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THE CHAIN MEDIATING ROLE OF PERCEIVED FAMILY SUPPORT FOR FORMAL AND INFORMAL SCIENCE LEARNING IN THE ASSOCIATION BETWEEN FAMILY SOCIOECONOMIC STATUS AND INFORMAL SCIENCE LEARNING EXPERIENCES

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Abstract. *Students' informal science learning experiences are believed to strongly influence their attitudes toward science and their abilities in the subject. Factors associated with students' informal science learning experiences include family socioeconomic status and perceived family support. However, little is known about whether perceived family support for children's formal and informal science learning differs significantly. The present study filled this gap by exploring how students' perceived family support for formal/ informal science learning affected the link between their socioeconomic status and their experiences of informal science learning. Survey data were collected from 486 Chinese grade 4-6 primary school students. Structural equation modeling demonstrated that the students' socioeconomic status and their informal science learning experiences were significantly and positively correlated. This association was chain-mediated through two categories of perceived family support. Specifically, students' socioeconomic status affected their informal science learning experiences through the separate mediating role of family support for formal science learning and the sequential mediation of perceived family support for formal and informal science learning. These results uncover the role that family support plays in students' science education; accordingly, parents are encouraged to help their children learn science both formally and informally.*

Keywords: *primary school students, mainland China, informal science learning experiences, family support, socioeconomic status*

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Introduction

Students have access to a wider range of science learning outside of traditional classroom settings. It is widely acknowledged that scientific knowledge is accumulated both formally through schooling and informally through everyday life experience (Bell et al., 2009; Duschl et al., 2007; Lin & Schunn, 2016). Students gain informal science learning experiences (ISLEs) through various activities such as visiting museums, zoos, and science centres, participating in extracurricular clubs or programs, watching science-related TV shows, and reading (Hofstein & Rosenfeld, 1996; Lin & Schunn, 2016; Ramey-Gassert & Walberg, 1994; Rennie, 2014). Previous studies have shown that ISLEs can positively and significantly predict students' attitudes toward science (Dabney et al., 2012; Henriksen et al., 2015; Knox et al., 2003; Markowitz, 2004; Paris et al., 1998) and science literacy (Hong et al., 2008; OECD, 2011; Suter, 2014).

Moreover, there is a consistent body of research demonstrating that family socioeconomic status (SES) is associated with the prevalence of students' ISLEs (DeWitt & Archer, 2017; Hofferth & Sandberg, 2001; Won & Han, 2010; Zhang & Tang, 2017). For example, students from higher SES families were able to access extracurricular activities more readily than their counterparts from lower SES families (Dawson, 2014a; Mcnamara, 2018). Meanwhile, parental involvement or support may mediate the association between students' family SES and their learning experiences (Conger et al., 2010; Liu & Shunn, 2020). Earlier research indicates that students from higher SES families perceive larger amounts of family support for science learning (Deng et al., 2016; Galindo & Sheldon, 2012; Kohl et al., 2000; Simon, 2004; Waanders et al., 2007), which is positively associated with more ISLEs (Bonnette et al., 2019; Nugent et al., 2015).

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Despite these findings, few studies have examined the interrelationships between students' family SES, perceived family support for science learning, and ISLEs. It is also worth noting that students' perceived family support for formal (FS-F) and informal (FS-I) science learning may play different roles in these linkages. Due to the emphasis Chinese parents place on their children's formal science learning to improve their academic achievement in the subject (Li, 2012; Pan, 2013; Wu, 2013), Chinese students' perceived family support for informal science learning may be a consequence of formal science learning. Motivated by these concerns, this study aimed to examine the roles that Chinese students' perceived family support for their formal and informal science learning played in explaining the association between their family SES and ISLEs.

Literature Review

Informal Science Learning Experiences

Informal science learning experiences (ISLEs) have been broadly defined as experiences of learning science that take place away from a conventional educational setting (Falk & Dierking, 1992). Consequently, venues such as museums, scientific centres, zoos, parks, television, the Internet, and community-based groups and projects all play a role in facilitating such education (National Science Teachers Association, 1998). Previous studies have shown that such ISLEs are essential for students to understand nature and develop skills and interests in scientific learning (Bamberger & Tal, 2007; Bell et al., 2009). ISLEs can thus complement formal science education (Reiss et al., 2016; Russell et al., 2013).

Recent research has identified different types of students' ISLEs. One classification divided ISLEs into three categories based on where science learning occurs: daily environments (e.g., while watching TV), design environments (e.g., when visiting science museums), and project learning environments (e.g., when participating in summer camps or clubs) (Bell et al., 2009). Similarly, Dewit and Archer (2017) classified ISLEs into the three categories of daily experience (e.g., watching TV), informal experience (e.g., visiting museums), and school-organized activities (e.g., school trips). In another recent study, Lin and Schunn (2016) identified the four dimensions of secondary students' ISLEs as in-home, semiformal, nature, and museums, each of which afforded different opportunities for learning and motivation support.

In mainland China, informal science learning is often called "popular science" and is viewed as an important means for citizens to develop scientific literacy. In this context, learning in technology and science museums, zoos, and landscaped gardens (museum learning) was most highly regarded by respondents (Tang, 2012). In addition to museum learning, Ren et al. (2012) emphasized online gaming and virtual environments made possible by the Internet, multimedia, and virtual reality technology. Indeed, virtual environments were incorporated by Liu et al. (2013) into their classification of Chinese students' ISLEs, alongside daily living environments, designable environments, and after-class and adult programs. Moreover, Chinese students' ISLEs may vary by subject (Huang, 2017; Ren et al., 2017). Among kindergarten students, learning might occur in green spaces, during outdoor activities, and during everyday scientific activities (Huang, 2017). However, for Chinese teenagers, the most common ISLEs were linked to the media, science popularization activities, and science popularization websites (Ren et al., 2017).

Overall, many previous studies have attempted to establish evidence for such ISLE subcategories, whose affordances for science learning vary (Lin & Schunn, 2016), as well as their benefits to students (Kong et al., 2014; Sha et al., 2016; Uitto et al., 2006). However, there is no current consensus on the types of informal science learning typically experienced by Chinese primary school students. To fill this gap, this study first identified and explored the kinds of ISLEs commonly obtained by such students to determine their most significant dimensions.

The Association between Family Socioeconomic Status and Informal Science Learning Experiences

Children of school age do not enjoy equitable access to education, a fact reflected in students' science learning (Dewit & Archer, 2017; Zhao & Fu, 2016). Among the various factors influencing students' ISLEs, family socioeconomic status (SES) may be the most influential. Family SES, which refers to the range of social resources owned by a family, is a core factor in adolescent development (Liu et al., 2020). It can be objectively measured in terms of parents' education, employment, and income (Bradley & Corwyn, 2002; Hauser, 1994; Matthews & Gallo, 2011; Mueller & Parcel, 1981; Sirin, 2005), as well as family resources such as books, computers, and study materials (Coleman, 1988; Duncan & Brooks-Gunn, 1997; Entwisle & Astone, 1994; OECD, 2016; Xiao, 2009; Zhao, 2019).

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Students' family SES may play a role in the opportunities available to them in the field of science learning, both formally and informally. For instance, Crosnoe and Trinitapoli (2008) and Hofferth and Sandberg (2001) found that varying family incomes were reflected in the various ways in which students spent their non-school time. Students who came from families with higher incomes were more likely to spend time with family members doing activities outside the home (such as visiting zoos and museums), whereas their peers who came from families with lower incomes spent more time doing activities inside the home, such as watching popular science TV programs (Crosnoe & Trinitapoli, 2008).

Similarly, Fredericks and Simpkins (2012) found that students with higher-level household resources had more opportunities to develop ISLEs, while DeWitt and Archer (2017) reported that those with higher levels of cultural capital were more likely to take part in daily science, science activities, and school-led science. Finally, Zhang and Tang's study (2017) confirmed that students in urban areas who came from families with higher socioeconomic status or whose moms had higher levels of education were more likely to participate in informal science learning activities.

Based on these findings, the following hypothesis was proposed:

H1: Chinese primary school students' family SES positively predicts their ISLEs.

The Potential Mediating Effect of Students' Perceived Family Support

Family support (FS) refers to the help and guidance provided by parents or guardians to support children's learning behavior, strategies, emotions, and materials in a particular family setting to optimize their academic progress (Caplan, 1974; Scott-Jones, 1995). Family support involves family members participating in children's learning, paying attention to their education, providing them with learning resources, and so on (Deci & Ryan, 2000; Grolnick & Slowiaczek, 1994; Pomerantz et al., 2007; Scott-Jones, 1995; Wong, 2008). The results of these studies suggest that children's perceptions of support may be more critical than the assistance they actually receive.

In Yamamoto et al.'s (2016) parental engagement and investment framework, the resources that family members invest shape their children's learning. Previous research found that FS positively predicted students' engagement and the outcomes of general or specific science learning in formal and informal environments (Bonnette et al., 2019; Nugent et al., 2015; Simpkins et al., 2020). The involvement of parents in their children's schooling or homework was significantly and positively related to their participation and success in school and out-of-school activities (Paulson, 1994; Steinberg et al., 1992; Stevenson & Baker, 1987). Similarly, Pong et al. (2005) found that parental involvement by discussing school matters, checking homework, or participating in school activities, for instance, could improve students' grades. Recent research has highlighted the role of FS in informal science learning, with one study noting how parents frequently act as gatekeepers for their children's participation in STEM activities outside of school (Nugent et al., 2015). Students might acquire greater self-efficacy and STEM outcome expectations when their parents support their experiences and efforts within and beyond school. Recent research from Bonnette et al. (2019) further distinguished between *actual* FS—when parents who work long hours can take their children to clubs or museums, for instance—and *perceived* FS, such as when children believe their parents are either indifferent to or actively oppose their participation in informal science activities. Bonnette et al. (2019) found that, even when actually under-resourced, children who perceived higher levels of FS combined with informal learning experiences saw greater gains than those who did not share such perceptions. These results suggest that students' perceived FS may have a more noticeable effect on their informal science learning than actual support. Accordingly, the second hypothesis was formulated:

H2: Chinese primary school students' perceived family support positively predicts their informal science learning experiences.

The association between students' family SES and perceived FS has been consistently demonstrated by previous studies (e.g., Deng et al., 2016; Galindo & Sheldon, 2012; Kohl et al., 2000; Simon, 2004; Waanders et al., 2007). Generally, parents with higher SES can give their children more educational and cultural resources (Chesters, 2010; Nauert, 2008; Zhang, 2007; Zhou, 2013) and devote more time to their academic development (Guryan et al., 2008). The family stress model offers an analytic lens for understanding the link between students' family SES and perceived FS (Conger & Donnellan, 2007; Masarik & Conger, 2017). Due to poor circumstances, low-SES parents are more likely to have emotional or behavioral issues with their children. This decreases their energy and understanding of the school-based and extracurricular educational needs of their children. Parents with lower SES have less motivation and capacity to support their children's learning (Conger et al., 2010; Linver et al., 2002;

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Zhang, 2012), and may even pay less attention to their children (Bae & Wickrama, 2015). Similarly, low-income parents tend to be less interested in their children's education than their high-income counterparts (Becker, 1964; Camacho-Thompson et al., 2016; Kohl et al., 2000). One meta-analysis uncovered the generally positive association between SES and parental involvement in children's education (Wang et al., 2016), while Ye (2018) found that higher-SES parents were more inclined to support students' out-of-school education. In contrast, low-SES families are characterized by less parental support for children due to a lack of temporal and financial resources or unstable jobs (Hannum et al., 2009).

Despite the extraordinary challenges that low-SES students face, the lack of adequate economic support can be mitigated by the positive impacts of social support (Lempers & Clark-Lempers, 1990; Lee et al., 2009; North et al., 2008). Some families with a low SES may be able to help their children's learning by encouraging them to take part in learning activities and frequently offering emotional support for this purpose (Mayo & Siraj, 2015). Beyond this, lower-SES parents may also engage deeply in their children's education. Nonetheless, Yamamoto et al. (2016) reported that 20% of middle-SES children participated in at least two extracurricular activities, whereas the proportion of low-SES children was approximately 7%. One possible reason is that parents' social mobility (according to the parents themselves) may contribute to reducing the negative consequences that having a low family SES has on parental involvement in academic activities. That is, parents who have a high level of subjective social mobility may be more interested in the education of their children, regardless of their family SES (Mayer, 1997; Ng & Wei, 2020).

Specifically, the Chinese idea of *nourishment* calls for parents to be devoted to their children and make sacrifices. It is possible that this moral principle could enable low-income parents to encourage their children to do well in school despite their own financial difficulties. The power of this principle has been demonstrated by research showing that Chinese immigrant parents of medium SES had more developed ideas about raising children than their white, high-SES counterparts (Chao, 1994). Low-SES Chinese parents tend to display a particularly strong sense of responsibility (Yamamoto et al., 2016), and most Chinese children from low-income families are better supported than their American counterparts from high-income families, as Chinese-heritage parents typically have higher hopes for their children (Tsui, 2015). Accordingly, the following third hypothesis was proposed:

H3: Chinese primary school students' family SES can indirectly predict their ISLEs through the mediating role of perceived FS.

It is also worth noting that students' perceived family support can be classified into different aspects, which may play different mediating roles. For example, Yu (2019) divided family support into parents' educational expectations of their children, their formal educational investments such as helping and checking assignments and providing opportunities to attend extracurricular activities such as visiting museums and watching science fiction movies. Wu (2013) found that Chinese families attached great importance to guiding children's learning and providing them with formal educational resources and extracurricular activities.

The above studies highlight the need to distinguish between Chinese family support for formal (FS-F) and informal (FS-I) science learning. Previous studies have focused on the former, finding that Chinese parents pay more attention to students' formal than informal science learning to improve their children's achievement in the subject (Li, 2012; Pan, 2013; Wu, 2013), investing in their kids' education by paying for private tutors, extracurriculars, and remedial classes, and seeking out-of-school study counseling to improve their formal learning outcomes (Chung & Choe, 2001). Moreover, Chinese parents hold a deeply-rooted belief in the importance of students' academic success (Yamamoto et al., 2016), suggesting that they view informal science experiences as a means of promoting students' formal science learning. For example, parents will take their children to museums to enhance their school learning (Ma, 2019). Overall, the association between Chinese primary students' family SES and their ISLEs may be influenced first by family support for formal science learning (FS-F) and then by family support for informal science learning (FS-I).

Drawing on this analysis, the third hypothesis was split into three sub-hypotheses:

H3a: Chinese primary school students' family SES can indirectly predict their ISLEs through the mediating role of perceived FS-F.

H3b: Chinese primary school students' family SES can indirectly predict their ISLEs through the mediating role of perceived FS-I.

H3c: Chinese primary school students' family SES can indirectly predict their ISLEs through the chain mediation of perceived FS-F and FS-I.

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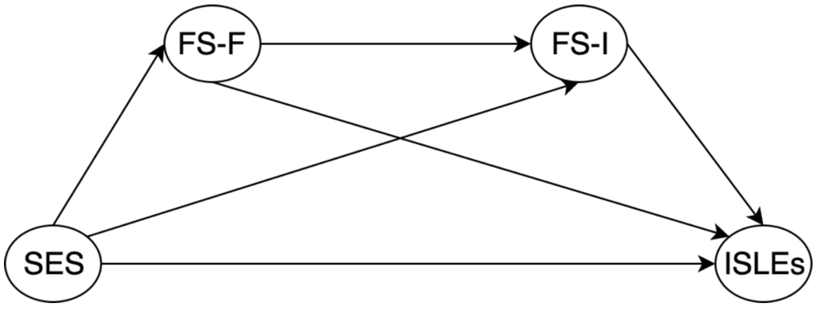
The Current Study

Although several studies have demonstrated that students' informal science learning experiences correlate with their family's socioeconomic status, it remains unclear how students' perceptions of family support influence this association. In addition, previous research has indicated that Chinese parents express different preferences for formal vs. informal science learning (Ma, 2019; Yamamoto et al., 2016; Yu, 2019; Wu, 2013). This prompted the current study to investigate how family support for formal and informal science learning might mediate the effect of family socioeconomic status on informal science learning experiences. Based on previous research, three hypotheses were proposed concerning the associations among students' socioeconomic position, perceived family support for formal and informal science learning, and informal science learning experiences. These were subsequently integrated into the theoretical model displayed in Figure 1.

Figure 1
Hypothesized Chain Mediation Model of the Association between Students' Family SES and ISLEs.



First, H1 assumed a direct effect of students' family socioeconomic status on their informal science learning experiences, i.e., SES→ISLEs (Fredericks & Simpkins, 2012; Zhang & Tang, 2017). Second, the model presumed, in line with H2, that students' perceived family support for science learning would influence their informal science learning experiences (Bonnette et al., 2019). Students' perceived family support was differentiated into support for formal and informal science learning, both of which are widely encouraged in Chinese families (Ma, 2019; Wu, 2013; Yamamoto et al., 2016; Yu, 2019). As a result, the model included two distinct pathways to describe the direct effects of students' perceived family support for formal/informal science learning on their informal science learning experiences (FS-F→ISLEs and FS-I→ISLEs, respectively). Third, H3a and H3b modeled how perceived family support for formal or informal science learning might mediate the influence of students' family socioeconomic status on their informal science learning experiences. These associations were represented by two separate pathways in the model (SES→FS-F→ISLEs and SES→FS-I→ISLEs). Finally, students' perceptions of family support for informal science learning were hypothesized to be an outcome of support for formal science learning, given Chinese parents' emphasis on school academic achievement (Li, 2012; Ma, 2019; Pan, 2013; Wu, 2013). Consequently, the model proposed a pathway based on H3c: SES→FS-F→FS-I→ISLEs. The theoretical model displayed in Figure 1 incorporates the above paths, in which the association between Chinese primary school students' family SES and ISLEs is sequentially mediated by perceived family support for formal (FS-F) and informal (FS-I) science learning.

This study's significance is threefold. First, it provides valuable insights into the structure of mainland Chinese students' informal science learning experiences. The factorial structure of these experiences may also exist in other regions with comparable degrees of economic growth (e.g., other developing countries; Hao, 2016) or similar cultural backgrounds (e.g, other countries in the East Asian Confucian cultural sphere; Chao, 1994). Second, to the best of our knowledge, this is the first research to differentiate between students' perceived family support for formal and informal science learning. It is critical to distinguish between these different forms of family support to better understand their complex role in science learning outcomes (Wu, 2013; Yu, 2019). Finally, this study's argument is that the association between students' family SES and their informal science learning experiences is sequentially mediated by perceived family support for formal and informal science learning. It has been suggested that such support may eliminate the disadvantage of accessing learning opportunities for students from lower socioeconomic backgrounds (Lee et al., 2009; Lempers & Clark-Lempers, 1990; Ng & Wei, 2020; North et al., 2008).

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Thus, gaining a deeper understanding of the mediating impact of support for formal and informal science learning on the causal link between family SES and ISLEs may help break the intergenerational transmission of poverty and promote more equitable science education.

Research Methodology

Background

In this study, structural equation modeling (SEM) was used to explore whether Chinese primary school students' perceived family support for formal (FS-F) and informal (FS-I) science learning mediated the association between their family SES and ISLEs. The Student Informal Science Learning Survey (see Appendix) was developed to measure all variables used to construct the theoretical model. The survey was administered to student participants between December 2020 and March 2021, and quantitative data were obtained. The resulting data was then used to validate the three measures of SES, perceived family support, and ISLEs. The students' family SES scale was validated using item response theory (IRT), while exploratory and confirmatory factor analyses (EFA/CFA) were used for the other two measures. This validation supported the division of Chinese primary school students' perceived family support into the two related but distinct dimensions of FS-F and FS-I. Finally, SEM was used to examine the hypothesized associations among SES, perceived FS-F and FS-I, and ISLEs proposed by the chain mediation model (Figure 1).

Measures

Before assessing their informal science learning experiences, family socioeconomic status, and perceived family support for formal and informal science learning, background information about the students was gathered. The complete Student Informal Science Learning Survey is available in the Appendix.

Family socioeconomic status. There is currently no consensus on the optimal way to measure family SES. However, previous studies have used three indicators: parental level of education, occupation, and family income (Lee et al., 2019; Sirin, 2005). While family income may be the best predictor of family SES (Larson, 2010; Lombardi & Dearing, 2021), children struggle to report this accurately. Therefore, researchers advocate using household goods in place of household income (e.g., Zhao, 2019), as widely adopted by large-scale international studies (OECD, 2017).

Accordingly, in this study, eight items were adapted and modified from the PISA (2015) survey to measure students' family SES. Students were asked to rate the number of TVs, cars, computers, mobile phones, and other goods at home on a 4-point scale (0 = none, 1 = one, 2 = two, and 3 = three or more), with higher scores indicating a higher family SES. The scale was validated using item response theory, in which a series of plausible values (PVs) were used as observed variables for estimating the latent variable of students' family SES in further SEM analysis.

Students' perceived family support for formal and informal science learning. Bonnette et al.'s Family Support Scale (2019) was modified to focus on support for either formal science learning (FS-F, e.g., "When I work on science homework at home, I have someone who can help me with it if I need help") or informal science learning (FS-I, e.g., "When I want to visit a science museum or zoo, someone in my family will ensure I can"). Responses to ten items were then graded on a 5-point scale (1 = strongly disagree; 5 = strongly agree), reflecting students' perceived FS for their formal and informal science learning (5 items apiece). Table 1 summarizes the subscales and items used together with measures of their validity.

Chinese primary school students' informal science learning experiences. A new scale consisting of 21 items rated on a 5-point scale (1 = never; 2 = once a year; 3 = several times a year; 4 = once a month; 5 = one or more times a week) was developed to measure the students' informal science learning experiences. Most (18) of these items were adapted from two previous studies (DeWitt & Archer, 2017; Lin & Schunn, 2016). For example: "How often do you watch science-related TV shows?" Concurrently, three new items were developed based on the ISLE categories derived from students' interview data (Li et al., 2021), such as "How often do you go online to find your own (extra) science exam questions and finish them?". These additional ISLEs cohered with the students' conceptions of informal science learning identified previously (Li et al., 2021); a high survey score indicated that the student had enjoyed many ISLEs. Table 1 also summarizes the subscales and items used to assess the students' ISLEs following validity analyses. After exploratory factor analysis, 13 of the original items were retained and grouped into three subscales: "everyday" science learning (5 items), museum learning (3 items), and school-led/semiformal science learning (5 items). All items concerning nature learning (e.g., "taking care of pets") were removed due to

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poor fit. The resulting factor structure was similar to those achieved in previous studies, but without the dimension of nature learning (DeWitt & Archer, 2017; Lin & Schunn, 2016).

Participants

To gather a sample representative of the diversity of primary school students across mainland China, four primary schools in southern China were purposefully sampled. These schools varied widely in terms of student enrolment, SES, teacher quality, and the economic development of the local community. Students from these schools had also contributed to a previous study on students' conceptions of informal science learning in informal environments (Li et al., 2021). All students in grades 4-6 from the four purposefully sampling schools participated in the survey, which constituted a total sample of 510 students. After excluding responses with missing, incomplete, excessive, inaccurate, or contradictory answers, 486 completed questionnaires were obtained (279 from males and 207 from females), with 154, 142, and 190 responses from the 4^{th}, 5^{th}, and 6^{th}-graders, respectively.

Procedure

The Student Informal Science Learning Survey was distributed to the participants in their classrooms. With the assistance of each class's head teacher, one study author explained the purpose and requirements of the survey to the students. The class's head teacher then delivered the questionnaires to those students who volunteered to participate. Students were asked to complete the questionnaires anonymously during a 45-minute free period. Only complete and valid data were used for analysis.

Data Analysis

The complete set of participant data (N = 486) was analyzed using SEM. Before conducting the primary SEM analysis, the validity and reliability of the three scales were rigorously tested.

Exploratory and confirmatory factor analyses (EFA/CFA) were conducted to validate the scales used to measure the students' informal science learning experiences and perceived family support. An exploratory (N = 243) and confirmatory sample (N = 243) were drawn at random from the complete sample.

To investigate the structure of the scales, a principal component extraction and oblimin rotation EFA were undertaken. Principal component extraction enabled the number of latent variables with eigenvalues greater than 1 derived from the empirical data to be determined. Using oblimin rotation to identify the factor structure for the two scales, items with a factor loading of less than .4 were eliminated (Netemeyer et al., 2003). The EFA allowed us to evaluate whether the items on the ISLE scale clustered into the appropriate subscales and if the FS-F and FS-I scales were genuinely separable. If the FS-F and FS-I items were loaded onto different factors, this would constitute empirical evidence for the multidimensionality of perceived FS. The internal consistency of the entire scale and its subscales was evaluated using Cronbach's alpha.

The resulting factor structures deriving from the EFA were then analyzed using CFA on the confirmatory sample data. Using the coefficients of the Root Mean Square Error of Estimation (RSMEA), Comparative Fit Index (CFI), and Tucker-Lewis Index, the fit of the CFA models were evaluated (TLI; Schreiber et al., 2006). CFI and TLI values of between .90 and .95 and RSMEA values below .08 would indicate a satisfactory model fit (Hu & Bentler, 1999; Schermelleh-Engel & Moosbrugger, 2003). The fit index χ^2/df was also used to evaluate the model data fit, with values of <3 considered satisfactory (Schermelleh-Engel & Moosbrugger, 2003).

To assess the scale's convergent and discriminant validity, the average variance extracted (AVE) value was calculated from the CFA outputs (Carter, 2016). When the AVE, which measures the amount of common variance among items in a subscale, is 0.5, the subscale's convergent validity is considered good. A subscale's discriminant validity is obtained when the square root of its AVE is greater than its overall correlation with another subscale. These measures would provide further empirical justification for separating family support into the FS-F and FS-I subscales. The composite reliability (CR) was calculated to assess the extent to which each subscale and the overall scale adhered to the internal consistency criteria.

To validate the family SES scale, the entire sample was analyzed using item response theory. The two-parameter logistic (2PL) IRT model was used to estimate family SES based on their responses to the scale. This model accounts for differential item difficulty (difficulty parameter, b) and differential ability to discriminate (discrimination param-

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eter, a) between high and low latent trait levels (i.e., family SES). The Graded Response Model (GRM; Samejima, 1969), which extended the dichotomous 2PL model by allowing ordered item responses, was used since these items were graded on a scale that ranged from 1 to 4 points. The scale's expected *a posteriori* (EAP) reliability was then computed. Specified for IRT models, the EAP reliability index is comparable to Cronbach's α, which is widely used in classical test theory. The fit of the IRT model was assessed based on root mean square deviation (RSMD) at the scale level and outfit and infit statistics at the item level, with RMSD values of ≤ 0.1 or below and outfit and infit values of 0.7–1.3 suggesting that the model fit was satisfactory. By integrating the IRT scaling of the SES items, five plausible values were obtained from the *a posteriori* distribution. This method has been widely applied in large-scale assessment programs such as PISA (Arikan et al., 2020; Sha et al., 2016; Tang & Zhang, 2020). The five plausible values were subjected to confirmatory factor analysis (CFA) to determine their validity (Brown et al., 2012).

After validating the scales, SEM was used to investigate the associations among the students' family SES, their perceptions of FS-F and FS-I science learning, and their ISLEs (i.e., to test the chain mediation model hypothesized in Figure 1). In particular, a two-stage process was adopted: the first stage used CFA to test a measurement model describing the latent factors (scales) and the observed variables (items); the second stage tested a structural model that described the associations between the latent factors. During the SEM analysis, the bias-corrected percentile bootstrap approach was used to test the path coefficients (including the mediation effect; Edwards & Lambert, 2007). If the bootstrap confidence intervals estimated for the path or effect coefficient did not contain 0, the statistical path or effect coefficient was determined to be statistically significant.

The IRT analysis was performed using R's mirt package (Chalmers, 2012). The EFA was performed in SPSS (version 23), while R's lavann and semTools packages (Jorgensen et al., 2022; Rosseel, 2012;) were used for the CFA and SEM analyses. Since the data were continuous, the maximum likelihood estimate (MLE) was utilized for the CFA.

Research Results

Examining the Quality and Dimensionality of the Scales

For the ISLE scale, the EFA with principal component extraction and oblimin rotation on the explanatory sample resulted in a three-factor solution based on the criterion of eigenvalues >1, with the "nature learning" subscale dropped on this basis. Thirteen items with factor loadings exceeding .40 and without cross-loadings were retained. All items designed to measure a specific latent factor were loaded onto a single factor representing everyday learning (EL), museum learning (ML), and school-led or semiformal learning (SL). The reliability coefficients for the three sub-scales revealed Cronbach's α values ranging from .731 to .832, exceeding the minimum threshold of .65 (DeVellis, 2016). After that, CFA was carried out to evaluate the extent to which the data from the confirmatory sample matched the derived factorial structure predicted by the EFA. The CFA indicated that the three-factor model adequately fit the data after dropping four items with high residual correlations (χ^2/df = 1.822 (< 3), RSMEA = .058 (< .08), TLI = .967, CFI = .978). The CFA results also showed that the factor loadings in the corresponding subscales were between .643 and .859, the average variance extraction (AVE) was between .507 and .520, and the combined reliability (CR) was between .754 and .859. Accordingly, the final three ISLE subscales were considered sufficiently reliable and valid for assessing primary school students' informal science learning experiences.

For the perceived family support scale, the EFA on the explanatory sample data resulted in two factors with eigenvalues >1, as expected. All items were retained and loaded onto one of the two factors of students' perceived family support for formal/informal science learning (FS-F/I). The Cronbach's α values were .761 and .798 for the FS-F and FS-I subscales, respectively, showing the satisfactory internal consistency of these items (DeVellis, 2016). Analysis of the confirmatory sample data to confirm the validity of the two-factor structure deriving from the EFA suggested dropping four items due to high residual correlations. The CFA suggested a good model-data fit: χ^2/df = 2.365 (<3), RSMEA = .075 (< .08), TLI = .970, and CFI = .984. The average variance extracted (AVE) statistics were .540 and .695 for FS-F and FS-I, respectively, showing that the convergent validity of these two subscales was sufficient. The subscales' discriminant validity was further supported by the square root of AVE statistics (.735 and .834), which exceeded the correlation between the FS-F and FS-I subscales (.733). The combined reliabilities (CRs) for the two subscales were .764 and .871, respectively. Accordingly, the two-dimensional FS scale was considered a sufficiently reliable and valid means of evaluating primary school students' perceived family support for science learning in formal or informal environments.

For the family SES scale measuring ownership of a range of home goods, the GRM extension of the 2PL IRT

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model was used for scaling. The discrimination indices ranged from 0.223 to 1.033, and the difficulty indices ranged from -2.724 to 1.078, pointing to the suitability of these items for distinguishing the socioeconomic statuses of families. Meanwhile, the RMSD (root mean square difference) value was below .1 (Daura et al., 1998), and the outfit and infit values ranged between 0.7 and 1.3 (Hill, 2009), again suggesting these items could be explained by the same latent estimate, i.e., family SES. As a reliability index specifically for IRT models, EAP reliability is comparable to Cronbach's α. The estimated EAP reliability for the family SES scale was found to be .623, which was also acceptable (DeVellis, 2016). The overall IRT analysis indicated that the family SES scale attained acceptable reliability and ideal validity. Subsequently, five plausible values generated from IRT scaling were used for further CFA and SEM analysis.

Table 1

Exploratory Factor Analysis and Confirmatory Factor Analysis of the ISLE and FS Scales (N_{efa} = 243 and N_{cfa} = 243, respectively)

Items	M	EFA					CFA				
		ESL	ML	SL	FS-F	FS-I	ESL	ML	SL	FS-F	FS-I
Informal science learning experiences (ISLEs)											
ISLE 1 Watching science-related TV shows	3.57	.792					.750				
ISLE 2 Reading books or magazines about science	3.57	.779					.732				
ISLE 3 Learning science online (e.g., YouTube, science websites, playing science games)	3.56	.660					.663				
ISLE 4 Discussing science with others outside school*	3.41	.584					/				
ISLE 5 Practicing science problems online*	2.72	.589					/				
ISLE 6 Visiting the museum	2.94		.898					.808			
ISLE 7 Vising a science centre, science and technology museum, or planetarium	2.67		.863					.859			
ISLE 8 Visiting a zoo or aquarium	3.05		.759					.786			
ISLE 9 Participating in science-related trips organized by the school *	3.61			.458					/		
ISLE 10 Participating in museum visits organized by the school*	2.74			.715					/		
ISLE 11 Participating in science-related presentations organized by the school	2.69			.681					.701		
ISLE 12 Participating in after-school science clubs	2.39			.367					.790		
ISLE 13 Participating in science and technology festivals organized by the school	3.24			.407					.643		
Perceived family support (FS)											
FS 1 My science learning in school is important to someone in my family.*	3.68				.679					/	
FS 2 When I work on science homework at home, I have someone who can help me with it if I need help.*	3.96				.649					/	
FS 3 Someone in my family makes sure I finish my science homework every day.	4.15				.860					.579	
FS 4 Someone in my family is interested in teaching me about science.	3.63				.448					.730	
FS 5 Someone in my family encourages me to learn science in various ways.	3.90				.500					.844	
IF 6 Someone in my family takes me to places where I can learn new science.	3.58					.642					/
IF 7 When I want to visit a science museum or zoo, someone in my family will ensure I can.	3.84					.822					.797

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Items	M	EFA					CFA				
		ESL	ML	SL	FS-F	FS-I	ESL	ML	SL	FS-F	FS-I
IF 8 When I want to read science-related books, someone in my family will ensure I can.	3.81					.778					.831
IF 9 When I want to watch science-related movies, someone in my family will ensure I can.	3.71					.787					.872
IF 10 Someone in my family has asked me to participate in extracurricular science activities.*	2.63					.628					/
Cronbach's alpha or CR		.832	.884	.731	.761	.798	.754	.859	.751	.764	.871
AVE							.754	.507	.520	.540	.695

Note. * = Items were dropped after CFA due to poor fit. Factor loadings are only displayed for items with loadings of > .40.
EL = everyday science learning; MS = museum learning, SL = school-led/semiformal science learning, FS-F = students' perceived family support for formal science learning, FS-I = students' perceived family support for informal science learning. For the CFA, all observed variables in the model were loaded onto the respective latent variables and all factor loadings were significant (p < .001).

Table 2
IRT Analysis of the SES Scale (N = 486)

Item	M	Discrimination (a)	**Difficulty (b)**	RMSD	**Outfit**	**Infit**
SES 1 Television	1.105	0.946	-2.724	.011	1.010	1.006
SES 2 Car	0.861	0.744	-0.850	.007	0.994	0.999
SES 3 Room with bathtub	0.784	0.406	-0.237	.014	0.994	1.001
SES 4 Mobile phone (with internet access)	1.707	0.560	-1.073	.006	0.943	1.016
SES 5 PC (desktop computer and laptop)	0.705	1.033	0.324	.006	1.005	1.010
SES 6 Tablet PC (e.g., iPad)	0.904	0.838	-0.793	.011	0.978	1.004
SES 7 Electronic reader (e.g., Kindle)	0.290	0.993	1.078	.033	1.044	0.988
SES 8 Musical instruments (e.g., guitar, piano)	1.107	0.223	-0.079	.006	1.002	1.002

Measurement Model

After initial tests of the scales confirmed their validity and reliability, the entire sample was included in the SEM analysis. Before this, a measurement model comprising all latent factors and their associations was analyzed using CFA on the entire sample.

The measurement model fit the data adequately (χ^2/df = 1.524, well below the threshold value of 3; RSMEA =.033, below the .08 threshold; TLI =.977 and CFI =.981 on the goodness of fit index). As shown in Figure 2, all observed items were loaded onto their corresponding latent factors and all factor loadings were found to be significant at p < .001, with values ranging from .622 to .864. Meanwhile, as expected, significant positive correlations were found between SES, FS-F, FS-I, and the three subscales of ISLEs. In the SEM analysis that followed, the three ISLE subscales were grouped into a second-order factor that represented the ISLEs as a whole latent variable.

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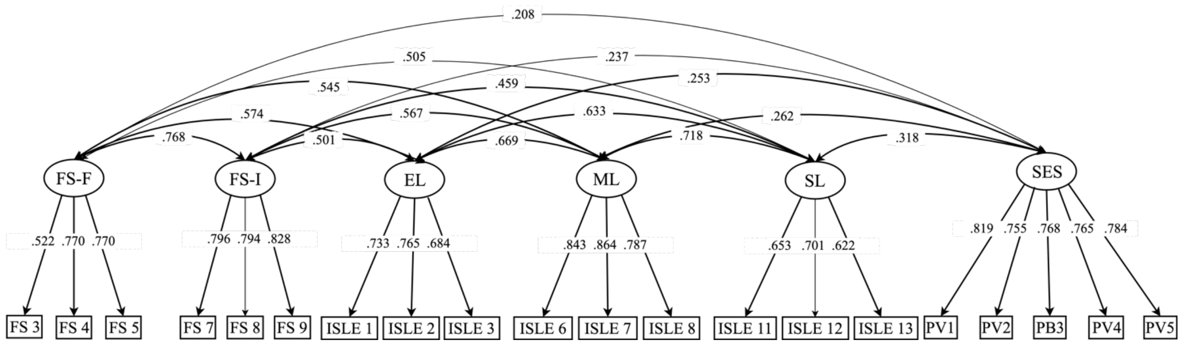
Figure 2

The Measurement Model of Students' Family SES, Perceived Family Support for Formal and Informal Science Learning (FS-F and FS-I), and ISLEs.



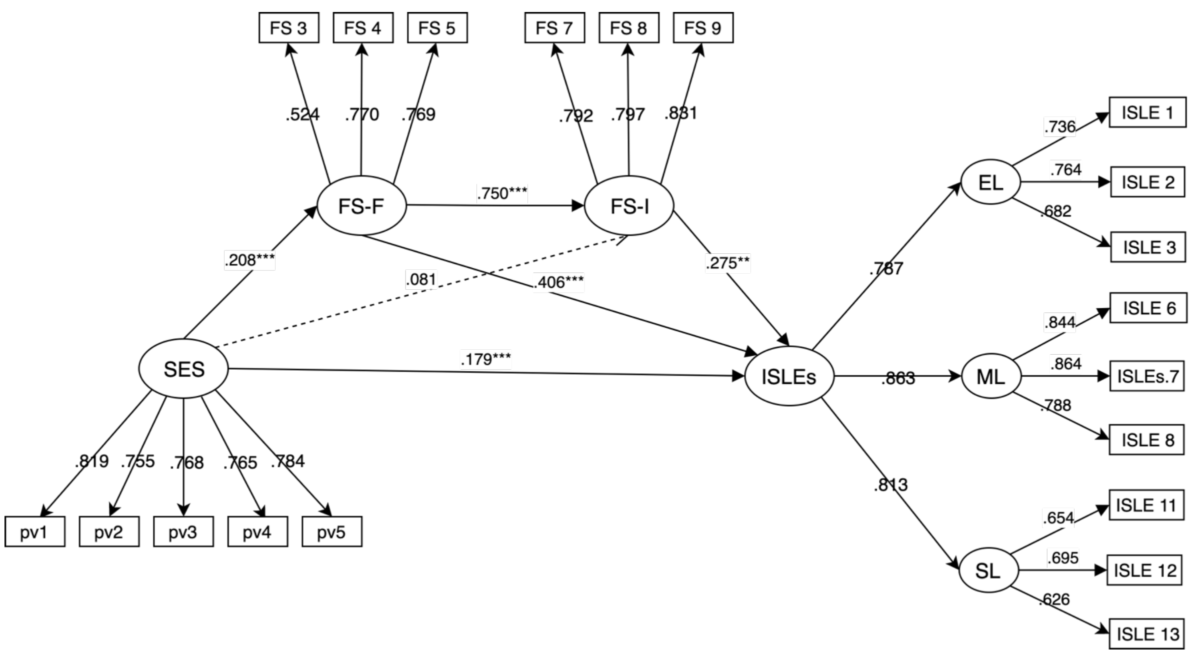
Note: The ISLEs scale was composed of three sub-scales.

Structural Model

SEM was employed to examine the structural associations among the latent factors and the mediation effects. Table 3 and Figure 3 show how students' perceived family support for formal and informal science learning (FS-F and FS-I) mediated the association between their family SES and their informal science learning experiences.

Figure 3

The Chain Mediation Model for the Association between Students' Family SES and ISLEs.



Note: Standardized estimated path coefficients: ***p ≤ .01, ***p ≤ .001*

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Table 3
Direct and Indirect Effects of the Chain Mediation Model

	Path	Effect	Effect size	95% CI		*p*
				Lower	Upper	
Direct effect	SES → ISLEs	.179	54.57%	.088	.270	***
Indirect effect	SES →FS-F → ISLEs	.084	25.61%	.028	.141	**
	SES →FS-I → ISLEs	.022	6.71%	-.005	.050	.114
	SES→FS-F → FS-I → ISLEs	.043	13.11%	.007	.078	*
Total indirect effect		.150	45.73%	.085	.214	***
Total effect		.328		.230	.427	***

Note: Standardized estimated path coefficients: *$*p \le .05$, $**p \le .01$, $***p \le .001$*

The overall effect of students' family SES on their ISLEs was .328, the direct effect was .179, and the total standardized mediating effect was .150. The standardized mediating effect was equivalent to 45.73% of the overall effect. Two significant effects (95% bootstrap confidence intervals without 0) comprised the mediating effect: SES → FS-F → ISLEs and SES→ FS-F → FS-I → ISLEs. The findings revealed that students' perceived family support for formal science learning (FS-F) mediated the association between their family SES and ISLEs with a path coefficient of .084, accounting for 25.61% of the total effect. The findings further demonstrated the chain mediation effect of students' perceived family support for formal (FS-F) and informal (FS-I) science learning in the association between their family SES and ISLEs (effect size = .043), accounting for 13.11% of the total effect. However, the hypothesized simple mediation effect of students' perceived family support for informal science learning (FS-I) was not significant, as the 95% bootstrap confidence interval for the SES →FS-I → ISLEs path included 0.

Discussion

The Direct Effect of Chinese Primary School Students' Family SES on their ISLEs

The current study demonstrated that, in mainland China, primary school students' family SES had a direct effect on their informal science learning experiences, as H1 predicted. Because the majority of studies into ISLEs have been conducted in Western contexts, this study aimed to describe and validate the structure of Chinese primary school students' ISLEs. It uncovered a three-dimensional structure of ISLEs consisting of everyday learning (EL), museum learning (ML), and school-led or semiformal learning (SL). The resulting factor structure was a reliable and valid measure of Chinese primary students' ISLEs. However, the factor structure for Chinese primary students identified in the current study differed slightly from its equivalents derived from Western samples. Specifically, while "learning science in nature" was highlighted in the two previous studies of American and English adolescents' ISLEs (DeWitt & Archer, 2017; Lin & Schunn, 2016), it had no place in the current study. A possible reason for this finding is that Chinese primary students have few opportunities to learn about science in nature—for both humanistic and social reasons. First, as Liu (2020) indicates, Chinese parents may view their children's nature education negatively and often show a lack of concern or even fear of outdoor educational activities due to risks to their children such as bacteria from animals, sunburn, or being scratched by plants. Secondly, with ongoing urbanization, the natural environment has shrunk drastically (Fu, 2020), objectively reducing opportunities for Chinese students to learn science in nature. Thirdly, as the burden of schoolwork on children grows heavier, the time they can spend in natural environments is reduced (Fan, 2018). The different ages of participants in the study may also be a factor: the research that yielded the dimension of nature learning was carried out with 6^{th} and 8^{th} graders in the US (Lin & Schunn, 2016), whereas the current study surveyed primary school students in grades 4 through 6. Parents tend to be more protective of younger children, which may limit their opportunities to commune with nature (Wang, 2019). In sum, the three-dimensional scale revised in the current study was found to be a reliable and valid instrument for assessing Chinese primary school students' informal science learning experiences.

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Although the ISLEs factor structure in this research differed from those of Western studies, the direct effect of students' family SES on their ISLEs was confirmed, corroborating the findings of prior studies (Carbonaro & Covay, 2010; Dabney et al., 2016; DeWitt and Archer, 2017; Lauert, 2003; Yamamoto, Li, & Liu, 2016**)**. This implies that inequality in informal science learning experiences due to family socioeconomic disparities may be a universal social issue—not one confined to Western natives (DeWitt and Archer, 2017) or East Asian immigrants (Yamamoto, Li & Liu, 2016**)**, but which also occurs in developing countries within the East Asian cultural sphere (in this study, mainland China).

One study conducted in the same setting found that high school students' ISLEs were positively affected by family SES, as indicated by their mothers' education levels (Zhang & Tang, 2017). The present study's use of another indicator of family SES, namely, household goods, again confirmed the direct effect of primary school students' family SES on their ISLEs. This suggests that household goods can serve as a sufficiently convenient indicator of family SES alongside or in place of family income (Crosnoe & Trinitapoli, 2008; Hofferth & Sandberg, 2001), or the more comprehensive alternative of "science capital" (DeWitt & Archer, 2017) in future studies.

The Direct Effect of Chinese Primary School Students' Family Support on their ISLEs

Students' perceived family support for learning has been established as an important variable in the learning experiences they acquire (Bonnette et al., 2019; Nugent et al., 2015; Simpkins et al., 2020). Most prior research has examined the effect of parental involvement in students' schooling (formal learning) on their academic achievement (Paulson, 1994; Steinberg et al., 1992; Stevenson & Baker, 1987). Nugent et al.'s (2015) research highlighted that parental support for both students' formal and informal learning could boost students' access to outside-of-school STEM activities, although these two types of learning were not separately measured but included in a general category of general science learning. The present study helped to resolve this ambiguity by determining that—to varying degrees—parental support for both formal (FS-F) and informal (FS-I) learning impacted elementary students' ISLEs.

The current study showed the necessity of distinguishing between family support for formal (FS-F) and informal (FS-I) science learning, which the EFA and CFA results derived as two separate and correlated factors from the survey data. Moreover, the discriminant validity of these two subscales was further supported by the square root of AVE statistics (.735 and .834) obtained using CFA. This finding echoed the Chinese educational idea that parents attach great importance to all aspects of their children's education and development. Many parents have realized the value of informal science learning as well as its formal counterpart in recent years (Chen, 2015). While primary-school-level STEM courses are now extremely popular, parents or schools are encouraged to supplement these by carrying out informal STEM learning activities for primary school students to promote their interest and abilities in the component subjects (Wang, 2017).

The two categories of perceived family support validated by the present study were then utilized to evaluate H2. Chinese primary school students' family support for formal and informal science learning was found to positively predict their ISLEs. Notably, however, the standardized direct effect of family support for formal science learning (FS-F→ISELs: .406) was obviously greater than that of informal science learning (FS-I→ISELs: .275). Students' perceived family support for formal science learning was also found to be significantly greater than for informal science learning (M_{FS-F} = 3.866 vs. M_{FS-I} = 3.744, $t(479) = 2.725$, $p = .01$, Cohen's d = .12), in line with previous studies in the context of mainland China (e.g., Li, 2012). To some extent, Chinese parents' indifference to extracurricular and informal learning may be due to the economic pressures common among parents in developing countries (Hao, 2016). For example, these parents often lack sufficient time to participate with their children in extracurricular science learning activities due to work pressure (Liu, 2015; Hannum et al., 2019) and some rarely take children to informal environments such as science and technology museums (Chen, 2015), instead encouraging them toward popular science books and programs or virtual environments (Pan, 2013). Overall, the disparity between the effects of students' perceived FS-F and FS-I on their ISLEs may reflect the educational philosophy of Chinese parents, who tend to emphasize their children's academic achievement (Yamamoto et al., 2016). This interpretation aligns with previous findings (Dabney et al., 2012; Henriksen et al., 2015) showing that as parents grow more aware of the benefits of informal science learning to academic attainment, their children receive more opportunities to learn the subject informally.

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The Chain Mediating Roles of Perceived Family Support for Formal and Informal Science Learning

The two categories of perceived family support uncovered by the current study were further used in the chain mediation model to examine the association between the SES of students' families and their informal science learning experiences. Whereas the straightforward mediating effect of students' perceived FS for formal science learning (FS-F) confirmed H3a, the effect of informal science learning (FS-I) was not statistically significant and did not, therefore, mediate the link between students' family SES and their ISLEs, leaving H3b unsupported. Finally, the students' perceived FS for formal science learning (FS-F) was also found to be a mediating variable in another path, in which students' family SES significantly and positively predicted their ISLEs via the sequential mediation of FS-F followed by FS-I, thereby supporting H3c.

Previous studies have recorded positive correlations between students' family SES and their perceived FS (Chesters, 2010; Nauert, 2008; Wang et al., 2016), but these were only repeated for the mediation of FS-F—not FS-I—in the current study. This may be due to our study's distinction between FS-F and FS-I and the introduction of both types of support into the chain mediation model, suggesting that perceived family support for formal scientific learning is a stable behavioral factor that predicts ISLEs and is predicted by family SES. This result also aligns with other studies indicating that Chinese parents show varying levels of support for formal and informal science learning (Hao, 2016; Pan, 2013), typically prioritizing the former (Li, 2012; Pan, 2013; Wu, 2013). Moreover, perceived family support for informal science learning is conditional on family support for its formal equivalent (Chung & Choe, 2001; Ma, 2019). In this case, students' perceived FS-F was found to predict their perceived FS-I.

Overall, the current study confirmed the presence of both direct and indirect links between students' family SES and their ISLEs uncovered by previous research (Carbonaro & Covay, 2010; Dabney et al., 2016; DeWitt and Archer, 2017; Lauert, 2003; Yamamoto, Li & Liu, 2016). This study extended these findings by demonstrating that the SES of students' families influenced their ISLEs via the two indirect pathways of perceived FS-F and FS-F→FS-I, thereby advancing knowledge of how students' family SES and ISLEs are related. Meanwhile, the results underline that parents must support their children's formal or informal science learning in a variety of ways, regardless of family SES level. This claim parallels those of Bonnette et al. (2019) that even under-resourced children who perceived greater family support experienced more gains combined with informal learning experiences than those who lacked such perceptions.

Conclusions and Implications

The present research aimed to examine the associations among Chinese primary school students' family SES, perceived family support for formal and informal science learning, and informal science learning experiences. The SEM revealed that (1) Chinese primary school students' family SES had a positive and direct effect on their ISLEs, (2) their family SES positively affected their ISLEs via the mediating role of FS-F, and (3) the students' perceived family support for formal and informal science learning sequentially mediated their family SES and informal science learning experiences.

The results, therefore, extend those of previous research, which did not differentiate between students' perceived family support for both formal and informal science learning. The results also underline the significance of different forms of family support for science learning, which have been shown to independently or sequentially mediate the association between students' family SES and their informal science learning experiences. It is recommended that more attention be paid to the diverse roles of family support for both types of science learning in increasing the opportunities for students to learn science informally. In particular, family support for informal science learning did not independently mediate the association between students' family SES and their informal science learning experiences but acted as a mediator of this association via perceived family support for formal science.

One limitation of this study is that family SES was only measured indirectly by the ownership of household goods. It would therefore be advantageous to evaluate family SES using multiple indicators, including household goods, parental occupation and education levels, and family income. The generalizability of the findings is further limited by the samples used for the study. Because the data were collected from 4^{th}-to-6^{th}-graders in southern China, the results may not apply to other groups of interest. Considerably more research is required to discover whether different forms of family support play comparable mediating roles in other economic or cultural contexts.

Informed by this study, parents are encouraged to foster their children's formal and informal science learning, since this will play a crucial role in their educational outcomes. Students from low-SES families can acquire access to informal science learning when they receive sufficient support from their families, even if this support targets

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informal rather than formal science learning. Encouraging parents to support both types of science learning may help overturn the link between structural inequities and unequal science educational outcomes, helping disrupt the intergenerational transmission of poverty.

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Declaration of Interest

The authors declare no competing interest.

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Appendix

Student Informal Science Learning Survey

This survey asks questions about you and your family members' involvement in learning science in informal environments (outside of school). This is NOT a test; we are simply interested in your opinion. There are no correct or incorrect replies. Your response will not be shared with your teachers and parents.

Part A: Personal and family information

Please fill in your responses on the line after the questions.
1. What is the name of your school?
__________________________.

2. How old are you?
__________________________.

Please tick the box in front of the option that matches your information.
3. Which grade are you in?
☐ Grade 4 ☐ Grade 5 ☐ Grade 6

4. Are you a boy or a girl?
☐ Boy ☐ Girl

5. How many of the following goods are there at your home? Please tick the box that matches your information.

	None	1	2	3 or more
Television	☐	☐	☐	☐
Car	☐	☐	☐	☐
Room with bathtub	☐	☐	☐	☐
Mobile phone (with internet access)	☐	☐	☐	☐
PC (desktop computer and laptop)	☐	☐	☐	☐
Tablet PC (e.g., iPad)	☐	☐	☐	☐
Electronic reader (e.g., Kindle)	☐	☐	☐	☐
Musical instruments (e.g., guitar, piano)	☐	☐	☐	☐

6. How much do you agree with the following statements? Please tick the box that matches your opinion.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
My science learning in school is important to someone in my family.	☐	☐	☐	☐	☐
When I work on science homework at home, I have someone who can help me with it if I need help.	☐	☐	☐	☐	☐
Someone in my family makes sure I finish my science homework every day.	☐	☐	☐	☐	☐

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	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Someone in my family is interested in teaching me about science.	☐	☐	☐	☐	☐
Someone in my family encourages me to learn science in various ways.	☐	☐	☐	☐	☐
Someone in my family takes me to places where I can learn new science.	☐	☐	☐	☐	☐
When I want to visit a science museum or zoo, someone in my family will ensure I can.	☐	☐	☐	☐	☐
When I want to read science-related books, someone in my family will ensure I can.	☐	☐	☐	☐	☐
When I want to watch science-related movies, someone in my family will ensure I can.	☐	☐	☐	☐	☐
Someone in my family has asked me to participate in extracurricular science activities.	☐	☐	☐	☐	☐

7. How often do you do the following things outside of school or after class? Please tick the box that matches you.

	Never	Rarely (once a year)	Sometimes (a few times a year)	Regularly (once a month)	Always (one or more times a week)
Watching science-related TV shows	☐	☐	☐	☐	☐
Reading books or magazines about science	☐	☐	☐	☐	☐
Learning science online (e.g., YouTube, science websites, playing science games)	☐	☐	☐	☐	☐
Discussing science with others outside school	☐	☐	☐	☐	☐
Practicing science problems online	☐	☐	☐	☐	☐
Attending science tutoring classes*	☐	☐	☐	☐	☐
Taking care of pets*	☐	☐	☐	☐	☐
Cultivating plants*	☐	☐	☐	☐	☐
Collecting plant specimens *	☐	☐	☐	☐	☐
Visiting the museum	☐	☐	☐	☐	☐
Vising a science center, science and technology museum, or planetarium	☐	☐	☐	☐	☐
Visiting a zoo or aquarium	☐	☐	☐	☐	☐
Doing experiments or using science kits*	☐	☐	☐	☐	☐
Fixing or building things*	☐	☐	☐	☐	☐
Nature walk or similar (e.g., city farm, botanic garden, wildlife site) *	☐	☐	☐	☐	☐

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	Never	Rarely (once a year)	Sometimes (a few times a year)	Regularly (once a month)	Always (one or more times a week)
Program computers (e.g., writing apps, building websites) *	☐	☐	☐	☐	☐
Participating in science-related trips organized by the school	☐	☐	☐	☐	☐
Participating in museum visits organized by the school	☐	☐	☐	☐	☐
Participating in science-related presentations organized by the school	☐	☐	☐	☐	☐
Participating in after-school science clubs	☐	☐	☐	☐	☐
Participating in science and technology festivals organized by the school	☐	☐	☐	☐	☐

Note. *Items were dropped after EFA due to low factor loading.

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