/edu0000263.

Guo, J., X. Hu, H. W. Marsh, and R. Pekrun. 2022. “Relations of Epistemic Beliefs with Motivation, Achievement, and Aspirations in Science: Generalizability Across 72 Societies.” *Journal of Educational Psychology* 114 (4): 734–751. https://doi.org/10.1037/edu0000660.

Händel, M., X. Duan, M. Sutherland, and A. Ziegler. 2014. “Successful in Science Education and Still Popular: A Pattern That Is Possible in China Rather Than in Germany or Russia.” *International Journal of Science Education* 36 (6): 887–907. https://doi.org/10.1080/09500693.2013.830232.

Hofer, B. K. 2000. “Dimensionality and Disciplinary Differences in Personal Epistemology.” *Contemporary Educational Psychology* 25 (4): 378–405. https://doi.org/10.1006/ceps.1999.1026.

Hofer, B. K., and P. R. Pintrich. 1997. “The Development of Epistemological Theories: Beliefs About Knowledge and Knowing and Their Relation to Learning.” *Review of Educational Research* 67 (1): 88–140. https://doi.org/10.3102/00346543067001088.

Ho, H. N. J., and J. C. Liang. 2015. “The Relationships Among Scientific Epistemic Beliefs, Conceptions of Learning Science, and Motivation of Learning Science: A Study of Taiwan High School Students.” *International Journal of Science Education* 37 (16): 2688–2707. https://doi.org/10.1080/09500693.2015.1100346.

Holmes, J. A. 2011. Informal learning: Student achievement and motivation in science through museum-based learning. *Learning environments research*, 14 (3): 263–277. https://doi.org/10.1007/s10984-011-9094-y.

Jones, M. G., A. Howe, and M. J. Rua. 2000. "Gender Differences in students' Experiences, Interests, and Attitudes Toward Science and Scientists." *Science Education* 84 (2): 180–192. https://doi.org/10.1002/(SICI)1098-237X(200003)84:2<180:AID-SCE3>3.0.CO;2-X.

Karakolidis, A., V. Pitsia, and A. Emvalotis. 2019. "The Case of High Motivation and Low Achievement in Science: What Is the Role of students' Epistemic Beliefs?" *International Journal of Science Education* 41 (11): 1457–1474. https://doi.org/10.1080/09500693.2019.1612121.

Karataş, H., and M. Erden. 2017. "Predictors of Academic Motivation: Epistemological Beliefs, Learning Approaches and Problem Solving Skills." *IOJES*. https://doi.org/10.15345/iojes.2017.04.001.

Katsantonis, I., R. McLellan, and P. E. Torres. 2023. "Unraveling the Complexity of the Associations Between students' Science Achievement, Motivation, and teachers' Feedback." *Frontiers in Psychology* 14:1124189. https://doi.org/10.3389/fpsyg.2023.1124189.

Kim, S. Y., and A. K. Hamdan Alghamdi. 2023. "Saudi Arabian Secondary School students' Views of the Nature of Science and Epistemological Beliefs: Gendered Differences." *Research in Science & Technological Education* 41 (3): 838–860. https://doi.org/10.1080/02635143.2021.1961721.

Kuhn, D., R. Cheney, and M. Weinstock. 2000. "The Development of Epistemological Understanding." *Cognitive Development* 15 (3): 309–328. https://doi.org/10.1016/S0885-2014(00)00030-7.

Kyriakopoulou, N., and S. Vosniadou. 2020. "Theory of Mind, Personal Epistemology, and Science Learning: Exploring Common Conceptual Components." *Frontiers in Psychology* 11:1140. https://doi.org/10.3389/fpsyg.2020.01140.

Lamb, R. L., L. Annetta, J. Meldrum, and D. Vallett. 2012. "Measuring Science Interest: Rasch Validation of the Science Interest Survey." *International Journal of Science and Mathematics Education* 10 (3): 643–668. https://doi.org/10.1007/s10763-011-9314-z.

Liang, J.-C., M.-H. Lee, and C.-C. Tsai. 2010. "The Relations Between Scientific Epistemological Beliefs and Approaches to Learning Science Among Science-Major Undergraduates in Taiwan." *The Asia-Pacific Education Researcher* 19 (1): 43–59. https://doi.org/10.3860/taper.v19i1.1508.

Lin, T. J., F. Deng, C. S. Chai, and C. C. Tsai. 2013. "High School students' Scientific Epistemological Beliefs, Motivation in Learning Science, and Their Relationships: A Comparative Study within the Chinese Culture." *International Journal of Educational Development* 33 (1): 37–47. https://doi.org/10.1016/j.ijedudev.2012.01.007.

Lin, P. Y., and C. D. Schunn. 2016. "The Dimensions and Impact of Informal Science Learning Experiences on Middle schoolers' Attitudes and Abilities in Science." *International Journal of Science Education* 38 (17): 2551–2572. https://doi.org/10.1080/09500693.2016.1251631.

Luce, M. R., M. A. Callanan, and S. Smilovic. 2013. "Links Between parents' Epistemological Stance and children's Evidence Talk." *Developmental Psychology* 49 (3): 454–461. https://doi.org/10.1037/a0031249.

Mason, L., P. Boscolo, M. C. Tornatora, and L. Ronconi. 2013. "Besides Knowledge: A Cross-Sectional Study on the Relations Between Epistemic Beliefs, Achievement Goals, Self-Beliefs, and Achievement in Science." *Instructional Science* 41 (1): 49–79. https://doi.org/10.1007/s11251-012-9210-0.

Meece, J. L., B. B. Glienke, and S. Burg. 2006. "Gender and Motivation." *Journal of School Psychology* 44 (5): 351–373. https://doi.org/10.1016/j.jsp.2006.04.004.

Merk, S., T. Rosman, K. R. Muis, A. Kelava, and T. Bohl. 2018. "Topic Specific Epistemic Beliefs: Extending the Theory of Integrated Domains in Personal Epistemology." *Learning and Instruction* 56:84–97. https://doi.org/10.1016/j.learninstruc.2018.04.008.

Muis, K. R. 2007. "The Role of Epistemic Beliefs in Self-Regulated Learning." *Educational Psychologist* 42 (3): 173–190. https://doi.org/10.1080/00461520701416306.

Neber, H., and M. Schommer-Aikins. 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.

OECD. 2017. PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving. PISA: OECD Publishing.

Owen, S. V., M. Toepperwein, C. E. Marshall, M. J. Lichtenstein, C. L. Blalock, Y. Liu, L. A. Pruski, et al. 2008. "Finding Pearls: Psychometric Reevaluation of the Simpson–Troost Attitude Questionnaire (STAQ)." *Science Education* 92 (6): 1076–1095. https://doi.org/10.1002/sce.20296.

Ozkal, K., C. Tekkaya, S. Sungur, J. Cakiroglu, and E. Cakiroglu. 2010. "Elementary students' Scientific Epistemological Beliefs in Relation to Socio-Economic Status and Gender." *Journal of Science Teacher Education* 21 (7): 873–885. https://doi.org/10.1007/s10972-009-9169-0.

Schommer, M. 1993. "Epistemological Development and Academic Performance Among Secondary Students." *Journal of Educational Psychology* 85 (3): 406. https://doi.org/10.1037/0022-0663.85.3.406.

Schommer, M. 1995. "An Emerging Conceptualization of Epistemological Beliefs and Their Role in Learning." In *Beliefs About Text and Instruction with Text*, edited by R. Garner and P. A. Alexander, 25–40. Hillsdale, NJ: Lawrence Erlbaum Associates.

She, H. C., H. S. Lin, and L. Y. Huang. 2019. "Reflections on and Implications of the Programme for International Student Assessment 2015 (PISA 2015) Performance of Students in Taiwan: The Role of Epistemic Beliefs About Science in Scientific Literacy." *Journal of Research in Science Teaching* 56 (10): 1309–1340. https://doi.org/10.1002/tea.21553.

Soltani, A. 2020. "Influence of Motivating Science Class, Family, and Peer Models on students' Approaches to Learning Science: A Structural Equation Modeling Analysis." *Research in Science Education* 50 (5): 1665–1687. https://doi.org/10.1007/s11165-018-9748-1.

Tabak, I., and M. Weinstock. 2008. "A Sociocultural Exploration of Epistemological Beliefs." In *Knowing, Knowledge and Beliefs: Epistemological Studies Across Diverse Cultures*, 177–195. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-1-4020-6596-5.

Vedder-Weiss, D, and D. Fortus. 2013. "School, teacher, peers, and parents' goals emphases and adolescents' motivation to learn science in and out of school." *Journal of Research in Science Teaching* 50(8): 952–988. https://doi.org/10.1002/tea.21103.

Watts, M., and D. Bentley. 1994. "Humanizing and Feminizing School Science: Reviving Anthropomorphic and Animistic Thinking in Constructivist Science Education." *International Journal of Science Education* 16 (1): 83–97. https://doi.org/10.1080/0950069940160106.

Wheaton, B. 1987. "Assessment of Fit in Overidentified Models with Latent Variables." *Sociological Methods Research* 16 (1): 118–154. https://doi.org/10.1177/0049124187016001005.

Windschitl, M. 1997. *Journal of Science Education and Technology*, 6 (1): 37–47. https://doi.org/10.1023/A:1022516901783.

Zhao, M., B. Mu, and C. Lu. 2016. "Teaching to the Test: Approaches to Teaching in Senior Secondary Schools in the Context of Curriculum Reform in China." *Creative Education* 7 (1): 32–43. https://doi.org/10.4236/ce.2016.71004.

Zhu, Y. 2019. "How Chinese students' Scientific Competencies Are Influenced by Their Attitudes?" *International Journal of Science Education* 41 (15): 2094–2112. https://doi.org/10.1080/09500693.2019.1660926.