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Conceptions, Self-Regulation, and Strategies of Learning Science Among Chinese High School Students

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Abstract This study explored the structural relationships among secondary school students' conceptions, self-regulation, and strategies of learning science in mainland China. Three questionnaires, namely conceptions of learning science (COLS), self-regulation of learning science (SROLS), and strategies of learning science (SLS) were developed for investigating 333 Chinese high school learners' conceptions, metacognitive self-regulation, and strategies in science. The confirmatory factor analysis results verified the validity of the three surveys. Moreover, the path analyses revealed a series of interesting findings. Learners with lower-level COLS, namely "memorizing," "testing," and "practicing and calculating," tended to use surface learning strategies such as "minimizing scope of the study" and "rote learning." However, learners' higher-level COLS, namely "increase of knowledge," "applying," "understanding," and "seeing in a new way," had complicated connections with their SROLS and SLS. On the one hand, learners' higher-level COLS had negative relations to "minimizing scope of the study" and "rote learning." On the other hand, their higher-level COLS were powerful predicators for their metacognitive self-regulation and further affected their use of "deep strategy" and "rote learning." Though Chinese secondary students with higher-level COLS usually have a negative view of "rote learning," the functioning of their metacognitive self-regulation may change their initial attitudes towards the surface strategy. Learners with higher-level COLS still used "rote learning" as a prior step for achieving deep learning. Therefore, we concluded that the

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SROLS played an important mediating role between the COLS and SLS and may change learners' original intention to utilize learning strategies.

Keywords Conceptions of learning science · Metacognitive self-regulation · Approaches to learning · Learning strategies · Chinese high school students · Science education

Introduction

Conceptions of learning constitute the core construct for understanding learners' beliefs in the nature of school knowledge and learning in class. Substantial research has been conducted to interpret students' conceptions of learning in general (e.g. Marshall, Summer & Woolnough, 1999; Marton, Dall'Alba & Beaty, 1993; Säljö, 1979) or conceptions of learning science in specific (e.g. Lee, Johanson & Tsai, 2008; Sadi & Lee, 2015; Tsai, 2004). In the field of science education, recent research focus has shifted from what conceptions of learning science are to how they develop, fluctuate, or interact with other variables, such as learners' self-efficacy (Lin, Tsai & Liang, 2012; Sadi & Dagyar, 2015), metacognitive self-regulation (Alpaslan, Yalvac, Loving & Willson, 2016; Cheng, Liang & Tsai, 2013) or their learning approaches (Chiou, Liang & Tsai, 2012; Lee et al., 2008; Lin et al., 2012). Moreover, since conceptions of learning are increasingly recognized to be culturally-dependent (e.g. Chiu, 2012; Lin & Tsai, 2008), scholars are asking for more contextualized exploration of students' conceptions of learning science and their learning process in a specified cultural background (e.g. Sadi & Lee, 2015; Zhao & Thomas, 2016). Taking Chinese secondary science learners as an example, mainland China has the largest population of high school students around the world and science is a required subject for all grades of students in junior high schools. Compared with science learners in the Western world, Chinese high school students have their distinctive characteristics (e.g. Bao, Cai, Koenig, Fang, Han, Wang & Wu, 2009; Zhao & Thomas, 2016). Further research is still needed to identify Chinese secondary students' interpretation of learning science and its relations to their employment of learning strategies. This research attempts to explore the structural relationships among secondary learners' conceptions, self-regulation, and strategies of learning science in mainland China.

Literature Review

Conceptions of Learning Science

The pioneering work on the categorization of students' conceptions of learning was proposed by Säljö (1979), and since then, researchers have further modified or extended the categories (e.g. Duarte, 2007; Eklund-Myrskog, 1998; Marton et al., 1993). Conceptions of learning are domain-specific (e.g. Tsai, 2004) and a large number of studies have discussed conceptions of learning science recently (e.g. Asikainen, Virtanen, Parpala & Lindblom-Ylänne, 2013; Lee et al., 2008; Zhu, 2013). Tsai (2004) classified Taiwanese high school students' conceptions of learning science (COLS) into seven categories as "memorizing," "testing or preparing for tests," "practicing and calculating," "increase of knowledge," "applying," "understanding," and "seeing in a new way." The subsequent studies confirmed the taxonomy and suggested a hierarchy of the seven types of conceptions. The first three, "memorizing," "testing" and "practicing and calculating" were viewed as the lower-level or unsophisticated conceptions, while the others were the higher-level or sophisticated conceptions (Chiou et al., 2012; Lin et al., 2012; Tsai, Jessie Ho, Liang & Lin, 2011). Based on Tsai's (2004) categories of COLS, Lee et al. (2008) developed a COLS questionnaire as a valid and reliable instrument for assessing high school students' conceptions of learning science.

Self-Regulation in Learning Science

Self-regulation was defined as "processes that learners use to activate and maintain cognitions, emotions, and behaviors to attain personal goals" (Zimmerman & Kitsantas, 2014, p. 145), and was also considered as "a multidimensional construct including cognitive, metacognitive, motivational, behavioral, and environmental processes" (as cited in Dörnyei & Ryan, 2015, p. 165). The significance of students' self-regulation on academic achievement has been well documented in the domain of science learning (e.g. Hsu, Iannone, She, Hadwin & Yore, 2016; Hsu, Yen, Chang, Wang & Chen, 2016; Taasoobshirazi & Sinatra, 2011). Many researchers further believed that metacognitive self-regulation played an especially important role in academic learning since it represented learners' awareness, knowledge, and control of cognition and could help them apply cognitive strategies more effectively (e.g. Leopold & Leutner, 2015; Schraw, Crippen & Hartley, 2006). Moreover, metacognitive regulation skills were regarded as crucial antecedents for understanding and deep learning in science (e.g. Cooper, Sandi-Urena & Stevens, 2008; Sandi-Urena, Cooper & Stevens, 2011; Zohar & Barzilai, 2013).

Strategies in Students' Approaches to Learning Science

The student approaches to learning (SAL) are important factors for predicting learning outcomes. The strategic factors of the SAL describe how learners are engaged in the actual tasks and usually consist of surface and deep strategies. In 2008, Lee and colleagues developed the survey of approaches to learning science (ALS) to assess Taiwanese high school students' science learning approaches. Their findings confirmed that science students' learning strategy had two individual factors, namely, deep strategy and surface strategy (Lee et al., 2008). As reviewed by Floyd, Harrington and Santiago (2009), surface learning was usually related to rote learning and reflected learners' desire to achieve success in exams, while deep learning demonstrated learners' higher-order thinking skills, not merely for passing exams.

Conceptions, Self-Regulation, and Strategies of Learning Science

In the field of education, scholars have shown an increasing interest in the relations between conceptions of learning and other related variables, such as learners' approaches to learning and their self-regulation. For instance, Purdie, Hattie and Douglas (1996) reported close relations between learners' conceptions of learning and their self-regulation strategies. Drawing upon the investigation of science students in Taiwan, researchers disclosed that learners with lower-level conceptions of learning tended to adopt surface learning strategies while students with higher-level conceptions of learning were more likely to use deep learning strategies (Chiou et al., 2012; Lin et al., 2012). Recently, Alpaslan et al. (2016) claimed that physics students' personal epistemologies indirectly influenced self-regulation through the mediating role of motivation beliefs.

Scholars have also intended to disclose the dynamics among the three constructs at a time. Heikkilä and Lonka (2006) made an attempt to integrate college students' approaches to learning and self-regulation with cognitive strategies. They found that the three theoretical constructs were interrelated. Loyens and his colleagues (2008) further released that self-regulation played a dominant role in mediating the influence of conceptions of learning on learners' operation of strategies. Based on the previous studies, it is very clear that conceptions, self-regulation, and learning strategies are intricately related and self-regulation may play as a mediator between conceptions and strategies of learning. However, few empirical studies have been conducted discussing the relationships among learners' conceptions of learning, self-regulation, and learning strategies in one model in the field of science education.

Research Purpose

The purpose of the current study was to investigate the relationships among Chinese high school students' conceptions, self-regulation, and learning strategies in science using the structural equation model (SEM) technique. As mentioned in the above literature review, the interrelations among the three research constructs have not been explicitly elaborated in earlier studies, and the SEM analysis in the current research is more exploratory in nature. In order to test the causality among the three constructs, we adhered to the previous theoretical frameworks as follows.

First, the present study adopted Tsai's (2004) categorization of the conceptions of learning science (COLS) with seven identified dimensions (memorizing, testing, practicing and calculating, increase of knowledge, applying, understanding, and seeing in a new way). It also employed the framework which grouped students' COLS into two levels, namely, the lower-level conceptions and the higher-level conceptions (Lee et al., 2008; Lin & Tsai, 2008). Moreover, the current study selected items from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia & McKeachie, 1991, 1993) to measure learners' metacognitive self-regulation of learning science (SROLS). The items about the SROLS not only concerned learners' preparation for learning tasks, such as goal-setting and task-analyzing, but also covered learners' specific actions of monitoring and further regulating their learning processes and outcomes by testing, questioning, or self-adjusting. According to Pintrich (2004), the boundary between monitoring and regulating was relatively vague since learners might simultaneously monitor and regulate their tasks during the learning processes. Cheng et al. (2013) and Alpaslan et al. (2016) also expressed similar arguments and proposed considering the planning phase as basic self-regulated learning, while the monitoring, controlling, and reflecting phases were seen as advanced self-regulated learning. Therefore, we categorized the items about goal-setting and task-analyzing in the SROLS as "basic self-regulation" whereas the rest items as "advanced self-regulation." Additionally, we followed the approaches to learning science questionnaire (Lee et al.,

2008) in designing the strategies of learning science (SLS) survey for assessing Chinese high school students' strategies in the process of science learning. Based on the research about Chinese students' learning strategies by Biggs (1996) and Kember, Biggs and Leung (2004), we maintained the factor of "deep strategy" and further divided the "surface strategy" into two factors, "minimizing scope of the study" and "rote learning" for better presenting learners' strategic behaviors in a Chinese educational setting.

Based on the aforementioned theoretical and empirical evidence, a hypothesized model was proposed. Figure 1 briefly illustrates the interrelationships among students' COLS, SROLS, and SLS. It was hypothesized that students' COLS may correlate to their SROLS. Besides, the higher-level COLS may be positively related to the "deep strategy" while the lower-level COLS may be positively associated with "minimizing scope of the study" and "rote learning." Moreover, learners' SROLS may play as the mediator and also positively correlate to their SLS. This study attempted to conduct the path analyses with the SEM technique to better understand the structural relationships among the three variables.

Methodology

Participants in the Study

The participants for this study included 333 8th grade students, made up of a similar number of participants from each of six different junior high schools in Beijing, China. Among them, 163 were male students (48.9 %). The average age of all participants ranged from 13 to 16, with a mean of 14.31 (S.D. = .56). Since the surveyed students came from different high schools and demographic regions with a variety of socio-economic backgrounds, they could be considered to represent many urban high school students in China. All the students volunteered to respond to the survey anonymously.

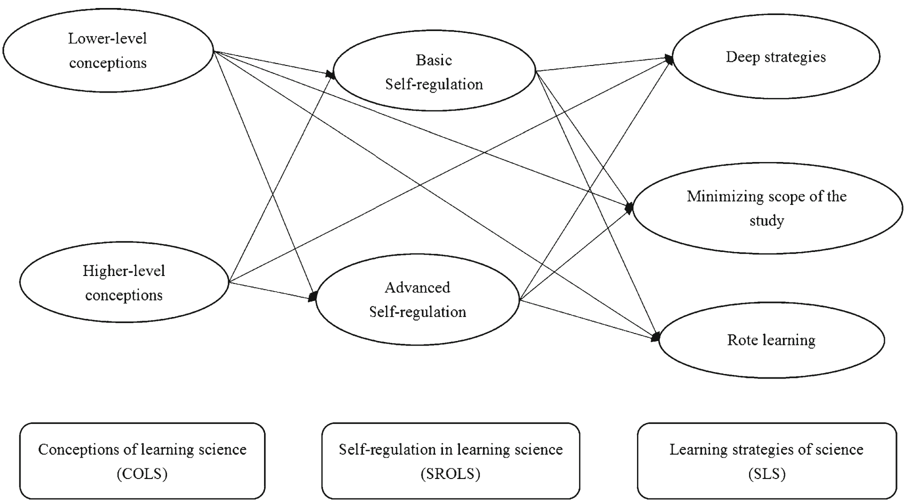

Fig. 1 The hypothetical model of structural relations among learners' COLS, SROLS, and SLS

Instruments

Instrument 1: the Conceptions of Learning Science Questionnaire

We used the questionnaire developed by Lee et al. (2008) for assessing learners' COLS. This original questionnaire was designed based on the seven categories of the COLS proposed by Tsai (2004), and the seven types of COLS were further grouped into lower-level and higher-level conceptions (Chiou et al., 2012; Lin et al., 2012; Tsai et al., 2011). The questionnaire was primarily targeted at Taiwanese high school students. Since high school students in mainland China and those in Taiwan share a similar cultural heritage, we employed the questionnaire and conducted the survey among our sample.

Instrument 2: the Self-Regulation of Learning Science Questionnaire

The MSLQ is a valid and reliable self-report instrument for measuring learners' motivation and learning strategies (Pintrich et al., 1991, 1993). It has been adapted for a number of research purposes (Duncan & McKeachie, 2005), and the 15 subscales of the questionnaire can be used together or separately (Pintrich et al., 1993; Zimmerman & Kitsantas, 2014). In the current study, we adopted the subscale concerning learners' metacognitive self-regulation in the MSLQ to form the SROLS questionnaire. The questionnaire included 12 items in total. Based on the previous studies (Alpaslan et al., 2016; Cheng et al., 2013), the metacognitive self-regulation concerning goal-setting and task-analyzing (five items) were labelled as "basic self-regulation" while another seven items were regarded as "advanced self-regulation."

Instrument 3: the Strategies of Learning Science Questionnaire

In this study, we adopted the items for assessing learners' strategies of learning science in the ALS questionnaire (Lee et al., 2008) and designed the survey of strategies of learning science (SLS) for measuring Chinese high school students' learning strategies in science. The original strategies of the ALS included "deep strategy" (six items) and "surface strategy" (five items). We added two items in "surface strategy" based on our previous interview with the sample students. Drawing upon the previous discussions about the contextual features of Chinese learners' strategies (Biggs, 1996; Kember et al., 2004), we further divided the "surface strategy" into two individual factors, namely, "minimizing scope of the study" and "rote learning." Eventually, 13 items with three factors were included in the SLS survey.

Data Collection and Analysis

The above questionnaires were administered among the participants with the permission of the high schools. As described above, the sample in this study volunteered to respond to the three questionnaires in one setting, and all the participants answered anonymously. The students' responses to the questionnaires were then collected and further analyzed for understanding the relationships among their conceptions, self-regulation, and learning strategies in science.

The data analysis procedure consisted of the following two steps. First of all, a multi-dimensional confirmatory factor analysis (CFA) was conducted to examine the factor structure of learners' COLS, SROLS, and SLS questionnaires at a time. Then, path analyses were conducted to investigate the structural relations existing among the above three instruments. In order to testify the convergent validity of the constructs, we followed the principles proposed by Hair, Black, Babin, Anderson and Tatham (2006) and Pedhazur (1997) and collected the values of item loadings, average variance extracted (AVE), and composite reliability (CR). Moreover, we used various measures (Jöreskog & Sörbom, 1993), such as the chi-square, the degree of freedom, χ^2 per degree of freedom, the root mean squared error of approximation (RMSEA), the goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), the normed fit index (NFI), the incremental fit index (IFI), the Tucker-Lewis index (TLI), and the comparative fit index (CFI) to present the model fitness. Since we proposed our hypothesized model on the basis of several individual empirical studies and the ties between the research constructs were not overtly presented by previous studies at a time, the whole study provided a tentative research model for understanding the intricate relations among learners' COLS, SROLS, and SLS.

Results

The CFA Analysis of the COLS, SROLS, and SLS questionnaires

In order to clarify the reliability and validity of the research instrument, the present study conducted a single CFA with all the items and dimensions of the three questionnaires (COLS, SROLS, and SLS) recruited in one model. A total of 46 items were retained in the final version of the survey (28 items for COLS, 9 items for SROLS, and 9 items for SLS). The ratio of participants (333 sample students) to the questionnaire items (46 items) in the current study was computed to 7.24 and met the 5:1 guideline proposed by Bentler and his colleagues (e.g. Bentler & Chou, 1987; Bentler, 1989).

As indicated in Table 1, all the factor loadings of the measured items were higher than the threshold value of .50 (ranging from .53 to .85). Besides, the reliability (Cronbach's alpha) coefficients for all factors ranged from .74 to .85 and the overall alpha was .91, indicating sufficient internal consistency of the factor items. Moreover, the composite reliability (CR) coefficients exceeded .70 (.74 – .85), and the average variance extracted (AVE) exceeded .40 (.44 – .59). According to Fornell and Larcker (1981), if the overall composite reliability is higher than .60 and the average variance explained of each construct is higher than .40, the convergent validity of the construct can be considered as adequate, although not rigorous. Finally, the goodness-of-fit (GOF) of the structure: chi-square = 1384.35, $p < 0.001$, degree of freedom = 961, χ^2 per degree of freedom = 1.44, GFI = .85, AGFI = .83, NFI = .82, IFI = .94, TLI = .93, CFI = .94, RMSEA = .04, indicating that the measurement model was of fine fit. Therefore, the validity and reliability of the three questionnaires in one model were established.

Table 1 The confirmatory factor analysis of the COLS, SROLS, and SLS questionnaires ($N = 333$)

Constructs and measurement items	Factor loading	*t*	AVE	CR	Alpha value	Mean	S.D.
The COLS Questionnaire							
Lower conceptions of learning science							
Memorizing (M)	-------	-------	.59	.85	.85	3.09	.93
M 1#	.80	-------				3.10	1.10
M 2	.82	15.53***				3.22	1.12
M 3	.72	13.45***				3.15	1.08
M 4	.73	13.65***				2.88	1.17
Testing (T)	-------	-------	.58	.85	.84	2.99	.96
T 5#	.80	-------				2.88	1.22
T 6	.81	15.54***				3.11	1.18
T 7	.81	15.39***				2.84	1.12
T 8	.62	11.44***				3.16	1.14
Practicing and calculating (PC)	-------	-------	.50	.80	.79	3.13	.82
PC 9#	.72	-------				2.93	1.07
PC 10	.75	12.16***				3.12	1.08
PC 11	.81	12.83***				3.04	1.06
PC 12	.53	8.8***				3.45	0.99
Higher conceptions of learning science							
Increase of knowledge (IK)	-------	-------	.47	.84	.84	3.72	.71
IK 13#	.65	-------				3.72	.97
IK 14	.69	10.64***				3.76	.94
IK 15	.68	10.53***				3.81	.94
IK 16	.73	11.14***				3.71	.91
IK 17	.72	10.97***				3.64	.92
IK 18	.64	9.95***				3.69	.99
Applying (A)	-------	-------	.49	.74	.74	3.68	.74
A 19#	.69	-------				3.73	.90
A 20	.66	10.07***				3.58	.93
A 21	.74	10.92***				3.74	.93
Understanding (U)	-------	-------	.56	.79	.79	3.89	.73
U 22#	.75	-------				3.94	.89
U 23	.67	11.27***				3.85	.84
U 24	.81	11.28***				3.88	.88
Seeing in a new way (S)	-------	-------	.57	.84	.84	3.77	.75
S 25#	.75	-------				3.74	.90
S 26	.77	13.56***				3.80	.91
S 27	.78	13.78***				3.79	.91
S 28	.71	12.48***				3.77	.92
The SROLS Questionnaire							
Basic self-regulation (BSR)	-------	-------	.44	.76	.75	3.55	.69
BSR 1#	.58	-------				3.43	.90
BSR 2	.76	9.49***				3.59	.89
BSR 3	.72	9.21***				3.50	.91

Table 1 (continued)

Constructs and measurement items	Factor loading	*t*	AVE	CR	Alpha value	Mean	S.D.
BSR 4	.59	8.13***				3.66	.94
Advanced self-regulation (ASR)	-------	-------	.46	.81	.80	3.52	.68
ASR 5#	.72	-------				3.35	.96
ASR 6	.73	11.91***				3.70	.86
ASR 7	.69	11.31***				3.60	.88
ASR 8	.57	9.39***				3.52	.90
ASR 9	.65	10.75***				3.45	.92
The SLS Questionnaire							
Deep strategy (DS)	-------	-------	.56	.79	.79	3.60	.81
DS 1#	.75					3.49	1.01
DS 2	.77	11.89***				3.68	.92
DS 3	.72	11.44***				3.62	.96
Minimizing scope of the study (Mini)	-------	-------	.55	.78	.77	2.96	.91
Mini 4#	.73					3.10	1.14
Mini 5	.85	12.12***				3.02	1.07
Mini 6	.63	10.28***				2.76	1.10
Rote learning (RL)	-------	-------	.52	.76	.76	3.24	.92
RL 7#	.73					3.34	1.07
RL 8	.74	11.18***				3.21	1.13
RL 9	.69	10.67***				3.16	1.17

Asterisk is for the probability note, and three asterisks indicate $p < .001$; # indicates a fixed item

The Path Analyses

After the CFA analysis, we then conducted the path analyses to explore the specific structural relationships among learners' COLS, SROLS, and SLS. We tested our hypothesized model, and the final structural model is displayed in Fig. 2. The model fitness indices were at first collected (the ratio of chi-square to degrees of freedom = 1.62, GFI = .97, NFI = .94, IFI = .91, TLI = .90, CFI = .91, RMSEA = .04), which indicate a fine model fit (e.g. Browne & Cudeck, 1993; Khine, 2013). Then, we made a summary of the standardized path coefficients, and the associated significance is indicated by asterisks in the figure.

As demonstrated in Fig. 2, "lower-level conceptions" in the COLS are significant predicators only for learners' "surface strategy" as "minimizing scope of the study" and "rote learning" in the SLS (path coefficient = .55, .62, respectively, $p < .001$). The findings support our hypothesis that learners' lower-level COLS (i.e. "memorizing," "testing," and "practicing and calculating") have a direct connection with their "surface strategy" in the SLS. However, it seems that learners' "lower-level conceptions" were neither related to the SROLS factors nor the "deep strategy."

On the contrary, a complicated picture is presented in Fig. 2 with regard to the relations among learners' "higher-level conceptions," SROLS, and SLS. Firstly, the "higher-level conceptions" are positively related to learners' "basic self-regulation" and "advanced self-regulation" (path coefficient = .39, .36, respectively, $p < .001$) in

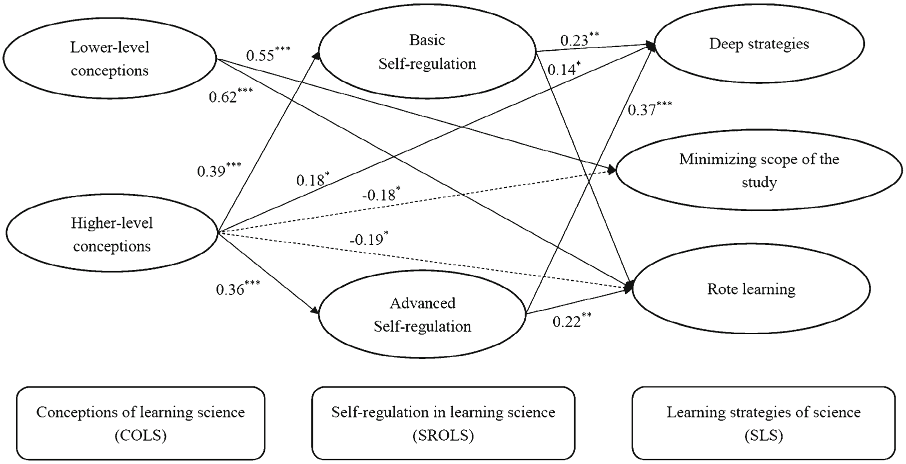

Fig. 2 The final model of structural relations among learners' COLS, SROLS, and SLS. The *solid lines* illustrate the positive relationships while the *dotted lines* represent negative relationships between the constructs. The *asterisk* is for the probability note, in which *one asterisk* indicates $p < .05$, *two asterisks* indicate $p < .01$, and *three asterisks* indicate $p < .001$. ($N = 333$)

the SROLS. Secondly, the "higher-level conceptions" are significantly positive factors for predicting "deep strategy" (path coefficient = .18, $p < .05$), but negative factors for explaining "minimizing scope of the study" and "rote learning" (path coefficient = −.18, −.19, respectively, $p < .05$) in the SLS. Besides, we also found correlations between students' SROLS and SLS. "Basic self-regulation" is a significantly positive factor for explaining "deep strategy" (path coefficient = .23, $p < .01$) and "rote learning" (path coefficient = .14, $p < .05$) in the SLS. Similarly, "advanced self-regulation" can also positively predict "deep strategy" and "rote learning." The coefficients of the correlations between "advanced self-regulation" for the SROLS and "deep strategy" and "rote learning" in the SLS were .37 ($p < .001$) and .22 ($p < .01$), respectively.

In sum, we found quite direct and positive relations between "lower-level conceptions" in the COLS and "minimizing scope of the study" and "rote learning" in the SLS. Furthermore, network-based relationships were disclosed with respect to the relations among the "higher-level conceptions" in learners' COLS, SROLS, and SLS. "Higher-level conceptions" in the COLS has a straightforward relationship with two factors in the SROLS, a positive relationship with "deep strategy" but negative relations with "minimizing scope of the study" and "rote learning" in the SLS. It can be inferred from the structural relations that the two factors in the SROLS seem to play mediating roles between the "higher-level conceptions" in the COLS and the three factors in the SLS.

Discussion

This study investigated the structural relationships and further testified the casualties among Chinese high school students' conceptions, self-regulation, and strategies of learning science. To begin with, we used Lee et al.'s (2008) COLS survey to measure learners' conceptions of science learning. The CFA results confirmed the validity and reliability of the questionnaire and revealed the same categorization of conceptions proposed by Tsai (2004). The findings were also consistent with a number of previous studies, treating conceptions of learning as a hierarchy, from lower-level to higher-level COLS (e.g. Chiou et al., 2012; Lin et al., 2012; Tsai et al., 2011). The current research also selected items in the MSLQ (Pintrich et al., 1991, 1993) for evaluating students' metacognitive self-regulation of learning science. The results also indicated the good validity and high reliability of the SROLS survey. It was further proven with two individual factors, namely "basic self-regulation" and "advanced self-regulation" as the earlier findings (Alpaslan et al., 2016; Cheng et al., 2013). Then, our findings confirmed the three factors in the SLS survey, namely, "deep strategy," "minimizing scope of the study," and "rote learning," which could be adopted as a valid and reliable instrument for assessing learners' strategies in the process of learning science. Finally, the path analyses further disclosed the complex interrelations among the three research constructs as follows.

The Role of Learners' Lower-Level COLS

As shown in Fig. 2, learners' "lower-level conceptions" of science have no significant relations with their meta-cognitive self-regulation and can only positively predict learners' "surface strategy" as "minimizing scope of the study" and "rote learning." It indicates that Chinese high school students who view learning science as "memorizing," "testing," and "practicing and calculating" may lack metacognitive ability in the process of learning science and seem to be very reluctant to use deep strategies. In contrast, they prefer rote memorization and tend to learn science for passing exams or achieving success in the course.

Our findings echo those of previous studies which stress the connections between learners' lower-level conceptions of learning and their surface strategies. Dart and his team reported a close association between high school students' conceptions of and approaches to learning and argued that learners who perceived learning as "remembering and reproducing" would most probably use surface approaches (Dart, Burnett, Purdie, Boulton-Lewis, Campbell & Smith, 2000). According to Ferla, Valcke and Schuyten (2008), unsophisticated learners tend to regard learning as memorization and seem to adopt surface strategies. In Lee et al.'s (2008) research, lower-level COLS (such as "testing" and "calculate and practice") were found to affect learners' surface approaches to learning science as well. More recently, Chiou and his colleagues (2012) revealed the positive correlations between the high school students' conceptions and surface strategies of learning physics in Taiwan. Our research findings are in concordance with previous research results and demonstrate strong correlations between Chinese high school students' lower-level COLS and their utilization of surface strategies for learning science.

The major possible explanation for the findings may relate to the examination-oriented school culture or social expectations of students' science learning in mainland China. Being similar to the secondary students in Taiwan (Hong & Peng, 2008; Tsai & Kuo, 2008), mainland Chinese high school students also have to take entrance examinations to be admitted to the high-ranking senior high schools or universities. They are expected by their parents and teachers to perform well and to remain competitive in various types of exams. Also as shown in Zhao and Thomas's (2016) findings, Chinese high school science learners regard learning science as passing exams for avoiding distress, being more competitive among their peers or assessing their own learning achievements. This social and cultural emphasis in exams may shape learners' lower-level conceptions and further affect their employment of learning strategies in science. Thus, high school science learners with unsophisticated conceptions of science learning in China prefer to complete assignments and practice to do better in exams instead of achieving deep understanding of science or applying what they have learnt in real life.

Exam-oriented culture affects science learners' conceptions of learning and their learning approaches (e.g. Tsai, 2004; Tsai et al., 2011; Tsai & Kuo, 2008) and also has a strong influence on learners' passive learning behaviors (Kember et al., 2004). Therefore, we recommend educators pay more attention to Chinese learners' inclination to lower-level conceptions and its possible relations to their strategy use in learning science. Relevant interventions, such as diversifying evaluations criteria (Tsai et al., 2011; Tsai & Kuo, 2008), enhancing learners' inherent value of science learning, or increasing their internal interest in natural world (Zhao & Thomas, 2016), should be adopted for altering Chinese students' long-held and unsophisticated view on learning science.

The Role of Learners' Higher-Level COLS

Our SEM results also display the interesting role played by learners' higher-level COLS. Referring to Fig. 2, we can see the significantly positive relations among learners' "higher-level conceptions," their self-regulation and "deep strategy." Nevertheless, learners' "higher-level conceptions" have significantly negative relations with "rote learning" and "minimizing scope of the study."

Our findings show that learners with "higher-level conceptions" tend to be more capable of regulating their own learning in science, not only at a basic level but also at an advanced level. It is similar to the findings disclosed by several previous investigations. For instance, Purdie et al. (1996) pointed out that learners' advanced conceptions of learning, such as "understanding," have a close association with their frequent use of self-regulated learning strategies. Ferla et al. (2008) also claimed that learners who view learning as a way of seeking understanding (a factor of the higher-level conceptions of learning), usually make stronger use of self-regulated strategies. Besides, our results are in line with the findings made by Lee et al. (2008), who noted that Taiwanese high school students with "higher-level conceptions" tend to employ "deep strategy." Therefore, we can conclude that Chinese high school students with more sophisticated conceptions of learning science usually have better metacognitive awareness, possess better competence to regulate their learning, and prefer to employ deep strategies in learning science. They may not focus their learning solely on memorization or rote learning for achieving success in exams as learners with lower-level conceptions.

The Mediating Role of Learners' SROLS

Most interestingly, our findings disclose the mediating role played by learners' metacognitive self-regulation in the finalized SEM model. According to Fig. 2, learners' "basic self-regulation" and "advanced self-regulation" are both positively related to "higher-level conceptions," "deep strategy," and "rote learning." The SROLS in the present study mainly represents learners' metacognitive self-regulation. The metacognitive component of self-regulation is considered as a mediating factor in learners' learning (Loyens, Rikers & Schmidt, 2008) and researchers believe that learners with metacognitive regulation are inclined to adopt various learning strategies (e.g. Vermunt & Vermetten, 2004; Zimmerman, 1990). In our research, "basic self-regulation" concerns learners' metacognitive ability to make plans for learning; thus, it is possible that learners with this type of metacognitive regulation may use higher order higher-order thinking skills (features of deep learning) for setting goals in learning science. "Advanced self-regulation" refers to learners' metacognitive ability to monitor, control, or reflect on their own learning. It is also reasonable that learners with "advanced self-regulation" would adopt deep learning strategies in their science learning.

As for possible reasons behind the connections between the SROLS and "rote learning," we assume that it is largely influenced by the socio-cultural factors. In mainland China, rote memory is considered as one of the factors for conceptualizing Chinese learners' intelligence (Chen, 1994). As for many Chinese students, rote memorization serves as a preparatory stage for better understanding (Zhao & Thomas, 2016; Zheng, Liang, Yang & Tsai, 2016) and also a required learning strategy for acquiring information and knowledge (Schunk & Zimmerman, 2003). Therefore, on the one hand, Chinese high school students with sophisticated COLS may be more self-regulated, prefer to adopt "deep strategy." On the other hand, they may also use "rote learning" as a tactical strategy for achieving their objectives of learning science, particularly for better understanding (Zhao & Thomas, 2016). This finding seems to be contradictory to the negative relations between "higher-level COLS" and "rote learning" as in above-mentioned discussion. However, through the mediating role of metacognitive self-regulation, sophisticated learners would still adopt "rote learning" as one of their learning strategies.

Although Chinese students are usually considered as passive or syllabus-dependent rote learners and their learning strategies are frequently criticized (for a review, see Jiang & Smith, 2009), our research delineates the complexity of "rote learning" as a surface strategy. Students with higher-level COLS generally may not use "rote learning" since it was originally a type of surface learning strategy. However, the functioning of their metacognitive self-regulation may change their initial intention to use learning strategies. These learners may consider "rote learning" as a prior step leading to their deeper understanding; thus, they may still use "rote learning" for achieving deep learning. Actually, the complicated nature of "rote learning" has already been noticed by a number of previous studies. For instance, Cheng rebutted the over-generalization of Chinese students as "reticent and passive" learners and cautioned that their learning strategies may be far more complicated than assumed (Cheng, 2000, p. 436). Kennedy (2002) urged clarification of the notion of rote learning and argued that Chinese learners' rote learning is a prelude to their deep understanding. Biggs (1996) also proposed that Chinese students' strategy use was "purposeful rather than mechanical" (as cited in Jiang & Smith, 2009, p. 287). Our research results about the mediating role of metacognitive self-regulation once again remind educators and researchers to reappraise Chinese learners' "rote learning" and the role of self-regulation on changing learners' strategy use as well.

Future Research

This exploratory study investigated the interplay among three different research constructs, namely, learners' COLS, SROLS, and SLS. The structural relationship framework among the three variables reflects Chinese mainland high school students' conceptions, self-regulation, and strategies of learning science. More importantly, we verified the mediating role played by self-regulation bridging Chinese secondary learners' conceptions and strategies of learning science. We recommend that future research replicate the current research among high school students in other academic domains or cultural contexts. Since the present study only selected high school students in one city in northern China, more representative samples could be invited from different parts of mainland China. Besides, a comparative study between high school students in Taiwan and mainland China in terms of their COLS, SROLS, and SLS would provide both sides with more interesting and meaningful implications for science education in secondary schools.

Moreover, a number of researchers have realized the limitations of self-report questionnaires and have recommended collecting learners' views through interviews, observations, or other qualitative research methods (e.g. Schraw, 2000; Tsai et al., 2011). Based on the current research, future investigations should be employed for exploring the specific reasons behind the interwoven relations among the three different research constructs. Particularly, the present research delineates the mediating role played by the metacognitive self-regulation between the COLS and SLS, which has not been sufficiently discussed in previous studies. Qualitative findings could provide more convincing evidence for explaining the results disclosed in our research.

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Appendix 1

Three Questionnaires (English Version)

The Questionnaire for the COLS: Conceptions of Learning Science

Factor 1 Memorizing (M)

1. Learning science means memorizing the important concepts found in a science textbook.
2. Learning science means remembering what the teacher lectures about in science class.
3. Learning science means memorizing scientific symbols, scientific concepts, and facts.
4. When learning science, just like when learning history or geography, the most important thing is to memorize the content of the text book.

Factor 2 Testing (T)

5. Learning science means getting high scores on examinations.
6. I learn science so that I can do well on science-related tests.
7. The major purpose of learning science is to get more familiar with test materials.
8. There is a close relationship between learning science and taking tests.

Factor 3 Practicing and calculating (PC)

9. Learning science means constantly practicing calculation and solving problems.
10. Learning calculations or problem-solving will help me improve my performance in science courses.
11. Learning science means knowing how to use the correct formulae when solving problems.
12. There is a close relationship between learning science, being good at calculations, and constant practice.

Factor 4 Increase of knowledge (IK)

13. Learning science means the acquisition of knowledge about science.
14. Learning science means acquiring knowledge that I did not know before.
15. I am learning science when the teacher tells me scientific facts that I did not know before.
16. Learning science helps me acquire more facts about nature.
17. I am learning science when I increase my knowledge of natural phenomena and topics related to nature.
18. For me, learning science means getting new knowledge.

Factor 5 Applying (A)

19. Learning science means acquiring knowledge and skills to enhance the quality of our lives.
20. Learning science means learning how to apply knowledge and skills I know to unknown problems.
21. We learn science to improve the quality of our lives.

Factor 6 Understanding (U)

22. Learning science means an understanding of some problems or phenomena that couldn't be solved before.
23. Learning science means enlarging my knowledge scope and experience.
24. Learning science helps me understand more natural phenomena and knowledge about nature.

Factor 7 Seeing in a new way (S)

25. Learning science means using a new viewpoint to view natural phenomena or topics related to nature.
26. Learning science means changing my way of viewing natural phenomena and topics related to nature.
27. Learning science means finding a better way to view nature or topics relating to nature.

28. Learning science means finding a more reasonable way to explain the topics in our lives.

The Questionnaire for the SROLS: Self-Regulation of Learning Science

Factor 1 Basic self-regulation (BSR)

1. I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.
2. When studying for this course I try to determine which concepts I don't understand well.
3. When I study for this class, I set goals for myself in order to direct my activities in each study period.
4. If I get confused taking notes in class, I make sure I sort it out afterwards.

Factor 2 Advanced self-regulation (ASR)

5. When reading for this course, I make up questions to help focus my reading.
6. When I become confused about something I'm reading for this class, I go back and try to figure it out.
7. If course readings are difficult to understand, I change the way I read the material.
8. Before I study new course material thoroughly, I often skim it to see how it is organized.
9. I ask myself questions to make sure I understand the material I have been studying in this class.

The Questionnaire for the SLS: Strategies of Learning Science

Factor 1 Deep strategy (DS)

1. I like constructing theories to fit odd things together when I am learning science topics.
2. I try to find the relationship between the contents of what I have learned in science subjects
3. I try to relate new material to what I already know about the topic when I am studying science.

Factor 2 Minimizing scope of the study (Mini)

4. As long as I feel I am doing well enough to pass the examination, I devote as little time as I can to studying science subjects. There are many more interesting things to do with my time.
5. I generally will restrict my study to what is specially set as I think it is unnecessary to do anything extra in learning science.

6. I find that studying each topic in depth is not helpful or necessary when I am learning science. There are too many examinations to pass and too many subjects to be learned.

Factor 3 Rote learning (RL)

7. When learning science, I would like my teacher to tell us the focus of examinations, then we can be better prepared for the exams.
8. When learning science, I will recite or memorize related contents repeatedly until I remember all the contents in the learning unit.
9. When learning science, I focus on the part related to the examination and memorize it in particular.

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