Is There a Self-Regulated Learning Model in East Asian Educational Systems? A Cross-Sectional Study Based on PISA 2012.

Inaugural-Dissertation

der Fakultät Humanwissenschaften

der Otto-Friedrich-Universität Bamberg

vorgelegt von

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Bamberg, den 31.05.2018

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Datum der Abschlussprüfung: 13.11.2018

URN: urn:nbn:de:bvb:473-irb-466173
DOI: https://doi.org/10.20378/irb-46617

Acknowledgment

May 30, 2018 is the day I write this acknowledgment to express my thanks to the people who have supported and helped me during my PhD. study. This dissertation would not have been possible without the financial support of the Bamberg Graduate School of Social Sciences (BAGSS) and Prof. Carstensen.

I am especially indebted to my collaborators, Professor Dr. Carstensen, Department of Psychological Methods of Educational Research at the University of Bamberg, Associate Professor Dr. Yi-Hsin Chen, Department of Educational Measurement and Research at the University of South Florida, Associate Professor Dr. Sarah Kiefer, Department of Educational Psychology at the University of South Florida, and Associate Professor Dr. Jihyun Lee, Department of Education at the University of New South Wales. Your knowledge of international large-scale assessments, methodology and self-regulated learning theory have guided me in the right direction. I thank you all for your unconditional support and for your feedback on my manuscripts. It was an honor and a privilege to collaborate with you. I really enjoyed my discussions with you and I hope that we will have many discussions in the future.

I would like to thank my committee members, Prof. Hatrig and Prof. Gebel. Your informative suggestions have helped me to improve my work. I really appreciated your encouragements, which have kept me moving forward and have helped me to reach my potential.

I would like to thank my friends, Benjamin Spreng, Eugene Yip, John P. Banchani, Melanie Madden, Ming-Chia Yeh, Olivia Hu, and Tyas Mekar Sari for accompanying me in this journey. You have made my PhD life much happier. Thank you Benjamin Spreng and Eugene Yip for sharing your PhD experiences with me, and for providing suggestions on how surveys could be improved from a natural science perspective. Thank you John P. Banchani, Ming-Chia Yeh, Olivia Hu, and Tyas Mekar Sari for always taking your time to comfort me when I encountered difficulties. Special thanks to Melanie Madden for the many discussions and for supporting my English writing over the past three years.

Most importantly, to my mother and father, thank you for sharing your passion on education, which has inspired me to pursue my PhD on education. Thanks to my sisters for keeping me up-to-date with academia news. Finally, and the most importantly, I would like to thank my lovely grandmother and my creative brother. To my grandmother, your unconditional love and patience are with me in whatever I pursue. To my little brother, you have shown to me what perseverance means and your creative thinking boosts my understanding and awareness of every human being. Life would not be as exciting and as interesting without you. This dissertation is for you, my grandmother and my little brother.

Abstract

The common stereotype of East Asian learning behavior is that East Asian student use memorization extensively, which is called rote-learning behavior. However, East Asian students' performance has been consistently ranked at the top on international large-scale assessments such as Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS). Such striking performance is unlikely to be attributable to rote-learning behavior. In this dissertation, we aimed to disentangle East Asian students' learning behavior by drawing on PISA 2012 with the following aims: (1) the frequency of use of memorization among East Asian students, (2) the relationships between learning strategies and mathematics performance, (3) the relationships between self-efficacy and learning strategies, (4) the relationships between intrinsic motivation, extrinsic motivation, and learning strategies.

To investigate the frequency of use of memorization, latent class analysis (LCA) were fitted to seven East Asian educational systems (i.e. Hong Kong, Japan, Korea, Macau, Shanghai of China, Singapore, and Taiwan) as well as the comparisons of the use of memorization across cultures, namely Taiwan and America by using the multiple-group LCA. This showed that East Asian students reported more control strategies, yet less memorization; only a few Taiwanese students (5%) reported memorization and more American students (19%) reported memorization compared to Taiwanese students.

Examining other factors, performance, self-efficacy, and motivation, related to learning strategies, showed that when East Asian students have lower performance, lower self-efficacy or lower motivation, they tend to report the use of memorization. In contrast, when students had higher performance, higher self-efficacy or higher motivation, they were likely to report control strategies.

In sum, we examined different angles to understand East Asian students' learning behavior by using PISA 2012 within a self-regulated learning framework. It is worth noting that the serotype of East Asian learning behavior was challenged. Moreover, it seemed that East Asian students' self-regulated learning behavior was in line with the self-regulated learning theory (SRL). Implications of these findings are discussed.

Key Words: *Learning Strategies, Self-efficacy, Intrinsic Motivation, Extrinsic Motivation, LCA, PISA*

Contents

1.1. Introduction

The use of memorization has been associated with East Asian students for decades (Biggs, 1998; Murphy, 1987; Samuelowicz, 1987). Today, many educational researchers still believe that East Asian students rely extensively on memorization. If East Asian students truly rely heavily on memorization, how could they have such a striking performance on international large-scale assessments? This paradox has existed for decades. However, it seems that recent studies and cross-cultural qualitative studies confront such belief and provide plausible explanations for the paradox. For example, several PISA studies have demonstrated that East Asian students report less memorization than their counterparts (Chiu, Chow, & McBride-Chang, 2007; Liu, 2009; Liu, & Wilson, 2009). Rather, most East Asian students report the frequent use of control strategies. On the other hand, cross -cultural researchers point out that East Asian students have different concepts of memorization compared to Western students (Kember, 2000; Kember & Gow, 1990; Sachs & Chan, 2003). Taken together, it seems that the belief of East Asian rote-learning behavior remains questionable. In this dissertation, we attempted to investigate the common belief of East Asian rote-learning behavior within a self-regulated learning perspective. Currently, most of self-regulated learning (SRL) studies have been developed within Western contexts, but have been less established in other contexts. An important question that should be addressed is whether SRL can be replicated in East Asian contexts. This is thus highly relevant to current research that tries to obtain a better understanding of the SRL applicability in East Asian contexts.

In recent years, some researchers suggest that students may combine various learning strategies during learning (Beishuizen, Stoutjesdijk, & Van Putten, 1994; Dignath, Buettner & Langfeldt, 2008; Entwistle & Entwistle, 2003; Marton, Dall'Alba, &Tse ,1996). For example, students memorize mathematics formulas and summarize notes to connect difficult concepts. During learning, students may apply a range of learning strategies rather than constantly apply a single learning strategy. Marton et al. (1996) also argue that East Asian students combined memorization and understanding. Although a combination of memorization and understanding is impractical from a Western perspective (Dahlin &Watkin, 2000), it may be advantageous for East Asian students. Thus, to address the combinations of learning strategies, latent class analysis (LCA) is applied in this study, which identifies distinct learning strategies types based on students' responses on the construct of learning strategies.

Altogether, the purpose of the dissertation is to explore four research questions within a SRL perspective by using LCA. First, do East Asian students tend to report memorization? Second, to what extent are learning strategies related to students' performance among East Asian students? Three, are the relationships between self-efficacy and learning strategies similar in an East Asian country and a Western country? Four, to what extent are learning strategies related to intrinsic motivation and extrinsic motivation among East Asian students? To answer these questions, PISA 2012 is used.

The outline of this synthesis is structured as following. First, we introduce a self-regulated learning theory's framework and East Asian students' learning behavior. Second, the main research questions and hypotheses in this dissertation are addressed. Third, a brief introduction of PISA 2012 and the LCA models are discussed. Fourth, we discuss main results in each manuscript. Finally, implications are provided.

1.2. Self-regulated Learning Theory (SRL)

There are varying self-regulated learning theories developed within Western contexts (Boekaerts, 1995; Pintrich, 2000; Zimmerman, 2001), yet these theories acknowledge that students improve their learning through regulating their cognition, motivation and behavioral components (Zimmerman, 2001). In the early stages of the SRL theory, most research focused on the components of cognition and metacognition. After the 1970s, motivation was embedded into the SRL theory. Therefore, it commonly agrees that cognition, motivation, and behavior play essential roles in SRL.

Zimmerman (2001) proposes three phases in the SRL: the forethought phase, the performance control phase, and the self-reflection phase (see Figure 1). In the forethought phase, students set desirable goals and make strategic plans based on the difficulties of tasks and their motivation and self-beliefs. In the performance control phase, students decide the degrees of efforts thereby adopting appropriate learning strategies. Through the self-reflection phase, students monitor their learning results by evaluating their performance and identifying possible attributions. In turn, they adjust their levels of goals, levels of motivation and self-beliefs and reselect appropriate learning strategies. During these three phases, students monitor, plan and adjust their cognition, motivation, and behavior to achieve their desirable goals.

In the SRL, motivation and self-beliefs drive the application of learning strategies. In this sense, when students are motivated intrinsically or extrinsically to learn, they tend to set challenging goals for themselves, which in turn means they adopt effective learning strategies to obtain their goals. Similarly, when students believe themselves more capable of learning in a specific task, they set higher goals for themselves and exert a lot of effort to achieve their goals thereby selecting effective learning strategies. Therefore, it seems that students not only need "will", but also "skill" to achieve their desirable goals. In the following section, we will illustrate the relationships between learning strategies and students' performance, the relationship between self-efficacy and learning strategies, and the relationships between motivation and learning strategies.

The relationships between learning strategies and performance

Learning strategies plays an essential role in the performance control phase in SRL. In this phase, not only do students have certain levels of intrinsic motivation, extrinsic motivation and self-efficacy, but they should also select appropriate learning strategies. Although learning strategies have diverse definitions (Schunk & Zimmerman, 2003; Weinstein & Mayer, 1986), these definitions converge in Weinstein and Mayer (1986)'s categorization on learning strategies, which is in line with PISA's definitions, cognitive strategies and metacognitive strategies (Weinstein & Mayer, 1986; Pintrich, 1999; Zimmerman & Martinez-Pons, 1986).

Cognitive strategies are broadly defined as memorization and elaboration strategies (Garcia & Pintrich, 1994; Weinstein & Mayer, 1986). *Memorization* is the term used when students rehearse materials to reproduce similar information, which is often conceived as a surface-level learning strategy in that students cannot develop high-level cognitive functioning (Biggs, 1993; Marton & Säaljö, 1976). Researchers acknowledge the importance of memorization for a certain task, for example, remembering a multiplication table; however, when tasks become complicated, students often need to understand and integrate the concepts that they have learnt. Thus, memorization is less effective to help students solve complex tasks. *Elaboration* is characterized as a deep-level cognitive learning strategy because it helps students connect old and new knowledge to deepen their knowledge (Biggs, 1993; Marton & Säaljö, 1976). Compared with memorization, elaboration is more effective and productive, for example, students only need to use elaboration to understand materials once; however, if they use memorization, they need to use memorization several times to help them understand the material.

Metacognitive strategies[1], termed as control strategies in PISA, is how students monitor their learning to identify their deficits, then plan, and control their learning. For example, when students monitor whether they have trouble understanding materials, this can in turn alert students as to whether they have adopted inappropriate strategies for that learning purpose (Winne, 1995). Through monitoring, planning and controlling, students are able to identify gaps and improve their learning.

A considerable number of studies have provided insight into the relationships between learning strategies and students' performance. It has been shown that memorization has a negative relationship with students' performance (Vermunt, & Vermetten, 2004; Zimmerman & Martines Pons, 1986). Hau and Hui (1996) show that memorization was negatively related to mathematic achievement among Hong Kong students. Likewise, Chiu et al. (2007) demonstrate that students who had low reading scores reported the use of memorization strategies in the majority of educational systems, in PISA 2000 data. In Vermunt and Vermetten (2004)'s systematic review, they argue that memorization can only help students retrieve factual knowledge, which in turn means students have difficulties applying factual knowledge to complicated tasks. Thus, it seems that memorization cannot improve students' performance.

In contrast, elaboration and control strategies can be predicted to have a positive impact on students' performance (Artelt, 2005; Chiu et al., 2007; Lee, 2014; Liem, Lau, & Nie, 2008; Murayama, Pekrun, Lichtenfeld, & vom Hofe. 2013). In Murayama, Pekrun, Lichtenfeld, and vom Hofe's six annual waves longitudinal study (2013), involving students from grade 5 to 10, shows that growth in mathematic achievement over the years was predicted by students' motivation and their use of elaboration learning strategies rather than intelligence. Artelt (2005) shows that t students' better performance in reading is positively related to more frequent use of control strategies in PISA 2000. Furthermore, Lee (2014) reveal that students' use of control strategies was the best predictor of reading achievement in all high-performing countries in PISA 2009. In general, educational studies in past decades have acknowledged that elaboration and control strategies can promote students' performance.

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[1] In this dissertation, we used control strategies to represent metacognitive strategies to be aligned with the PISA' learning strategy framework (see OECD, 2013).

The relationships between self-efficacy and learning strategies

According to Bandura (1977), *self-efficacy* is defined as students' confidence towards their abilities for specific tasks such as "How confident do you feel about having to solve an equation like 3x+5=17?" in PISA (OECD, 2014). Self-efficacy has an impact on students' performance. Students who are highly confident in their abilities tend to challenge and persist in difficult tasks, which in turn students obtain a better performance. In contrast, students with low confidence in their abilities tend to avoid difficult tasks and are less persistent in achieving their goals. Consequently, students are more likely to be low-achievers (Schunk & Pajares, 2002). Thus, high levels of self-efficacy can enhance students' academic performance.

In the SRL process, self-efficacy and learning strategies are mutually related constructs. Students who are confident in their ability in a specific domain are likely to regulate their behavior by adopting effective learning strategies (i.e., elaboration or control strategies) to improve their performance. Alternatively, students who apply learning strategies appropriately may have higher self-efficacy to attain a better performance. A large body of evidence has demonstrated positive relationships between self-efficacy and learning strategies by using a cross-sectional study and a longitudinal study (Berger & Karabenick, 2011; Diseth, 2011; Liem et al., 2008). Diseth (2011) claims that Norwegian students who reported high self-efficacy tended to use deep-level cognitive learning strategies, and self-efficacy was negatively related to memorization. Furthermore, regarding the causal relationship between self-efficacy and learning strategies, Berger and Karabenick (2011) show in a two-wave longitudinal study that self-efficacy positively predicted elaboration and control strategies; however, self-efficacy did not have any prediction on memorization. As a result, students who have more confidence in mathematics are likely to use elaboration or control strategies.

The relationships between motivation and learning strategies

Motivation has a similar role as self-efficacy in the SRL. Motivation drives students to set desirable goals and learning strategies. The level of goals and the types of learning strategies are based on the level of motivation. If students do not have strong motivation, they will have no goals or set easily-achieving goals. As a result, students exert less effort and choose less effective strategies such as memorization, which leads to low performance.

In Eccles and Wigfield's expectancy-value model (Eccles et al., 1983; Wigfield & Eccles, 1992), they postulate that the learning activities are intrinsically and extrinsically motivated. In their model, expectancy is the student's expectation of for success and value is how a student values learning, that is, students work on a particular domain because they are interested in it and they are extrinsically motivated due to its importance for their future. Following the expectancy-value model, we defined intrinsic motivation as students who are engaged in a particular subject for its own sake because the subject itself is interesting and extrinsic motivation as students who are engaged in a particular subject because they perceive the utility or importance in a particular subject.

Many researchers have argued that the relationship between intrinsic motivation and extrinsic motivation is rather complicated and it is an oversimplification to state that extrinsic motivation is the opposite of intrinsic motivation (Deci & Ryan, 2000; Bateman & Crant, 2003; Cameron, 2001; Pintrich, 1999). For example, when students have low intrinsic motivation for learning, extrinsic motivation may drive students to learn. Moreover, many studies have shown that intrinsic motivation and extrinsic motivation predict positive behavior, cognitive, and affective outcomes (d'Ailly, 2003; Deci & Ryan, 2008; Jang, Reeve, Deci, 2010; Prat-Sala & Redford, 2010; Zhu & Frederick, 2010). Overall, it appears that intrinsic motivation and extrinsic motivation can strongly drive a student to learn.

With a SRL framework, the selection of learning strategies is based on the level of motivation. In other words, students need sufficient motivation to be willing to adopt more effective and time-consuming learning strategies, such as elaboration or control strategies, compared with memorization. Consequently, students obtain better performance because they are equipped with more effective learning strategies and high level of motivation. A considerable number of studies have demonstrated that intrinsic motivation is positively related to elaboration and control strategies, whereas intrinsic motivation is negatively related to memorization or has no predictive value on memorization (Artelt, 2005; Prat-Sala & Redford, 2010; Walker, Greene, & Mansell, 2006; SoriĆ & PalekčiĆ, 2009). Walker et al. (2006) demonstrate that intrinsic motivation was positively related to deep-level cognitive learning strategies among college students, yet intrinsic motivation did not have any prediction on memorization. Prat-Sala and Redford (2010) reveal that intrinsic motivation was positively associated with deep-level cognitive learning strategies, but intrinsic motivation is negatively associated with memorization in a two-point longitudinal study. Artelt (2005) finds that the effect of intrinsic motivation on control strategies was substantial ($\beta = .26$) in a mediator model where intrinsic motivation and extrinsic motivation were predictors of reading performance through the use of control strategies in PISA 2000.

Moreover, extrinsic motivation has been positively associated with elaboration and control strategies (Berger & Karabenick, 2011; Lens, Simons, & Dewitte, 2002; Miller, Greene, Montalvo, Ravindran, & Nichols, 1996; Prat-Sala & Redford, 2010). Extrinsic motivation is positively related to control strategies after goals and perceived competences are controlled (Miller et al., 1996). Lens et al (2002) categorize extrinsic motivation as low and high based on the level of utility and importance (i.e. students choose the class because it is relevant to their future (high extrinsic motivation), or students choose a class because of credits (low extrinsic motivation)) and they find that students with low extrinsic motivation reported more memorization than students with high extrinsic motivation. Additionally, students with high extrinsic motivation reported more deep-level cognitive learning strategies than students with low extrinsic motivation. Similarly, Prat-Sala and Redford (2010) demonstrate that when students chose a class in order to obtain recognition from others, students rely on memorization heavily. However, when students chose a class because of its importance for their future, students reported less memorization, and more deeply-level cognitive learning strategies. Compared with choosing a class in order to obtain recognition, the importance of the future seems to have a higher level of extrinsic motivation, because the goals are long-term, which help students maintain a certain level of extrinsic motivation and be willing to exert more effort to achieve their goals in the long-term. Overall, it seems that extrinsic motivation is negatively associated with memorization, whereas extrinsic motivation is positively associated the elaboration and control strategies.

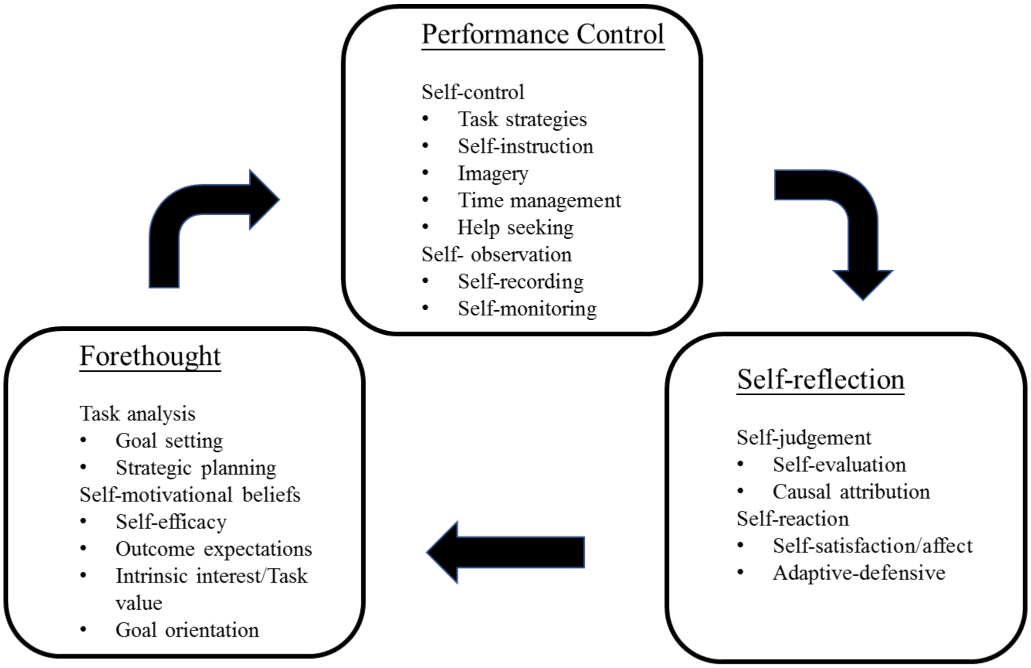

Figure 1. The three-phase model of self-regulated learning theory (Zimmerman, 20001).

1.3. East Asian Students' Learning Behavior

In SRL, Pintrich (2000) postulate that cognition, motivation, and behavior are influenced by environment. The process of SRL is affected by a number of social interactions such feedback and guidance. Within a cross-cultural perspective, it is believed that cultural values and beliefs probably impact upon educational settings (McInerney, 2011). Thus, across different cultures, the nature of SLR may function differently. In this section, we articulate how learning strategies, self-efficacy, and motivation operate in East Asian contexts.

Learning Strategies. The paradox of East Asian learners is that many researchers believe that East Asian students are rote-learners, implying a high tendency to use memorization regardless of their outstanding performance in international large-scale assessments. Such belief could be derived from a Western perspective and an Eastern perspective on teaching practices and learning environment in East Asian educational systems (Huang & Leung, 2005; Mok, 2006). The learning environment is examination-oriented in East Asian educational systems. In such environments, teachers are under a lot of pressure and stress, so teachers are less flexible in building an interactive learning environment. Consequently, most classroom environments remain teacher-centered. From a Western perspective, teach-centered environment has been suggested possibly to hinder students' ability to develop deep-level cognition. Furthermore, there are a considerable number of in-school and public examinations in East Asian educational systems (Birenbaum, Tatsuoka, & Xin, 2005; Yi, 2012), which directly or indirectly increase the use of memorization (Berger & Karabenick, 2011; Newstead & Findlay, 1997). Taken together, East Asian students have been gradually associated with rote-learning over the decades.

However, Biggs (1998) argues that such striking performance on international large-scale assessments for East Asian students could not be simply attributed to the frequent use of memorization; rather, East Asian students may use advanced learning strategies to attain such high performance. Additionally, recent PISA studies, PISA 2000, 2003, and 2009, have challenged the common view. These studies show that East Asian students had fewer tendencies to report memorization than their counterparts (Chiu et al., 2007; Liu, 2009; Lee, 2014). These findings may suggest that memorization does not help East Asian students achieve a better performance.

Many educationalists often deny the importance of memorization; however, cross-cultural qualitative and quantitative studies point out that memorization is believed that can form understanding by East Asian students and teachers, a concept that is different from the concept of memorization or rote-learning defined by a Western perspective (Dahlin & Watkins, 2000; Kember, 2000; Kember, & Gow, 1990; Sachs & Chan, 2003). In Dahlin and Watkin's (2000) qualitative study, Hong Kong students considered memorization is a necessary process to promote understanding, whereas German students conceptualized memorization as rote-learning. Zhu, Valcke and Schellens (2008) argue that Chinese students rely on memorization, but meanwhile they seek for better understating, which indicates that memorization is linked to understanding for Chinese students. However, based on their findings, they point out Flemish students considered remembering as rote-learning. Moreover, Marton et al. (1996) form two types of memorization, mechanical learning (i.e. rote-learning) and memorization that is related to understanding by conducting interviews for Chinese teachers and students (Figure 2). The later type of memorization is commonly perceived by Chinese teachers and students. They believe that memorization can enhance understanding, such as memorizing what is understood or understanding something by going through it several times and memorizing it. For example, at first time, students learn formulas by heart. After several uses with rote-learning, it helps them to understand applications of formulas in a specific mathematical context. Evidence for the connection between memorization and understanding in East Asian contexts may imply that East Asian students have different concepts on memorization than what Western students and researchers conceptualize.

According to the findings in the PISA studies, the framework of SRL, and cross-cultural studies, there are two plausible solutions to explain the paradox of East Asian students: (1) East Asian students may not heavily rely on memorization and, (2) the concepts of memorization among East Asian students may be different as Western students perceive. In order to address the paradox, we will examine whether or not East Asian students are likely to report memorization and whether or not the concepts of memorization differ between East Asian and Western culture.

Self-efficacy. Cross-cultural research argues that cultural factors shape students' learning beliefs (McInerney, 2011), which may influence the underling mechanism self-regulated learning and behavior. In cross-cultural research, the dimensions of individualism and collectivism are commonly adopted to explain the functioning of the self. In individualist cultures, often referred to English-speaking countries and Western Europe (Markus & Kitayama, 1991; Oyserman, Coon & Kemmelmeier, 2002), students tend to evaluate themselves based on self-referenced information.

In contrast, in collectivistic cultures, often referred to East and South Asian countries, individuals often consider other groups' feelings while evaluating themselves (Oyserman et al., 2002).

However, Bandura (1997; 2002) argues that self-efficacy operates equally across cultures, because people within collectivistic cultures behave differently, and it is the same fashion within individualistic cultures. Furthermore, in PISA studies, self-efficacy has been shown that it has a positive and powerful prediction on students' performance across countries (Stankov & Lee, 2017). Liu (2009) finds that the levels of self-efficacy for Hong Kong and American students were close, yet Hong Kong students had a lower self-concept than American students in PISA 2003. Therefore, based on previous cross-sectional studies, it confirms that the Bandura's argument that self-efficacy may has the same function across cultures.

Moreover, the nature of self-efficacy is for goal-orientated evaluation and the self-efficacy items (see Table 2 in Appendix C) do not reflect social comparative information, that is, students are not asked to compare their abilities to others. As a result, self-efficacy may not be influenced by the dimensions of collectivism-individualism. Altogether, it seems that self-efficacy operates in a similar fashion across cultures. To gain a clear understanding of whether self-efficacy functions similarly across cultures, another aim in this dissertation is to investigate whether the relationships between self-efficacy and learning strategies are the same across cultures.

Motivation. From a model of achievement goal theory (Ames, 1992; Dweck & Legget, 1988), achievement goals are commonly classified into mastery, performance-approach, and performance-avoidance goals (Elliot & Church, 1997). A mastery goal indicates that students try to accomplish challenging tasks and improve their understanding, which is related to intrinsic motivation because they learn for their own sakes. In contrast, students with performance-approach goals focus on being more capable than their peers or obtaining good grades, while students with performance-avoidance goals try to avoid difficult tasks that might show their incapability. Compared with a mastery goal, a performance-approach goal and a performance-avoidance goal are related to extrinsic motivation, because students learn for external factors.

Most East Asian educational systems are examination-oriented (Birenbaum, Tatsuoka, & Xin, 2005) where it is likely that students are encouraged to focus on their relative performance compared with their peers. Previous studies have shown that mastery and performance -approach goals are positively related among East Asian students (Ng, 2001; Salili, Chiu, & Lai, 2001). Zhu and Leung (2010) demonstrate that intrinsic motivation and extrinsic motivation had positive effects on mathematics performance in East Asian countries (i.e. Hong Kong, Japan, Korea, and Taiwan), whereas extrinsic motivation had a negative impact on mathematic performance in Western countries (i.e. Australia, England, The Netherlands and USA) by using the Trends in International Mathematics and Science Studies 2003. Thus, it seems that extrinsic motivation may have an additive effect to drive East Asian students to learn.

Although it seems that East Asian students are less likely to be encouraged to learn for their own interest, it could be that extrinsic motivation compensates the low degree of intrinsic motivation to facilitate East Asian students' desire to learn. Thus, it is important to take intrinsic and extrinsic motivation into account to obtain a clear understanding of the relationships between intrinsic motivation, extrinsic motivation, and learning strategies in East Asian contexts.

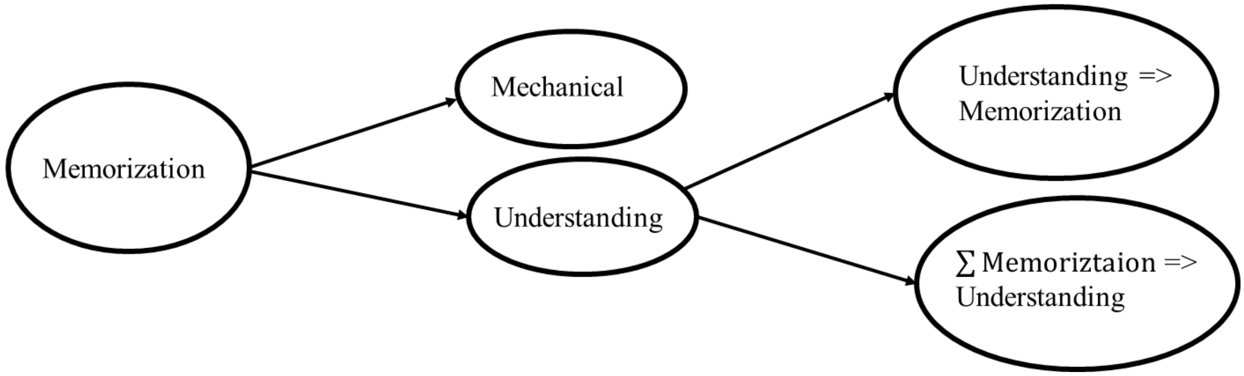

Figure 2. A perspective on memorization from East Asian students (Marton et al., 1996)

2. Overview Research Questions and Hypotheses

Cross-culture research recognizes that values, beliefs, and educational practices are embedded in social relationships and contexts, which may influence the nature of the SRL process across cultures. In this dissertation, we sought to investigate the generalizability of SRL to East Asian contexts and solve the common paradox of East Asian learners' behavior, rote-learning behavior, within a SRL framework by taking learning strategies, performance, self-efficacy and motivation into account. We proposed four research questions examined through the lens of SRL by using PISA 2012 in all manuscripts.

Research question 1: Do East Asian students tend to report memorization? This research question will be addressed from two perspectives. First, we investigated the frequency of use of learning strategies. Framed within SRL (Zimmerman, 2001), students who are high-achievers tend to use elaboration or control strategies. Furthermore, empirical PISA studies have demonstrated that East Asian students report less memorization (Chiu et al., 2007; Liu, 2009; Lee, 2014). As a result, we expected that East Asian would report less memorization, but more elaboration or control strategies in PISA. Second, we explored whether or not East Asian students have different perceptions on learning strategies compared to Western students. In this sense, if East Asian students had different perceptions on memorization than Western student, it would suggest that East Asian students have fewer tendencies to endorse memorization than Western students. In this perspective, we did not make any hypotheses because cross-cultural qualitative studies (Marton et al., 1996) have a non-representative and small sample size, which makes it difficult to generalize to other East Asian populations. This research question will be answered by using latent class analysis (LCA) in manuscript 1 and by using multiple-group LCA in manuscript 2.

Research question 2: What are the extent of relationships between learning strategies and students' performance? Based on SRL and empirical studies (Vermunt, & Vermetten, 2004; Zimmerman, 2001), we expected that memorization is negatively associated with students' performance; however, elaboration and control strategies are positively associated with students' performance. This research question will be answered in manuscript 1 by using regression models where students' performance is a dependent variable and latent classes (i.e. the type of learning strategies) are independent variables.

Research question 3: Are the relationships between self-efficacy and learning strategies the same between an Eastern country (i.e. Taiwan) and a Western country (i.e. America)? According to SRL, it holds that students' belief about their abilities in a specific task is positively related to elaboration and control strategies (Berger & Karabenick, 2011; Linnenbrink & Pintrich, 2003; Zimmerman, 2001). In addition, several studies have pointed out that self-efficacy is the most salient predictor across cultures (Liu, 2009; Stankov & Lee, 2017). We hypothesized that elaboration strategies, control strategies, and self-efficacy are positively correlated across cultures, whereas memorization is negatively related to self-efficacy across cultures. This research question will be answered by multinomial regression analyses where latent classes are independent variables and self-efficacy is a dependent variable in manuscript 2.

Research question 4*:* What is the extent of the relationships between intrinsic motivation, extrinsic motivation, and learning strategies among East Asian students? Based on SRL and empirical findings, the level of intrinsic motivation is indicative of elaboration and control strategies (Walker et al., 2006; SoriĆ & PalekčiĆ, 2009); thus, we expected that intrinsic motivation would have a positive relationship with elaboration and control strategies, whereas intrinsic motivation would be negatively associated with memorization or would have no predictive value on memorization. Regarding extrinsic motivation, several studies have shown that extrinsic motivation has positive relationships with elaboration and control strategies, but has a negative relationship with memorization (Lens et al., 2002; Miller et al., 1996; Prat-Sala & Redford, 2010). Consequently, we hypothesized that extrinsic motivation would have positive relationships with elaboration and control strategies, yet a negative relationship with memorization. This research question will be answered in manuscript 3 by Analysis of variance (ANOVA) and the 3-step LCA after obtaining latent class memberships from LCA.

3. Method

Measures

Instrument of Learning Strategies. In PISA, each cycle has a main subject of focus: reading, mathematics, or science. However, not every cycle had the learning strategy items (Table 1). For example, in 2006 and 2015, the learning strategy items were not designed in the students' questionnaire. In PISA 2000, the learning strategy items have been criticized (Smuelstuen &

Bra°ten, 2007), because the descriptions of items were not limited to a specific domain (Hadwin, Winne, Stockley, Nesbit & Woszczyna, 2001). For example," When I study, I try to memorize everything that might be covered" (OECD, 2004). Such item design could not reflect students' learning behavior in a specific domain. Therefore, Smuelstuen and Bra°ten (2007) suggest that the design of the learning strategy items should be based on a specific context. In PISA 2003 and PISA 2009, the learning strategies items were revised to include a specific domain in the descriptions. For example, in PISA 2003, items added a mathematics context to the items, "When I study for Mathematics, I learn as much as I can off by heart"; in PISA 2009, the items added a reading context to the items, "When I study, I read the text so many times that I can recite it".

Although 2003 and 2009 added a specific domain to the statements, it adopted a 4-point Likert-scale to measure the frequency or agreement of learning strategies. It has been known that Liker-scale is subject to response styles (Chen, Jin & Wang, 2017; Jin & Wang, 2014). To address this issue, in PISA 2012, the forced-choice design for the learning strategies items were adopted to avoid response styles (OECD, 2013). In the forced-choice, students are only allowed to select one out of three learning strategies in each item. The details of the items of learning strategies for 2000, 2003, 2009 and 2012 PISA are referenced in Appendix A (Table A1-A3).

Instrument of Self-efficacy. The scheme of the items of self-efficacy in PISA 2012 is based on Bandura's social cognitive learning theory (2002). Self-efficacy measures the extent to which students identify their mathematical abilities given a specific mathematical task. The details of self-efficacy are Table 2 in Appendix C.

Instrument of Motivation. PISA 2012 follows the self-determined theory and expectancy-value theory (Ryan & Deci, 2009; Wigfield, Tonks, & Klauda, 2009) to design two motivational constructs, namely intrinsic motivation and extrinsic motivation. Intrinsic motivation measures students' enjoyment and interest while learning mathematics; extrinsic motivation measures students' perceptions of utility and importance on mathematics. The details of intrinsic and extrinsic motivation are reference in Table 1 in Appendix D.

Latent Class Analysis Models

The statistical models were used across three manuscripts on the basis of latent class analysis (LCA). LCA is similar to the confirmatory factor analysis (CFA), but a feature of the latent factor is different between LCA and CFA. In CFA, the latent factor is continuous, whereas in LCA, the latent factor is categorical, that is, a number of latent classes. Considering the nature of the learning strategies items, the nominal variables, and the possibility of combinations of learning strategies, LCA is so far an ideal method to fit the data for the purpose of this study.

LCA models were fitted into a different number of classes, but these models were not nested into each other. As a result, information criteria, AIC (Akaike, 1987), BIC (Schwarz, 1978), and adjusted BIC (a_BIC) (Sclove, 1987), were used. Among these information criteria, in the Nylund, Asparouhov, and Muthén (2007) LCA simulation study , BIC had a better performance on model selection compared with other information criteria. However, Marsh, Lüdtke, Trautwein and Morin (2009) suggest that when deciding the number of latent classes, researchers should consider meaningful interpretations of latent classes along with information criteria . Thus, all analyses were based on BIC along with our subjective evaluation to guide us to select a final fitted model.

Multiple-group Latent Class Analysis (MGLCA). MGLCA was applied in manuscript 2 to examine whether or not students have the same perceptions of learning strategies between an Eastern country and a Western country. Based on Collins and Lanza recommendations (2010), three steps were taken to examine measurement invariance using MGLCA. The first step was to determine the number of latent classes, so two models were examined, that is, a model with the combined sample and a model with each individual country assessed separately. For the next step MGLCA was fitted into the combined sample without any constraints on category- response probabilities and class size. If the number of latent classes were consistent and meaningful across single-group and multiple-group LCA analyses, the final step would be to investigate whether or not category- response probabilities are invariant across groups whereby we would compare the unconstrained model, which involves both freely-estimated category-response probabilities and class sizes across countries, with the constrained model, which includes equally-constrained category-response probabilities but freely-estimated class sizes across the two countries. If the constrained model fit the unconstrained model better, it would indicate that measurement invariance is valid across countries. In other words, an interpretation of each latent class has the same meaning across countries.

The 3-step Latent Class Analysis. The 3-step latent class analysis was used in manuscript 3 to investigate the relationships between intrinsic motivation, extrinsic motivation, learning strategies and students' performance. There are three steps to conduct the 3-step LCA. First, the LCA model without any covariates is fitted to a different number of latent classes. After selecting the final model for the LCA model without any covariates, the proportions of the class membership within each latent class are fixed. Consequently, the proportions of the class membership within each latent class remain the same as in the first step. In the last step, researchers can add an additional model such as a linear regression model to obtain the estimated coefficients such as slopes and intercepts for each latent class while fixing the proportions of the class membership in the second step (Asparouhov & Muthén, 2014).

Table1.

Items Descriptions of Learning Strategies in each PISA

Year	Main Domain	Existing Items	Format of Items	Statements in Items
2000	Reading	Yes	4-point Likert-scale(Frequency)	General
2003	Mathematics	Yes	4-point Likert-scale(Agreement)	Including a mathematics context
2006	Sciences	No		
2009	Reading	Yes	4-point Likert-scale(Frequency)	Including a reading context
2012	Mathematics	Yes	Forced-choice	Including a mathematics context
2015	Sciences	No		

4.1. Main Results

This dissertation expands our knowledge of the generalizability of self-regulated learning theory in East Asian contexts. In this section, we summarize the results of four research questions through three manuscripts. Manuscript 1 (Appendix B) investigated the frequency of the use of learning strategies and the relationships between learning strategies and mathematics performance. Manuscript 2 (Appendix C) examined whether or not the perceptions of learning strategies are the same across Taiwan and USA and the relationships between self-efficacy and learning strategies. Manuscript 3 (Appendix D) investigated the relationships between intrinsic motivation, extrinsic motivation, and learning strategies.

Research question 1: Do East Asian students tend to report memorization? **(Answered by manuscript 1 and manuscript 2)**

Based on the LCA results in the manuscript 1, the results showed three classes of learning strategy use, namely: memorization (17%), control (58%), and the combination of control and elaboration (25%) among East Asian students. Furthermore, we examined the perceptions of learning strategies between Taiwan and USA in manuscript 2. The results demonstrated that Taiwanese and American students had the same perceptions on memorization, elaboration and control strategies. Only a few Taiwanese students reported memorization (5%), and American students reported using more memorization (19%). Most Taiwanese students reported using the elaboration strategy (63%), whereas most American students reported using the control strategy (57%).

Research question 2: What are the extent of the relationships between learning strategizes and students' performance? **(Answered by manuscript 1)**

In the manuscript 1, the LCA results showed that there were three latent classes, namely, memorization, control and the combination of control and elaboration strategies in East Asian educational systems. To understand the relationships between learning strategies and mathematics performance, the latent classes were independent variables and mathematics performance was a dependent variable. According to descriptive statistics, the lowest mathematics performance occurred in the memorization class. Moreover, in the regression analyses where gender and the economic, social and cultural status (ESCS) were taken into account, the effects of control strategies and the combination of control elaboration were significantly positively related to mathematics performance in most East Asian educational systems compared to memorization.

Research question: Research question 3: Are the relationships between self-efficacy and learning strategies the same between Taiwan and America? **(Answered by manuscript 2)**

To investigate the relationships between self-efficacy and learning strategies, the multinomial regression analyses were used in each country, Taiwan and the USA. Based on descriptive statistics, the lowest self-efficacy means for Taiwanese and American students were in the memorization class and elaboration class, respectively. The highest self-efficacy means appeared in the elaboration class for Taiwanese students and in the control class for American students. In the multinomial regression analyses where gender ESCS and self-efficacy were independent variables and the latent class (i.e. the type of learning strategies) were dependent variables. Taiwanese students' self-efficacy had a significantly negative impact on memorization use compared to control use, indicating that high self-efficacy students were less likely to report using the memorization strategy than the control strategy. There was no significant impact of students' self-efficacy on the use of either elaboration or control strategy. For American students, there was no significant impact of students' self-efficacy on use of memorization compared with the control strategy. American students' self-efficacy had a significantly negative impact on the elaboration use, compared to the control use, meaning that high self-efficacy students were less likely to report using the elaboration strategy than the control strategy.

Research question 4: What is the extent of the relationships between intrinsic motivation, extrinsic motivation, and learning strategies among East Asian students? **(Answered by manuscript 3)**

We applied one-way analysis and variance (ANOVA), and a 3-step LCA method to answer this question after obtaining latent classes in each educational system. The ANOVA results revealed that when students reported memorization, their intrinsic motivation and extrinsic motivation were significantly lower than when they reported elaboration and control strategies. However, it is unclear whether or not intrinsic motivation and extrinsic motivation were higher in the control strategies than in the combination of learning strategies. In a 3-step LCA method, the results showed that when students used elaboration, control, or a combination of learning strategies, intrinsic motivation was significantly positively related to mathematic performance. However, intrinsic motivation did not predict mathematic performance when students adopted memorization except for in Singapore. Compared with intrinsic motivation, it seems that extrinsic motivation had less impact on mathematic performance across East Asian educational systems; however, it appears that extrinsic motivation played an important role for Taiwanese and Koran students. When Taiwanese and Korean students were classified into control, elaboration or the multiple learning strategies classes, extrinsic motivation was positively related to mathematics performance. Furthermore, extrinsic motivation either had no prediction or negative effect on mathematics performance in the memorization class among East Asian students.

4.2. Discussion

This dissertation explored whether or not East Asian students are likely to adopt memorization from the SRL perspective. We adopted the SRL framework to replicate previous findings to understand the applicability of the SRL in East Asian contexts.

Across three manuscripts, the results showed that the common belief of East Asian students' rote-learning behavior was confronted whereby we investigated the use of learning strategies in East Asian educational systems and we compared the use of learning strategies across two selected countries (i.e. Taiwan and America) with different cultures. When students' performance, self-efficacy and motivation were taken into account, the results showed that only students with low-self-efficacy, low intrinsic motivation, low extrinsic motivation or with low performance were likely to report memorization in East Asian contexts. This finding is aligned with previous the SRL literature, indicating these components, learning strategies, self-efficacy and motivation, in the SRL can be applicable in East Asian contexts.

The use of learning strategies

The results were in accord with our hypotheses that East Asian students reported less memorization. We first investigated the patterns of use of learning strategies among East Asian educational systems in manuscript 1. We found that most East Asian students were classified into the control strategy class. The proportions of students in the memorization class were the smallest compared to the control class and the combination of learning strategies classes.

We further compared the perceptions of learning strategies and the patterns of learning strategies between Eastern and Western cultures, Taiwan and America, in manuscript 2. Results showed that measurement invariance was valid between Taiwan and USA, which suggested that memorization, elaboration, and control measured the same concepts in these samples. However, the results were not in accord with the qualitative studies (Dahlin & Watkins, 2000; Kember, 2000; Sachs & Chan, 2003), which claim that East Asian students may not have the same perception of memorization as Western students. The different results may be due to the fact that the current dissertation applied a quantitative method. Compared with qualitative methods, quantitative methods can only reflect students' rough learning behavior, yet qualitative methods can detect a more nuanced view of students' learning behavior.

Based on the results of measurement invariance, we confirmed that Taiwanese students were less likely to report memorization than American students, and most Taiwanese students reported elaboration. When comparing the latent prevalence, a larger proportion of American students reported to use the memorization learning strategy compared to Taiwanese students.

Building upon evidence in manuscript 1 and manuscript 2, the patterns of use of learning strategies are consistent with previous PISA research indicating that East Asian students have a lower tendency to report the memorization strategy than Western students (Chiu et al., 2007; Liu, 2009; Liu & Wilson, 2009). Similarly, Liu and Wilson (2009) indicate that American students outperformed Hong Kong students on reproduction items in PISA 2003. They argue that American students may use more memorization strategies than East Asian students (Liu & Wilson, 2009). Thus, based on our findings, the common belief of East Asian students' rote learning is challenged. Rather, most East Asian students adopt control strategies.

The relationships between learning strategies and mathematics performance

The results were consistent with our expectations that memorization was negatively associated with students' performance, while metacognitive learning strategies were positively associated with students' performance. Manuscript 1 showed that there was a positive relationship between control strategies and mathematic performance, while there was a negative relationship between memorization and mathematic performance. It seems that only the use of memorization was less effective in helping students obtain better mathematic performance than control and the combination of learning strategies across East Asian educational systems. As memorization simply requires students to reproduce knowledge, it is only beneficial to solve simple questions (Garcia & Pintrich, 1994). However, when students encounter complicated mathematics questions, it is necessary to use elaboration or control strategies to help them solve complicated questions. Consequently, memorization may not be an appropriate strategy to facilitate students' performance.

Compared with the combination of learning strategies, control strategies had a stronger effect on mathematic performance, suggesting that the use of control strategies is of particular importance in East Asian students' mathematics learning. As self-regulated learners set specific learning goals, they monitor, regulate, and plan their performance based on their goals. The process of constant monitoring, regulating, and planning reflect self-regulated learners' internal feedback thereby allowing them to adjust their learning strategies and identify their knowledge gap (Pintrich, 1999; Zimmerman, 2001). As a result, self-regulated learners improve their performance.

In the results, it is not clear whether or not the use of multiple learning strategies is better than the sole use of control. Currently, there are few studies addressing the use of multiple learning strategies, but the results are mixing (Beishuizen et al.,1994; Dignath et al., 2008). Future research should explore what kind of combinations of learning strategies can promote learning.

The relationships between self-efficacy and learning strategies

The results in manuscript 2 partially confirmed our hypotheses that the relationship between self-efficacy and memorization was negative in Taiwan, and the relationships between self-efficacy and elaboration or control strategies were positive in Taiwan and the USA, respectively.

Expectedly, Taiwanese students with the highest self-efficacy reported elaboration strategies and American students with the highest self-efficacy reported control strategies the most. The results were in accord with the SRL and previous studies, indicating high self-efficacy promotes students to choose effective learning strategies, elaboration or control (Berger & Karabenick, 2011; Diseth, 2011; Zimmerman, 2001). Unexpectedly, different patterns occurred between Taiwan and America when students had the lowest self-efficacy. Taiwanese students with the lowest self-efficacy adopted memorization, whereas American students with the lowest self-efficacy adopted elaboration. The pattern among Taiwanese students is in line with SRL. Students with low self-efficacy have been shown to be likely to adopt memorization more often than students with higher self-efficacy (Berger & Karabenick, 2011; Diseth, 2011; Zimmerman, 2001). However, it is surprising that this is not the case in an American context. Within a SRL framework, students with high self-efficacy are likely to adopt elaboration or control strategies, and it is unlikely that students with low self-efficacy would adopt memorization rather than elaboration strategies. Future research should investigate whether or not American students with low self-efficacy are more likely to use elaboration rather than memorization.

The relationships between motivation and learning strategies

In manuscript 3, we hypothesized that intrinsic motivation was positively associated with elaboration and control strategies; intrinsic motivation was negatively associated or did not predict memorization. Likewise, we expected that extrinsic motivation was positively associated with elaboration and control strategies, yet extrinsic motivation was negatively associated with memorization. As expected, compared with memorization, when students reported elaboration or control strategies, their intrinsic motivation were higher. In applying these findings to the SRL (Zimmerman, 2001), highly intrinsic motivated students have clear and specific goals; thus, they are willing to select elaboration or control strategies that are more time-consuming and advanced than memorization to attain their goals.

Additionally, highly extrinsically motivated students were more likely to select control or elaboration strategies than memorization, which is in accord with existing literatures (Berger & Karabenick, 2011; Lens et al., 2002; Prat-Sala & Redford, 2010; Zhu & Leung, 2010). Following the mechanism of SRL, it is logical to conjecture that students who have higher extrinsic motivation are more likely to use elaboration or control strategies to obtain better performance. However, it is important to note that extrinsic motivation in PISA are relevant to utility and values as students perceive the usefulness of mathematics in the future. Prat-Sala and Redford (2010) point out that different types of extrinsic motivation showed different patterns with memorization. When extrinsic motivation derives from recognition from others, students rely on memorization heavily. However, when extrinsic motivation originates from getting higher grades, students reported less memorization, but more deeply-level learning strategies. Future research should consider different types of extrinsic motivation in SRL, which can flesh out the relationships between motivation and learning strategies.

Moreover, the relationships between intrinsic motivation, extrinsic motivation, learning strategies, and mathematics performance were investigated. Expectedly, intrinsic motivation positively predicted mathematic performance when students reported elaboration or control strategies. Compared with intrinsic motivation, extrinsic motivation only positively predicted mathematic performance in Taiwan and Korea when those students reported control, elaborations, or multiple learning strategies. These results mirrored Zhu and Frederick's findings (2010). They point out that extrinsic motivation has additive patterns in Taiwan and Korea compared to other East Asian educational systems in TIMSS 2003. Thus, the role of extrinsic motivation may have a particular important role in certain East Asian educational systems.

5. Implications and Future Research

The dissertation has theoretical implications for cross-cultural understanding of the self-regulation learning process, including the relationships between learning strategies, self-efficacy, and motivation. East Asian students with high self-efficacy, high motivation and high performance were likely to use elaboration or control strategies. The findings might inform that the roles of self-efficacy, motivation and learning strategies in the SRL can be replicated in East Asian contexts.

Results have important implications for classroom instruction in East Asian contexts. The findings demonstrated that East Asian students reported less memorization and Taiwanese students reported less memorization than American students. In East Asian educational systems, although classroom is often perceived as teacher-centered (Hung, 2014), teachers often provide students higher-level questions (Biggs, 1998). Such questions involve substantial cognitive loadings, which in turn promotes students to think deeply and simulates students' high-order cognition (Baumert et al., 2010; Paris & Paris, 2001). Thus, teacher instruction plays an essential role in the students 'self-regulated learning behavior. Future research should consider the quality of questions in teaching practices.

Although this dissertation made several contributions, there are some limitations that should be considered in evaluating this dissertation. First, this dissertation does not take teaching instruction into account. Teaching styles could possibly influence students' self-regulated learning such as the level of cognitive engagement (Baumert et al, 2010). For example, teachers can provide students high-level questions that cannot be solved immediately (Baumert et al, 2010; Paris &

Paris, 2001). In turn, this stimulates students' higher-order cognition and motivation such that students are more likely to adopt deep-level cognitive or metacognitive learning strategies.

Second, due to the focused domain in PISA 2012, we only focused on students' self-regulated learning in mathematics. However, students may apply various learning strategies based on the specific domain (Wolters & Pintrich, 1998). Research has shown that students demonstrate different self-regulated learning behavior in different domains (Wolters & Pintrich, 1998; Wolters, Yu, & Pintrich, 1996). Wolters and Pintrich (1998) demonstrated that when students learn social sciences, they report more memorization and elaboration than when they learn math and English. Future research should integrate other domains to understand whether students display different self-regulated learning behavior across domains.

Third, PISA adopts self-reported learning strategies. Self-reported learning strategies are often questioned, because items are ambiguous and there are a limited number of types of learning strategies (Winne, Jamieson-Noel, & Muis, 2002). Even though the statements of learning strategies in PISA 2012 are based on mathematics, PISA does not provide a variety of mathematics activities. Given that that learning is a dynamic process, the items of learning strategies in PISA only roughly reflect students' learning behavior, because students can use a diverse range of learning strategies during learning. It would be valuable for future research to consider observational approaches that allow researchers to identify a more detailed learning strategy and which may be a good method to gain insight into how teaching practices interact with students' self-regulated learning.

Last, a common limitation is the causality. Because this study is of correlational nature, it is difficult to establish whether or not self-efficacy or motivation is the cause of the selection of learning strategies or the selection of learning strategies causes lower self-efficacy and motivation or some other process causes both, the selection of learning strategies and lower self-efficacy and motivation.

6. Conclusion

Self-regulation learning plays an essential role in students' learning and it is one of the most popular topics in psychology and education fields, yet the generalizability of SRL in East Asian contexts has not captured a lot of attention from researchers. In order to investigate the generalizability of SRL in East Asian contexts, this dissertation investigated four aspects of SRL, namely (1) the frequency of use of learning strategies, (2) the relationships between learning strategies and performance, (3) the relationship between self-efficacy and learning strategies, (4) the relationships between motivation and learning strategies. The findings in this dissertation revealed that the components of learning strategies, self-efficacy and motivation in the SRL can be replicated by using PISA 2012. This information can provide insights for other educational systems that strive to tailor their educational systems based on East Asian educational systems. Moreover, the results of these LCA analyses can serve as a starting point for extending the SRL theory for recognizing the combinations of learning strategies

7. References

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8. Appendix

8.1. Appendix A: Items of Learning Strategies in 2000, 2003, 2009 and 2012.

Table A1.

Items of Learning Strategies in PISA 2000.

How often do these things apply to you?	Almost never/ Sometimes/ Often/ Almost always
Memorisation strategies	
When I study, I try to memorise everything that might be covered	
When I study, I memorise as much as possible	
When I study, I memorise all new material so that I can recite it	
When I study, I practice by saying the material to myself over and over	
Elaboration strategies	
When I study, I try to relate new material to things I have learned in other subjects	
When I study, I figure out how the information might be useful in the real world	
When I study, I try to understand the material better by relating it to things I already know	
When I study, I figure out how the material fits in with what I have learned	
Control strategies	
When I study, I start by figuring out what exactly I need to learn	
When I study, I force myself to check to see if I remember what I have learned	
When I study, I try to figure out, as I read, which concepts I still haven't really understood.	
When I study, I make sure that I remember the most important things	
When I study, and I don't understand something, I look for additional information to clarify the point	

Table A2.

Items of Learning Strategies in PISA 2003

To what extent do you agree with the following statements?	Strongly agree/Agree/Disagree Strongly disagree
Memorisation strategies	
When I study Mathematics, I make myself check to see if I remember the work I have already done	
I go over some problems in Mathematics so often that I feel as if I could solve them in my sleep	
When I study for Mathematics, I learn as much as I can off by heart	
In order to remember the method for solving a Mathematics problem, I go through examples again and again	
To learn Mathematics, I try to remember every step in a procedure	
Elaboration strategies	
When I am solving Mathematics problems, I often think of new ways to get the answer	
I think how the Mathematics I have learnt can be used in everyday life	
I try to understand new concepts in Mathematics by relating them to things I already know	
When I am solving a Mathematics problem, I often think about how the solution might be applied to other interesting questions	
When learning Mathematics, I try to relate the work to things I have learnt in other subjects	
Control strategies	
When I study for a Mathematics test, I try to work out what are the most important parts to learn	
When I study Mathematics, I try to figure out which concepts I still have not understood properly	
When I cannot understand something in Mathematics, I always search for more information to clarify the problem	
When I study Mathematics, I start by working out exactly what I need to learn	

Table A3.

Items of Learning Strategies in PISA 2009

When you are studying, how often do you do the following? Almost never/ Sometimes/ Often/ Almost always
Memorisation strategies
When I study, I try to memorize everything that is covered in the text
When I study, I try to memorize as many details as possible
When I study, I read the text so many times that I can recite it.
When I study, I read the text over and over again.
Elaboration strategies
When I study, I try to relate new information to prior knowledge acquired in other subjects.
When I study, I figure out how the information might be useful outside school.
When I study, I try to understand the material better by relating it to my own experiences.
When I study, I figure out how the text information fits in with what happens in real life
Control strategies
When I study, I start by figuring out what exactly I need to learn.
When I study, I check if I understand what I have read.
When I study, I try to figure out which concepts I still haven't really understood.
When I study and I don't understand something, I look for additional information to clarify this.
When I study, I make sure that I remember the most important points in the text.

Table A4.

Items of Learning Strategies in PISA 2012: Forced-choice Items

Strategy	Statement
	Item 1
Control	When I study for a mathematics test, I try to figure out what are the most important parts to learn
Elaboration	When I study for a mathematics test, I try to understand new concepts by relating them to things I already know.
Memorization	When I study for a mathematics test, I learn as much as I can by heart.
	Item 2
Control	When I study mathematics, I try to figure out which concepts I still do not understand completely.
Elaboration	When I study mathematics, I think of new ways to get the answer.
Memorization	When I study mathematics, I make myself check to see if I remember the work I have already done.
	Item 3
Control	When I study mathematics, I start by working out exactly what I need to learn.
Elaboration	When I study mathematics, I try to relate the work to things I have learned in other subjects.
Memorization	When I study mathematics, I go over some problems so often that I feel as if I could solve them in my sleep.
	Item 4
Control	When I cannot understand something in mathematics, I always search for more information to clarify the problem.
Elaboration	I think about how the mathematics I have learned can be used in everyday life.
Memorization	In order to remember the method for solving a mathematics problem, I go through examples again and again.

8.2. Appendix B: Manuscript 1. A revised version has been published: Yi-Jhen Wu, Claus H. Carstensen & Jihyun Lee: A new perspective on memorization practices among East Asian students based on PISA 2012 (2019, Educational Psychology -An International Journal of Experimental Educational Psychology; Received 13 May 2018, Accepted 23 Jul 2019, Published online: 06 Aug 2019)

https://doi.org/10.1080/01443410.2019.1648766

A New Perspective on Memorization Practices among East Asian Students Based on PISA 2012

Abstract

This study examined learning strategy use in mathematics among East Asian students in East Asian educational systems. By employing latent class analysis on the Programme for International Student Assessment (PISA) 2012 data, we found four classes of learning strategy types, namely, memorization with metacognitive strategies (17.49%), metacognitive strategies with memorization (50.70%), elaboration only (10.33%), and metacognitive strategies with elaboration (16.47%). The results showed that the majority of the students in all seven East Asian educational systems belonged to the "metacognitive strategies with memorization" class, and most students adopted more than one type of learning strategy when learning mathematics. Additionally, students who reported the use of metacognitive strategies along with either memorization or elaboration showed higher mathematics achievement. We conclude that the cognitive processes employed by students of East Asian backgrounds are more complex and nuanced than the previous perception that they relied heavily on memorization.

Keywords: *Learning Strategies, Mathematics, PISA, Latent class analysis*

Memorization, often referred to as rote learning, is a cognitive process where information is retained and reproduced verbatim without any further mental processes involving information transformation (Marton & Säaljö, 1976; Walker, Greene & Mansell, 2006; Zimmerman & Martinez-Pons, 1986). Memorization as students' learning strategy has been a controversial topic with its benefits and limitations extensively debated in various research subfields. For instance, neuroscientists have claimed that repetition of problem-solving practices can strengthen neural pathways for memory, which is required to acquire, accumulate, and retrieve declarative or procedural knowledge (Looi, Thompson, Krause, & Kadosh, 2016). Mathematics education researchers have long debated whether young children need to memorize basic mathematics rules in the early stage of learning, prior to the development of mathematical reasoning skills (Smith & Smith, 2006; Lee, Ng, & Ng, 2009; Kember, 2016). While positive views on memorization do exist among mathematics education researchers, others have dismissed potential benefits of memorization in mathematics. They argue that learning by memorization does not lead to long-term mathematics outcomes, which requires deeper-level understanding beyond factual knowledge (Biggs, 1993; Marton & Säljö, 1976).

Comparative education researchers have also pondered on the use of memorization in learning across different cultural groups. The debate was mainly sparked by East Asian students' superior mathematics performance. From the early 1980s, when Western researchers investigated East Asian students and their classrooms in East Asia, they noted heavy reliance on rote-learning practice in the learning environment of East Asia (Biggs, 1998; Murphy, 1987; Samuelowicz, 1987). Since then, a more nuanced view has been proposed that East Asian students' use of memorization may be context- or task-dependent and that memorization is often used in conjunction with other learning strategies (Dahlin & Watkins, 2000; Kember, 2000; Marton, Dall'Alba, & Tse, 1996). Despite the findings and implications from previous studies, the perception that memorization is the main learning strategy among East Asian students still exists among researchers and practitioners alike (Hung, 2014; Lau & Ho, 2016). Given this common view about East Asian students, coupled with their high mathematics performance in international assessments, it is important to examine whether memorization should still be an effective strategy for East Asian students to obtain high mathematics performance.

Recognizing how high-performing East Asian students study mathematics might provide insights for mathematics education researchers to understand whether it is necessary to instruct students to memorize the basic mathematical knowledge such as multiplication tables. Therefore, this study aimed to investigate (a) whether East Asian students use memorization as their main learning strategy for mathematics; (b) whether they use memorization in conjunction with other strategies; and (c) whether memorization, or memorization in combination with other learning strategies is beneficial to their mathematics achievement. If consistent answers can be found for the research aims (a)-(c) among students in different East Asian educational systems, then the type of learning strategy practice that the majority of them adopt may be considered as one possible explanation for the high mathematics performance of East Asian students in recent intentional assessments.

We employed the Programme for International Student Assessment (PISA) 2012 Student Questionnaire data in which the sample consisted of 15-year-old students, mainly in Grades 8 to 10. We examined East Asian students' use of memorization and other learning strategies in mathematics learning as the predictor variables and mathematics achievement as the outcome variable. A caveat of the use of the Student Questionnaire data is that students have answered the questionnaire themselves; thus, their *report* on the use of a learning strategy cannot be considered as their *actual use* of that particular learning strategy. However, the method of collecting data on students' learning strategies in previous studies, including those cited in the literature review, tends to rely on student's self-reported data.

Literature Review

Learning Strategies in the Theory of Self-Regulated Learning

Self-regulated learning (SRL) theory (Zimmerman, 2001) provides a conceptual framework for how students regulate their own use of learning strategies, motivation, and behavior. There are three phases in the SRL: the forethought phase, the performance control phase, and the self-reflection phase (Zimmerman, 2001). In the forethought phase, students set their desirable academic goals. In the performance control phase, students employ appropriate learning strategies and regulate their personal efforts to optimize how they achieve their goals. In the self-reflection phase, students self-evaluate their own performance by checking their learning gaps for improvement or by trying to recognize possible causes of misunderstanding. During these phases, self-regulated learners monitor, evaluate, and adjust their learning strategies, their own motivation level and the learning goals, to obtain desirable performance (Dent & Koenka, 2016; Pintrich & Groot, 1990; Zimmerman & Martinez-Pons, 1986).

The SRL theory has instigated many empirical studies to define different types of learning strategies and to illustrate the effectiveness of these learning strategies (Dent & Koenka, 2016; Pintrich & Groot, 1990; Zimmerman & Martinez-Pons, 1986). Although various classifications of learning strategies have been proposed (Kember, Biggs & Leung, 2004; Lee &

Shute, 2010; Marton & Säaljö, 1976; Weinstein & Mayer, 1986; Zimmerman & Martinez-Pons, 1986), many studies have followed the work of Weinstein and Mayer (1986) in conceptualizing learning strategies as cognitive and metacognitive strategies. *Cognitive strategies* refer to the mental processes related to acquisition and storing of information, organizing, summarizing, and making sense of the information by connecting new and prior knowledge (Weinstein & Mayer, 1986; Zimmerman & Martinez-Pons, 1986). During mathematics learning, students may remember formulas, summarize a mathematical concept that they have learnt, or connect a mathematics concept to their real-life experiences.

Metacognitive strategies refer to the monitoring, controlling and regulating of cognitive activities and actual behavior (Weinstein & Mayer, 1986; Zimmerman & Martinez-Pons, 1986). Most metacognitive strategies involve three types of general strategies: planning, monitoring, and evaluating (Pintrich & De Groot, 1990). Typical metacognitive learning strategies involve observing and modifying one's learning processes and outcomes, and managing and controlling one's effort, learning environment, and motivation (Pintrich & De Groot, 1990). In mathematics learning, metacognitively-aware students may plan the steps needed to solve mathematics tasks, to check their own understanding of the concepts learnt, to seek help, and to evaluate their own learning strategies to improve performance (OECD, 2013).

The PISA 2012 followed the Weinstein and Mayer's (1986) taxonomy and made the distinction among three types of learning strategies for mathematics: (a) memorization, (b) elaboration, and (c) metacognition (OECD, 2013). Based on the definition from previous literature (Weinstein & Mayer, 1986), memorization and elaboration are classified as cognitive strategies in PISA 2012. The following section illustrated the relationships between learning strategies and mathematics performance.

Memorization Strategies and Mathematics Achievement

Students may benefit from memorizing factual knowledge in the initial stage of mathematics learning (Dinsmore & Alexander, 2016), while exclusive use of memorization would not lead to the development of complex problem solving or higher-order mathematical reasoning skills (Biggs, 1993; Marton & Säljö, 1976; Mclnerney, Cheng, Mok, & Lam, 2012). A meta-analysis by Dent and Koenka (2016) revealed that memorization had a negative association with academic achievement including mathematics across different age/grade levels. Other empirical studies have also supported the same finding, for example, among Hong Kong secondary school students (Mclnerney et al., 2012) and among Hong Kong and U.S. students in PISA 2003 data (Liu, 2009). These results suggest that it is unlikely that higher-performing students rely on memorization skills alone as their learning strategy for mathematics.

Elaboration Strategies and Mathematics Achievement

Elaboration is defined as mental processes and actions related to using several pieces of information to create meaningful interpretations, to connect new and prior knowledge to real-life experiences, and to manipulate learning tasks at hand by summarizing, phrasing and questioning (Pintrich & Groot, 1990; Walker et al., 2006). Elaboration as a learning strategy is often recognized as a means to facilitate a high level of cognitive engagement for deep-level learning (Biggs, 1993; Marton & Säaljö, 1976).

Educational studies have investigated whether elaboration strategies would actually demonstrate a positive effect on student learning including mathematics (Chiu, Chow, & McBride-Chang, 2007; Donker, de Boer, Dignath van Ewijk, & van der Werf, 2014; Liu, 2009; Murayama, Pekrun, Lichtenfeld, & vom Hofe, 2013). Researchers have claimed that the use of elaboration in learning tasks enhances engagement in deep learning, complex problem solving, as well as long-term memory and effective retrieval of information (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Mayer, 1980). A longitudinal study involving six waves of annual data collected from students in Grades 5 to 10 (Murayama et al., 2013) reported that the growth of mathematics achievement was predicted by students' motivation and elaboration strategies. A meta-analysis by Donker et al. (2014) also presented strong empirical support for students' use of elaboration strategies in mathematics achievement. Out of the many subtypes of learning strategies that they included in their analysis (e.g., rehearsal, organization, planning, monitoring, evaluation, effort, peer and environment management, motivational strategies), they found that "in mathematics elaboration was the only sub-strategy which improved student performance significantly more than other methods" (p.12).

Although the longitudinal and meta analytic studies reported a positive relationship between elaboration and mathematics achievement for secondary school students, cross national studies based on PISA data revealed that the expected positive relationship was not always demonstrated across educational systems (Chiu et al, 2007; Liu, 2009; OECD, 2005). For instance, Chiu et al. (2007) claimed that students' "elaboration strategies were not linked to achievement in any domains or culture" (p.359) in the PISA 2000 data, while memorization had a negative association with reading, mathematics, and science in the majority of educational systems. The unexpected relationship between elaboration and mathematics performance also occurred in PISA 2003, that is, elaboration either had a positive or negative relationship with mathematics performance across educational systems (Liu, 2009; OECD, 2005). Thus, the relationship between elaboration and mathematics performance did not yield a consistent pattern of results across different educational systems.

Metacognitive Strategies and Mathematics Achievement

As defined earlier, it is said that metacognitive strategies are used when students observe, monitor, plan, and adjust their own cognitive processes to maximize their learning (Pintrich & De Groot, 1990). It is believed that metacognitively aware students would have a good understanding of their own strengths and weaknesses, evaluate appropriate strategies to enhance performance, and will try to modify a pattern of behaviors that can be conducive to learning (Pintrich & De Groot, 1990).

Most empirical studies demonstrated that metacognitive strategies are effective in helping students obtain high mathematics performance. For instance, through the meta-analysis of the intervention studies aimed at various learning outcomes of primary and secondary school students (i.e., mathematics, reading, writing, other subjects, strategy use, and motivation), Dignath and Büttner (2008) showed moderately strong effect sizes of metacognitive strategies for both primary and secondary school levels. The study also reported a stronger relationship of metacognitive strategies with mathematics than with other subjects. A case study based on Grade 6 students in Germany (Perels, Dignath, & Schmitz, 2009) also claimed that classroom-based intervention for improving students' mathematics performance was effective when students were exposed to explicit instruction on applying metacognitive strategies for goal setting, distraction management, self-motivation, and planning and concentration in the self-regulation training program.

However, when PISA data was examined at the within-educational system level, the expected positive relationship did not exist consistently across different educational systems. Chiu et al. (2007) reported that only a few educational systems had a significantly positive coefficient of metacognitive strategies in predicting students' mathematics performance (i.e., Albania, Hong Kong, Portugal, and Thailand) in the three-level regression model. The other 30 educational systems showed either negative or no relationships between students' reported use of metacognitive strategies and their mathematics achievement. Thus, similar to the results relating to elaboration, the relationship between metacognitive strategies and mathematics performance was not uniformly obtained across different educational systems.

The Use of Memorization among East Asian Students

The paradox of East Asian learners has been a topic of educational research discourse in the past several decades. The paradox is that researchers have believed that most East Asian students use memorization heavily while they still have striking mathematics performance in international assessments (Biggs, 1988; Kember, 2000). It appears puzzling to Western researchers that East Asian students' high mathematics performance could not be due to their extensive use of memorization. To unravel the paradox, there are two plausible explanations. It is probable that East Asian students do not use memorization extensively. Alternatively, East Asian students may use memorization together with other types of learning strategies (Dahlin & Watjins, 2000; Kember, 2016).

In fact, a few recent PISA-based studies have shown that memorization strategy was used significantly less among East Asian students than their Western counterparts. For example, Chiu et al (2007) found that East Asian students did not have a higher endorsement of memorization than those in other educational systems in the PISA 2000 data. Moreover, Chiu et al (2007) found that East Asian students who reported a greater use of memorization did not have higher scores in any PISA subjects including mathematics. Likewise, a similar finding was also reported in PISA 2003. Liu (2009) demonstrated that American students reported a greater use of memorization than Hong Kong students; the use of memorization was a negative predictor for mathematics performance for Hong Kong and American students. Thus, PISA findings have challenged the common belief about memorization use of East Asian learners.

Another perspective can be drawn from cross-cultural qualitative research by drawing attention to the complexity of how memorization is utilized among East Asian students (Dahlin & Watjins, 2000; Marton et al, 1996; Kember, 2000; Kember, 2016). The study of Matron et al. (1996) was the first to distinguish between memorization as rote-learning versus memorization as a way to understand the learning material. They illustrated that a student can learn by memorization: "because each time I (the student) repeat, I (the student) would have some new idea of understanding, that is to say I (the student) can understand better" (p.81).

Dahlin and Watkins' (2000) study further pointed out that there are cross-cultural similarities and differences in the interpretation of memorization among Hong Kong and German students. They reported that indeed, 90% of Hong Kong students as opposed to only 50% of German students expressed the views that their teachers often asked them to recite texts, but that there were hardly any differences shown by the majority of both cultural groups when they rejected the idea that “repetition helps memorizing by creating a deep impression” or “repetition alone can lead to new meaning”. Strong cultural differences were shown in the statement “repetition plus attentive effort can lead to new meaning”, which was expressed by 60% of Hong Kong students as opposed to only 33% of German students. The authors also suggested that the majority of Hong Kong students were familiar with the concept of learning by a combination of both memorization and understanding while the majority of German students viewed memorization versus understanding as two mutually exclusive ways of studying (Dahlin & Watkins, 2000). A similar view was shown in Kember (1996) who noted that Asian students intended to do both simultaneously (i.e., memorization and understanding), which could be considered as the solution to resolve the paradox of East Asian learners. Later, Kember (2016) concluded that “the approaches to learning of Chinese students revealed the existence of intermediate approaches, combining memorising and understanding, which were distinct from rote learning” and that “learning approaches are reformulated as a continuum between pure surface and deep poles characterised by the presence of understanding and memorisation in the intention and strategy and in the sequence of their use”(p.1).

Aims of the Present Study

Previous PISA findings and qualitative studies have shed light on the learning strategies of East Asian students. However, there is little evidence to suggest that East Asian students across different educational systems indeed use memorization more or less than what is expected from the common perception (Biggs, 1998). While previous qualitative studies have well argued for East Asian students’ combined use of surface-learning by memorization and deep-learning by understanding, the conclusion tended to be based on small-scale qualitative research (Dahlin &

Watkins, 2000; Marton et al, 1996) or on a synthesis of many prior studies (Kember, 2016). Additionally, the majority of the previous studies were based on Hong Kong students. To date, no study has examined whether the combined practice of memorization and understanding can be generalized to East Asian students across educational systems. If students in different East Asian educational systems tend to adopt the combined learning strategy practice, it may well be considered as one possible explanation for their high mathematics performance.

Due to the lack of prior studies that have focused on the combined learning strategy practices among East Asian students, this study aims to fill the research gap in the following ways. First, we aim to examine whether East Asian students use memorization as their main learning strategy or whether they use memorization in conjunction with other strategies. Second, we aim to find out what types of learning strategy used by East Asian students would explain their high mathematics performance, which can be used as evidence to explain the “paradox of East Asian learners”.

Method

Data

We examined seven East Asian educational systems from the PISA 2012 data: Hong Kong (N = 4,670, female = 46%), Japan (N = 6,351, female = 48%), South Korea (N = 5,033, female = 47%), Macau (N = 5,335, female = 49%), Shanghai of China (N = 5,177, female = 51%), Singapore (N = 5,546, female = 50%), and Taiwan (N = 6,046, female = 51%). The PISA 2012 adopted a two-stage complex survey design to select a representative sample of fifteen-year-old students in each educational system. In the first stage, schools with eligible fifteen-year-old students were systematically sampled based on the probabilities proportional to the school size. Once schools were selected, approximately 35 students were selected with an equal probability within the sampled school (OECD, 2014).

Mathematics Learning Strategies

Data on students' use of learning strategies in mathematics were collected via self-reporting to the PISA 2012 Student Questionnaire. In the PISA 2012 cycle, three types of learning strategies - memorization, elaboration, and metacognition - were measured with a forced-choice format. Four items were used to ask about students' use of learning strategies in mathematics. Within an item, the three statements represented memorization, elaboration, and metacognitive strategies, respectively. Due to the forced-choice format, students were asked to choose only one learning strategy out of three presented in one item to indicate the learning behavior for mathematics that best represent themselves (Table 1).

<u>Insert Table 1</u>

Mathematic Performance

The PISA 2012 adopted a booklet design whereby each student was randomly assigned to one of thirteen booklets and tested on a portion of items from the entire item pool. Thus, raw scores of each student cannot be compared because they took different parts of the test. The PISA 2012 used the item response theory (IRT) framework to estimate a latent posterior distribution for each student and five plausible values were drawn from the posterior distribution with a mean of 500 and a standard deviation of 100 to represent students' mathematics scores (OECD, 2014). All five plausible mathematics values were used in the analysis of this study.

Covariates

In calculating the estimates of the learning strategy variables for predicting mathematics scores, students' gender and family socio-economic status (SES) were used as covariates. Female students were coded as 0 and male students were coded as 1. In PISA, the economic, social and cultural status (ESCS) index was constructed on a scale with a mean of 0 and a standard deviation of 1 across the OECD educational systems (OECD, 2014) to measure students' ESES. The index was derived from the highest occupational status of parents, highest educational level of parents, and home possessions including family wealth, cultural possessions, home educational resources and the number of books in the home.

Statistical Analysis

Latent class analysis (LCA, Hagenaars & McCutcheon, 2002) was the main statistical analysis used in this study to identify learning strategy patterns among East Asian students. LCA produces estimates of conditional probabilities of individuals belonging in a class where individuals in the same latent class are similar to each other in terms of their item responses. Cluster analysis produces similar results (i.e., classification of students into latent classes based on a set of variables) but LCA has additional advantages that: (a) individuals are assigned to latent classes based on conditional probabilities and (b) an overall fit of a model to the observed data is statistically assessed to decide the best fitting model for the given data (Hagenaars & McCutcheon, 2002).

To decide the number of learning strategies types, we followed two criteria – statistical criteria and interpretability – suggested by Marsh, Lüdtke, Trautwein and Morin (2009). First, two statistical criteria, Bayesian information criterion (BIC; Schwarz, 1978), and adjusted BIC (a_BIC; Sclove, 1987), were used to assess the model fit, with lower values suggesting a better model fit. However, when there was a conflicting result between BIC and a_BIC, we used BIC to decide on the best model, because BIC has robust performance in LCA (Nylund, Asparouhov, & Muthén., 2007). We did not consider Akaike's information criterion (AIC; Akaike, 1974), because it has not been recommended for assessing model fit (Nylund et al., 2007).

Second, we considered the interpretability of the different solutions of learning strategies types. When interpreting classes, we considered an overall pattern across four items, that is, the most dominant learning strategy and the least dominant learning strategy that were reported by students across four items. For example, if three out of four items have the highest probability on memorization and only one item had the highest probability on the metacognitive strategy, we labelled this class as "*memorization with metacognitive strategies*", where memorization is the first learning strategy and metacognitive strategies is the second. When two learning strategies are labelled in a latent class, the first learning strategy is reported more frequently, followed by the second learning strategy. Additionally, given that prior literature has noted that the use of memorization may be context- or task-dependent, when interpreting classes, we paid attention to item 1 (Table 1) because only item 1 describes a different learning context in mathematics, which is about preparation for mathematics tests.

Students' class membership was computed as data for further analyses. Regression analysis was conducted with class membership as an independent variable to predict mathematics scores to examine which learning strategy groups showed higher mathematics achievement scores. LCA and regression analyses were conducted in Mplus 7.4 (Muthén & Muthén, 2015).

Preliminary Analysis

In the preliminary analyses, we conducted LCA for each educational system separately to obtain insights on how many solutions should be considered when LCA is fitted into a sample combined with seven East Asian educational systems. The model selection was based on BIC, a_BIC and also on theoretical interpretations. Across all educational systems, the lowest BIC and a_BIC occurred in the 3-class model in Japan, Macau, and Singapore. The lowest BIC and a_BIC occurred in the 4-class model in Taiwan. The conflicting results from BIC and a_BIC were shown in Hong Kong, South Korea, and Shanghai, and we used the BIC along with the interpretations of classes to decide the model. As a result, the 2-class model for Hong Kong, and the 3-class model for South Korea and Shanghai were chosen. Note that the details of these preliminary results are available upon request. The analyses performed for each of the seven educational systems suggested the number of classes was between 2 and 4. Therefore, we fitted 1-class (as the baseline model) to 4-class solutions to the data that were combined across all seven educational systems.

Results

Latent Class Analysis Results

Table 2 presents the results of BIC, and a_BIC. The model fit becomes better when the number of classes increases from 1 to 4 in sequence. In deciding the best model, we also considered BIC, a_BIC and the class interpretation, as mentioned earlier. As a result, the 4-class model appears to be the best fitting and also has the most interpretable solution. The four classes obtained in the 4-class solution are labelled as *memorization with metacognitive strategies* (17.49%, Class 1), *metacognitive strategies with memorization* (50.70%, Class 2), *elabo*ration (10.33%, Class 3), and *metacognitive strategies with elaboration* (16.47%, Class 4), based on their conditional probabilities on the items. As the class labels indicate, the majority of the students (Classes 1, 2, and 4) reported the use of more than one mathematics learning strategy.

Insert Table 2

The Interpretations of Classes. Table 3 shows the conditional probabilities across four items in each class. In Class 1 (*memorization with metacognitive strategies*), three out of the four items have the highest conditional probabilities on memorization (.423 on item 1, .667 on item 2, and .673 on item 4) while the highest conditional probability is on metacognitive strategies (.516 on item 3; the description of metacognitive strategy for item 3 was “When I study mathematics, I start by working out exactly what I need to learn.”). It is interpreted that the students in this class primarily reported using memorization for mathematics, but they sometimes reported using metacognitive strategies. The students belonging in this class reported using memorization to prepare for mathematics tests, i.e. item 1, “When I study for a mathematics test, I learn as much as I can by heart.”

In Class 2 (*metacognitive strategies with memorization*), three out of the four items have the highest conditional probabilities on metacognitive strategies (.625 on item 1, .718 on item 2, and .755 on item 3) and one item shows the highest conditional probabilities on memorization (.579 on item 4; the description of memorization for item 4 was “In order to remember the method for solving a mathematics problem, I go through examples again and again”). Based on these conditional probabilities, students in this class reported using metacognitive strategies to prepare for mathematics tests (based on item 1, “When I study for a mathematics test, I try to figure out what are the most important parts to learn”). Although the class labels between Class 1 and Class 2 are similar, the students in Class 1 reported mainly using memorization, and the students in Class 2 reported mainly using metacognition.

In Class 3 (*elaboration strategies*), all four items have the highest conditional probabilities on the item choice representing elaboration (.485 on item 1, .395 on item 2, .600 on item 3, .630 on item 4). This was the only class where students reported using only one cognitive learning strategy, namely elaboration.

In Class 4 (*metacognitive strategies with elaboration*), three out of the four items have the highest conditional probabilities on metacognitive strategies (.530 on item 2, .447 on item 3, and .535 on item 4) and one item is on elaboration (.711 on item 1 "When I study for a mathematics test, I try to understand new concepts by relating them to things I already know"). Thus, students in this class mostly reported using metacognitive strategies for mathematics content learning (i.e., items 2, 3, and 4) and using elaboration for test preparation (item 1).

Insert Table 3

Sizes of Classes. Table 3 shows that the largest group among the three latent classes is Class 2 (*metacognitive strategies with memorization*), to which the majority of the East Asian students (50.7%) belonged. Class 3 (*elaboration strategies*) is the smallest (10.33%, see Table 3). We calculated the percentages of students belonging to each learning strategy class in each of the seven East Asian educational systems (see Table 4). In Class 1 (*memorization with metacognitive strategies*), more than 10% of Shanghainese (19.1%), Singaporean (14.1%), Taiwanese (13.5%), Japanese (12.3%), and Korean (11.4%) students belonging to this class. Across all seven educational systems, the majority of the students belonged to Class 2, while some variations are also noted across the educational systems: more than 70% in Japan (76%), Hong Kong (74%), Macau (73%), and Singapore (72%), followed by Korea (65%), and then by Shanghai (55%) and Taiwan (58%). In Class 3, only Taiwan (15.0%) and Shanghai (10.3%) has more than 10% of students in this class. In Class 4 (*metacognitive strategies with elaboration*), Shanghai (15.2%), Korea (14.2%), and Taiwan (13.9%) has more than 10% of students in this class. While there are some variations in the percentages of students belonging to each class, the majority of students across all seven educational systems belonged to Class 2 who reported using *metacognitive strategies* for the most part but using *memorization* to "remember the method for solving a mathematics problem" (i.e., item 4).

Insert Table 4

The Relationship between Learning Strategies and Mathematics Performance

The PISA 2012 mathematics scores of the four learning strategy classes are presented for the seven educational systems in Figure 1. The lowest mathematics scores are shown in Class 1 (*memorization with metacognitive strategies*) in five out of seven educational systems, with the exception of Korea and Singapore where their lowest mathematics scores are shown in the *elaboration* class. The highest mathematics scores are shown in Class 4 (*metacognitive strategies with elaboration*) in five out of seven educational systems, with the exception of Singapore and Macau. It is worth noting that the mathematics scores are substantially lower in Class 1 (*memorization with metacognitive strategies*) than in Class 2 (*metacognitive strategies with memorization*) in all or educational systems.

Insert Figure 1

To examine the relationship between the learning strategy classes and mathematics scores, we conducted regression analyses for each educational system while taking ESCS and gender into account. Note the regression analysis for Macau did not converge; therefore, we do not provide the results for Macau. Class 1 (*memorization with metacognitive strategies*) was used as the reference group to demonstrate the relative effects of being in Class 2 (*metacognitive strategies with memorization*), Class 3 (*elaboration strategies*), or Class 4 (*metacognitive strategies with elaboration*), with all other conditions remaining equal. Table 5 presents the estimated standardized coefficients of the regression analysis, conducted for each of seven educational systems. Being classified into Class 2 (*metacognitive strategies with memorization*) is significantly positively related to mathematics performance in all or educational systems, relative to Class 1 (*memorization with metacognitive strategies*).

The effect of Class 3 (*elaboration strategies*) shows mixed results across the educational systems (Table 5). The effect of being in Class 3 (*elaboration strategies*) relative to being classified into Class 1 (*memorization with metacognitive strategies*) is significantly and positively related to mathematics performance in Hong Kong and Shanghai. However, the effect of being in Class 3 (*elaboration strategies*) on mathematics performance is significantly negative in Korea, while having no significance in Japan, Singapore and Taiwan.

Being in Class 4 (*metacognitive strategies with elaboration*) shows the significantly positive relationship with mathematics scores in all East Asian educational systems, except for Singapore (Table 5). Despite minor differences in the results, the most notable pattern of the regression analysis results is that students classified into Class 1 (*memorization with metacognitive strategies*), who reported using memorization as their main learning strategy, have lower mathematics scores, compared to Class 2 (*metacognitive strategies with memorization*) and Class 4 (*metacognitive strategies with elaboration*).

Insert Table 5

Discussion

The present study aimed to examine learning strategy use of East Asian students with a focus on their use of memorization in mathematics learning. We examined (a) whether memorization is the dominant learning strategy among East Asian students, (b) whether East Asian students combine memorization with other learning strategies, and (c) what types of learning strategy would show the better mathematics performance among East Asian students. We found that most East Asian students were classified into Class 2 (*metacognitive strategies with memorization*) who reported using a combined strategy of metacognition and memorization with the majority of the time using metacognition rather than memorization. The least number of East Asian students were classified into Class 3 (*elaboration strategies*), a finding suggesting that most East Asian students (i.e. Class1, Class 2, and Class 4) reported using multiple learning strategies rather than relying on one strategy. The results also indicated that students who reported using metacognitive strategies along with either memorization (Class 2, *metacognitive strategies with memorization*) or elaboration (Class 4, *metacognitive strategies with elaboration*) showed higher mathematic performance in most of the seven educational systems. A more detailed discussion about the findings is presented below.

Variations in the Use of Learning Strategies

We found that most East Asian students reported using a combination of memorization and metacognitive strategies (i.e., Class 1 and Class 2), while the majority of the students belonged to Class 2 (*metacognitive strategies with memorization*) rather than Class 1 (*memorization with metacognitive strategies*). Students in Class 2 reported using metacognitive strategies frequently although they also reported using memorization (Item 4, "In order to remember the method for solving a mathematics problem, I go through examples again and again"). Although item 4 was seen as a memorization strategy, the statement of item 4 emphasizes "*go through examples,*" which is not identical to *memorizing word by word* or *by heart*. Going through examples might represent East Asian students' learning practice to connect what they memorize to what they understand, as noted in an excerpt in Marton et al. (1996) "*Because each time I repeat, I would have some new idea of understanding, that is to say I can understand better*" (p.81). Given this interpretation, Class 2 could be viewed as evidence of the students utilizing memorization for better understanding, as prior qualitative studies suggested (Dahlin & Watkins, 2000; Marton et al, 1996; Kember, 2016). Overall, our findings are in agreement with a view that East Asian students may use memorization for understanding (Dahlin & Watkins, 2000). No group that endorsed the employment of memorization exclusively for mathematics learning emerged from the LCA analysis.

The statements of item 1 ("*When I study for a mathematics test, I learn as much as I can by heart*") and item 3 ("*When I study mathematics, I go over some problems so often that I feel as if I could solve them in my sleep*") were closer to the rote-learning concept than item 4. The conditional probabilities of items 1 and 3 were very low among the students in Class 2 (*metacognitive strategies with memorization*), Class 3 (*elaboration strategies*) and Class 4 (*metacognitive strategies with elaboration*). The conditional probabilities of item 3 and item 4 were not high even for Class 1 (*memorization with metacognitive strategies*) who reported using memorization as the main strategy. The results were in accord with previous PISA studies that have challenged the common perception about East Asian learners exclusively relying on rote-learning (Chiu et al., 2007; Liu, 2009). The Chiu et al. (2007) and Liu (2009) studies based on the PISA 2000 and PISA 2003 data have also indicated that East Asian students did not adopt memorization extensively. Our study further revealed how memorization may or may not be used for different classes of learning strategy groups, by focusing on the item descriptions

Among the four classes that the LCA revealed, students in Class 3 (*elaboration strategies*) reported using this strategy across all items. Class 3 is the smallest among the four classes. Students in Class 4 (*metacognitive strategies with elaboration*) reported mainly using metacognitive strategies with an occasional use of elaboration when preparing for mathematics tests. One interesting point is that that most East Asian students reported using multiple leaning strategies (i.e. Class1, Class 2, and Class 4).

Nuanced Relationships between Learning Strategies and Mathematics Performance

Our results showed that most East Asian students in Class 1 (*memorization with metacognitive strategies*) had on average the lowest mathematics scores while students in Class 2 (*metacognitive strategies with memorization*) had the second highest mathematics performance in most educational systems. Moreover, in all seven educational systems, being in Class 2 was related to higher mathematics scores. These findings are in line with the notion that East Asian students' higher mathematics performance in recent international assessments may be attributable to their effective use of memorization to enhance understanding (Dahlin & Watkins, 2000; Kember, 2016; Marton et al, 1996). Previous qualitative studies have not demonstrated empirical evidence of how memorization and understanding might interplay to contribute to East Asian students' superior mathematics scores. Our study is the first to provide the empirical evidence to support the notion that the combined use of memorization and understanding was positively related to mathematics achievement among East Asian students. It should be noted that students who were classified into Class 1 (*memorization with metacognitive strategies*) could be viewed as using a combined strategy of memorization and understanding, However, students in Class 1 reported using mainly memorization and their mathematics score was the lowest in most systems, which supports the claim that lower mathematics scores were associated with more extensive use of memorization (Chiu et al., 2007; Liu, 2009).

Class 3 (*elaboration strategies*) displays diverse patterns across educational systems. There is no definite relationship between elaboration and mathematics performance relative to Class 1(*memorization* with *metacognitive strategies*). Elaboration is significantly positively related to mathematics performance in Hong Kong and Shanghai. There is no significant relationship between Class 3 and mathematics performance in Japan, Singapore and Taiwan. These findings are partially in line with PISA studies, which found that the relationship between elaboration and mathematics performance was not consistently the same across educational systems (Chiu et al, 2007; Liu, 2009; OECD, 2005). Furthermore, elaboration was significantly negatively related to mathematics performance in Korea. Particularly in Korea and Singapore, when students report elaboration, their mathematics performance shows the lowest averages. Given that the mixed results of elaboration consistently occur across educational systems in different PISA cycles, future research should investigate whether elaboration functions differently across educational systems by taking other variables into account.

Our regression analysis showed that mathematics scores were the highest in Class 4 (*metacognitive strategies with elaboration*) for all but Singapore. Note that mathematics performance between Class 2 (*metacognitive strategies with memorization*) and Class 4 differed only slightly in Singapore. It is worth noting that students who reported using the combination of cognitive and metacognitive strategies (i.e. Class 2 and Class 4) higher mathematics performance. This finding broadly supports the SRL theory (Pintrich & Groot, 1990; Zimmerman, 2001) because the theory recognizes and emphases metacognitive strategies for student learning (Zimmerman, 2001). Additionally, Pintrich and Goot (1990) have pointed out "cognitive strategy use without the concomitant use of self-regulatory strategies is not conducive to academic performance." (p.38). Thus, building upon the SRL theory and our empirical evidence, it seems that the combination of cognitive and metacognitive strategies is the effective strategy to help East Asian students obtain higher mathematics performance.

Conclusion

In general, the present study showed that East Asian students combine memorization with metacognitive strategies in mathematics learning, and that they also adopt different mixtures of memorization and metacognitive strategies. Among the students who used more metacognitive strategies and less memorization, their mathematics performance was higher than students who used more memorization and less metacognitive strategies. Moreover, most East Asian students reported using multiple learning strategies for learning mathematics. The combined use of metacognitive strategies and elaboration is the most effective learning strategy for mathematics performance, following by the combined use of metacognitive strategies and memorization. Thus, it appears that the role of metacognitive strategies seems to be important for students' achievement in mathematics.

Limitations of the Present Study

Although the present study provides another perspective on memorization to unravel the paradox of East Asian leaners, the findings should be viewed with limitations. First, self-reported data does not necessarily capture the actual use of learning strategies by students. Observational and think-aloud approaches may provide the detailed use of learning strategies. Second, we did not consider the sequential use of memorization, that is, memorization could be used before or after students' attempt to understand the learned materials (Dahlin & Watkins, 2000). Operationalizing various forms of memorization practices could also provide new insight into how memorization might be linked to the process of student understanding. Finally, the present study focuses on only learning strategies and mathematics achievement, while leaving other psychological variables in the sphere of the SRL theoretical framework out of the scope of this study. To gain a better understanding of East Asian students' mathematics learning outcomes, other psychological characteristics can be considered.

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Table 1

Mathematics Learning Strategies

Strategy	Statement
	Item 1
Metacognitive	When I study for a mathematics test, I try to figure out what are the most important parts to learn
Elaboration	When I study for a mathematics test, I try to understand new concepts by relating them to things I already know.
Memorization	When I study for a mathematics test, I learn as much as I can by heart.
	Item 2
Metacognitive	When I study mathematics, I try to figure out which concepts I still do not understand completely.
Elaboration	When I study mathematics, I think of new ways to get the answer.
Memorization	When I study mathematics, I make myself check to see if I remember the work I have already done.
	Item 3
Metacognitive	When I study mathematics, I start by working out exactly what I need to learn.
Elaboration	When I study mathematics, I try to relate the work to things I have learned in other subjects.
Memorization	When I study mathematics, I go over some problems so often that I feel as if I could solve them in my sleep.
	Item 4
Metacognitive	When I cannot understand something in mathematics, I always search for more information to clarify the problem.
Elaboration	I think about how the mathematics I have learned can be used in everyday life.

Memorization	In order to remember the method for solving a mathematics problem, I go through examples again and again.

Table 2

Model Selection

	AIC	BIC	a_BIC
1-class Model	195959	196024	195999
2-class Model	193512	193651	193597
3-class Model	192752	192964	192881
4-class Model	**192607**	**192892**	**192781**

Note. The bold represents the smallest value.

Table 3

The Conditional Probabilities and Class Size in the 4-class Model

	Class1 Memorization+ Metacognitive	Class 2 Metacognitive+ Memorization	Class 3 Elaboration	Class 4 Metacognitive+ Elaboration
Class Size (%)	17.49	50.70	10.33	16.47
Item1				
Metacognitive	.349	**.625**	.314	.275
Elaboration	.228	.245	**.485**	**.711**
Memorization	**.423**	.130	.202	.014
Item2				
Metacognitive	.245	**.718**	.357	**.530**
Elaboration	.088	.050	**.395**	.398
Memorization	**.667**	.232	.249	.072
Item 3				
Metacognitive	**.516**	**.755**	.342	**.447**
Elaboration	.122	.139	**.600**	.382
Memorization	.362	.106	.059	.171
Item 4				
Metacognitive	.228	.336	.159	**.535**
Elaboration	.098	.085	**.630**	.186
Memorization	**.673**	**.579**	.210	.279

Note. Numbers in **bold** indicate the highest response probability within an item.

Table 4

Percentages of Students in Each Latent Classes by Educational Systems

	Hong Kong	Japan	Korea	Shanghai	Singapore	Taiwan	Macau
Class 1 (Memorization + Metacognitive)	.093	.123	.114	.191	.141	.135	.087
Class 2 (Metacognitive + Memorization)	.740	.755	.650	.554	.721	.576	.727
Class 3 (Elaboration)	.074	.051	.094	.103	.062	.150	.093
Class 4 (Metacognitive + Elaboration)	.093	.071	.142	.152	.077	.139	.093

Table 5

The Standardized Estimated Coefficients in the Regression Analyses

	Hong Kong	Japan	South Korea	Shanghai	Singapore	Taiwan
Intercept	**5.847**	**5.806**	**5.356**	**5.974**	5.332	**4.756**
	(.100)	(.083)	(.099)	(.086)	(.082)	(.070)
ESCS	**.265**	**.318**	**.298**	**.395**	**.368**	**.398**
	(.017)	(.015)	(.016)	(.015)	**(.014)**	(.013)
MALE	**-.070**	**-.116**	**-.072**	-.035	.018	-.016
	(.019)	(.016)	(.017)	(.016)	(.016)	(.015)
Class 2	**.159**	**.098**	**.144**	**.137**	**.063**	**.169**
(Metacognitive + Memorization)	(.027)	(.020)	(.025)	(.021)	(.021)	(.023)
Class 3	**.075**	-.003	**-.082**	**.079**	-.017	.050
(Elaboration)	(.023)	(.018)	(.021)	(.020)	(.018)	(.021)
Class 4	**.122**	**.073**	**.203**	**.143**	.032	**.188**
(Metacognitive + Elaboration)	(.024)	(.018)	(.023)	(.020)	(.019)	(.019)

Notes. The reference group is Class 1 (Memorization + Metacognitive). The bold represents statistically significant differences at $p < .01$. The numbers in parenthesis are the estimated standard error. The regression analysis for the Macau sample did not converge, so we did not provide the estimated of coefficients in the table.

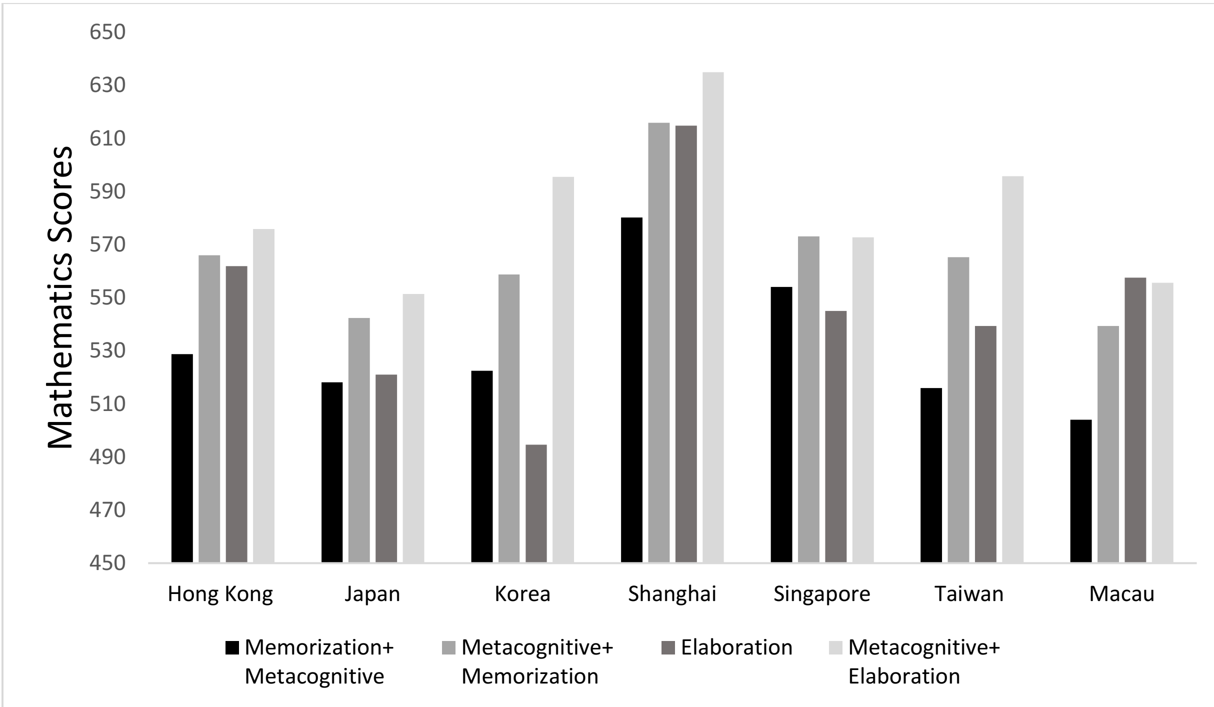

Figure 1. Mathematics scores by four types of learning strategies.

8.3. Appendix C: Manuscript 2. A revised version has been published: Yi-Jhen Wu, Sarah M. Kiefer & Yi-Hsin Chen: Relationships between learning strategies and self-efficacy: A cross-cultural comparison between Taiwan and the United States using latent class analysis (2019, International Journal of School & Educational Psychology; Published online: 24 Jan 2019)

https://doi.org/10.1080/21683603.2019.1566104

Relationships between Learning Strategies and Self-Efficacy: A Cross-Cultural Comparison between Taiwan and USA Using Latent Class Analysis

Abstract

Learning behavior of East Asian students has been debated due to striking performance on international large-scale assessments. This study was a comparative study using latent class analysis to examine students' perceptions of learning strategies, students' reported learning strategy use, and the relationships between learning strategies and self-efficacy across Taiwanese and American students in the Programme for International Student Assessment (PISA) 2012. The results indicate that learning strategy items were perceived equivalently. Taiwanese students (5%) reported less memorization than American students (19%). More Taiwanese students (63%) reported elaboration strategy; more American students (57%) reported control strategy. High self-efficacy Taiwanese students reported memorization the least; high self-efficacy American students reported elaboration less than control strategy. Implications are discussed.

Keywords: learning strategies; self-efficacy; latent class analysis; PISA 2012

Relationships between Learning Strategies and Self-Efficacy: A Cross-Cultural Comparison Using Latent Class Analysis

Students adopt different strategies in their learning process. Among the learning strategies, memorization has been questioned for its effectiveness by self-regulated learning (SRL) theory and research (Berger & Karabenick, 2011; Pintrich & De Groot, 1990). When students adopt surface-level memorization strategies, they tend to have lower levels of motivation and academic performance compared to students who adopt deep-level learning strategies (Berger & Karabenick, 2011; Walker, Greene, & Mansell, 2006). However, this is often not the case for East Asian students' learning behavior. Although East Asian students have been perceived to be rote learners for decades (Leung, 2006; Purdie, Hattie, & Douglas, 1996), they consistently outperform their Western counterparts in the Programme of International Student Assessment (PISA), especially in the mathematics domain (OECD, 2014b; OECD, 2016). Given that East Asian students have outstanding mathematic performance in PISA, it raises compelling questions about the extent to which East Asian students use memorization to achieve high mathematics performance, and the extent to which the perception of memorization among East Asian students is the same as Western students.

This comparative study makes a unique contribution to the field, studying the generalizability of the SRL theory in an East Asian context by using PISA data. PISA is a three-year cycle of an international large-scale assessment organized by the Organisation for Economic Co-operation and Development (OECD) since 2000. Every cycle focuses on different domains. In PISA 2012, the focus is on mathematics. PISA offers insight for educational policy makers by evaluating 15-year-old students' acquisition of knowledge and skills across educational systems. Given that the focus on this study is mathematics, PISA 2012 is the most relevant data to this study. Therefore, in this study, we used PISA 2012 to examine to what extent the measurement of learning strategies in PISA 2012 – designed using a Western perspective – is able to measure the same concept for 15-year old Taiwanese and American students by using multiple group latent class analysis (MGLCA). Specifically, we examined Taiwanese and American students' self-reported learning strategy use to see to what extent students from different cultures perceive the concepts of learning strategies (i.e., memorization, elaboration, and control strategies) differently. This study had two secondary aims: 1) to investigate students' use of learning strategies to see to what extent the pattern for Taiwanese students is similar to that for American students; and 2) to examine the relationships between students' self-efficacy and learning strategy use for Taiwanese and American students separately to understand to what extent the relationships between self-efficacy and learning strategies are the same across cultures.

Self-Regulated Learning (SRL) Theory

Self-regulated learning is defined as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment'' (Pintrich, 2000, p. 453). There are three phases in the SRL process: the forethought phase, the performance control phase, and the reflection phase. In the forethought phase, students set goals in light of their perceived self-efficacy as well as other beliefs and motivation. In the performance control phase, students adopt learning strategies for maintaining goals and monitor progress towards goal attainment. In the reflection phase, students evaluate their performance and the adjustments they made during the performance phase. These three phases influence each other mutually until students achieve their goals (Pintrich, 2000; Zimmerman, 2001; Zimmerman & Schunk, 2011). Although there are several important constructs that influence students' SRL processes, we only focused on two essential constructs in the SRL theory, self-efficacy and learning strategies, in the current study.

Self-efficacy plays an essential role in activating the three phases of the self-regulated learning process (Pintrich & De Groot, 1990). Self-efficacy influences goal setting in the forethought phase, learning strategy selection and use in the performance control phase, and evaluation criterion used in the reflection phase (Pintrich & De Groot, 1990; Zimmerman & Labuhn, 2012). According to Bandura (1977), self-efficacy is defined as students' confidence towards their abilities for specific tasks. Students who are highly confident in their abilities tend to initiate and persist in difficult tasks. In contrast, students with low confidence in their abilities tend to select easy tasks and are less persistent in achieving their goals (Schunk & Pajares, 2002). Thus, high levels of self-efficacy can enhance students' academic performance and aspirations.

Learning strategies are a crucial element in SRL, especially in the performance control phase where students adopt learning strategies to achieve their goals and develop their cognitive functioning. Although there are several classifications for learning strategies in the literature (Marton & Säljö, 1984; Pintrich & De Groot,1990; Weinstein & Mayer, 1986), two main classifications include cognitive and metacognitive strategies. Cognitive strategies include memorization and elaboration, which are consistent with PISA classifications (Weinstein & Mayer, 1986). Memorization strategies are conceptualized as surface-level learning strategies, which involve knowledge without further processing and comprehension (Biggs, 1987; Marton & Säljö, 1984). In contrast, elaboration strategies are conceptualized as deep-level learning strategies, which involve the in-depth understanding of knowledge by organizing, restructuring, and integrating new knowledge with prior knowledge (Biggs, 1987; Marton & Säljö, 1984). Metacognitive strategies, termed control strategies by PISA, involve students regulating their learning by evaluating, planning, and closing any identified knowledge gaps (Weinstein & Mayer, 1986).

Compared with memorization, elaboration and control strategies foster students' performance (Metallidou & Vlachou, 2007; Valentine, DuBois, & Cooper, 2004; Vermunt & Vermetten, 2004). Although some simple tasks only require memorization such as recalling multiplication tables, students often need to understand and integrate concepts with what they have learned. For a more complicated task, memorization is less effective than elaboration and control strategies. Elaboration strategies have been found to positively predict students' English achievement (Liem, Lau, & Nei, 2008), whereas control strategies are associated with increased reading performance (Artelt, 2005). However, memorization is negatively related to student mathematics performance (Köller, 2001; Zimmerman & Martinez-Pons, 1986). For instance, Chiu, Chow, and Mcbride-Chang (2007) found that students who reported using memorization strategies had lower reading scores than students who reported using elaboration or control strategies across educational systems in PISA 2000. As a result, compared with memorization, elaboration and control strategies are considered more effective because they help students link new information to old information and identify knowledge gaps to improve their performance across different domains.

In the SRL process, self-efficacy and learning strategies are mutually related constructs. Students who are confident in their ability in a specific domain are likely to regulate their behavior by adopting effective learning strategies (i.e., elaboration or control strategies) to improve their performance. In turn, students who use effective learning strategies are likely to increase their confidence through their academic performance. Accumulating evidence has established a positive relationship between self-efficacy and learning strategies (Berger &

Karabenick, 2011; Diseth, 2011; Liem et al., 2008) and indicates that self-efficacy explains a substantial variance in learning strategies across domains and grade levels (Zimmerman & Martinez-Pons, 1986). Diseth (2011) claimed that Norwegian students who reported high self-efficacy tended to use deep-level learning strategies, and self-efficacy was negatively related to memorization. Furthermore, regarding the causal relationship between self-efficacy and learning strategies, Berger and Karabenick (2011) found in a two-wave longitudinal study that self-efficacy positively predicted elaboration and control strategies other than memorization. Consequently, students who have more confidence are likely to use elaboration or control strategies across different academic domains, including mathematics, which is the focus of this study.

East Asian Students' Learning Behavior

East Asian students have been viewed as rote learners for decades (Ho, 2009; Leung, 2006; McInerney, 2011; Purdie et al., 1996). However, there is growing evidence challenging this view. First, several PISA studies have demonstrated that East Asian students had a lower tendency to report memorization than Western students (Chiu et al., 2007; Liu, 2009; Liu & Wilson, 2009). Chiu et al. (2007) found that East Asian students reported lower memorization strategy use compared with other counterparts in PISA 2000, a result that was in contrast with the common perception of East Asian students as rote learners. Similarly, Liu and Wilson (2009) pointed out that American students outperformed on reproduction mathematics items compared to Hong Kong students in PISA 2003.

Second, researchers have argued that the perception of memorization is different between East Asian and Western cultures (Bigss, 1988; Kember, 2000; Kember & Gow, 1990; Sachs & Chan, 2003). Zhu, Valcke, and Schellens (2008) indicated that the concept of remembering was positively correlated with memorization for Flemish students but was positively correlated with deep-processing learning strategies for Chinese students. In Dahlin and Watkins (2000)'s qualitative study, Hong Kong students believed memorization boosted understanding, whereas German students believed that memorization involved rote learning and may not boost understanding.

According to the SRL theoretical framework, if East Asian students tend to use memorization, they should have low mathematics performance in international large-scale assessments. However, East Asian students have outstanding mathematics performance in international large-scale assessments. In international large-scale assessments such as PISA and the Trends in Mathematics and Sciences Study (TIMSS), East Asian educational systems have been ranked in top positions within the mathematics domain (Leung, 2017; Mullis, Martin, Foy, & Hopper, 2016; OECD, 2014b; OECD, 2016). Thus, it might be logical to assume that East Asian students use superior learning strategies to achieve high performance. Conflicting results and possible misperceptions of East Asian students in the literature call for additional clarity regarding: (i) the perception of memorization between East Asian and Western students, and (ii) the use of memorization strategies among East Asian and Western students. In order to address these, the current study examined whether learning strategies are measurement invariant and the frequency use of learning strategies across countries.

East Asian Students' Learning Beliefs

Cross-cultural research indicates cultural factors shape students' learning beliefs (McInerney, 2011), which may have implications for self-regulated learning and behavior. Cross-cultural researchers often use the dimensions of individualism and collectivism to explain the functioning of self. English-speaking countries and Western Europe are considered individualistic, whereas East and South Asian countries are considered collectivistic (Markus & Kitayama, 1991; Oyserman, Coon, & Kemmelmeier, 2002). In collectivistic cultures, students often consider other groups' feelings while evaluating themselves, whereas in individualistic cultures, students tend to evaluate themselves based on self-referenced information (Oyserman et al., 2002).

However, Bandura (1997; 2002) argued that the concept of self does not differ between collectivist and individualistic cultures, and that self-efficacy operates equally across cultures. This aligns with mathematical self-efficacy, which involves students' confidence in solving a specific mathematics task rather than comparing themselves with classmates and may be less likely to be susceptible by the dimensions of collectivism-individualism. Thus, mathematical self-efficacy may be a salient factor across cultures. This aligns with recent research, as Stankov and Lee (2017) demonstrated that mathematical self-efficacy had a positive and powerful prediction on students' performance across cultures in PISA, compared with other non-cognitive factors. Similarly, Liu (2009) found that self-efficacy was the best predictor on mathematics performance in Hong Kong and America by using PISA 2003. Liu (2009) also claimed that the levels of self-efficacy for Hong Kong and American students were similar, yet Hong Kong students had lower levels of self-concept than American students. Thus, given that the nature of mathematical self-efficacy and the similar effect of mathematical self-efficacy on mathematics performance across countries, it appears that mathematical self-efficacy has a universal impact on students' mathematical learning.

To gain a clearer understanding of whether self-efficacy functions differently across cultures, one of the aims in this study was to examine the relationships between self-efficacy and learning strategies across East Asian and Western cultures.

Purpose of Study

This study was a comparative study that used self-reported inventories of mathematics learning strategies and self-efficacy to understand underlying SRL mechanisms across cultures in order to provide insights to the applicability of SRL. Specially, the following questions were addressed:

Research question 1: To what extent do Taiwanese students and American students have the same perceptions of learning strategies? Methodologically speaking, are the items of learning strategies measurement-invariant between Taiwan and USA? We did not make a specific hypothesis regarding whether or not learning strategies were measurement-invariant, as current literature is based on qualitative studies with small sample sizes and may not be representative of other East Asian populations (Kember, 2000; Kember & Gow, 1990; Sachs & Chan, 2003). Thus, the investigation of measurement invariance on learning strategies was exploratory in nature.

Research question 2: To what extent are Taiwanese students more likely to report memorization than American students? Framed within SRL (Zimmerman, 2001) and recent empirical PISA studies (Chiu et al., 2007; Liu, 2009; Liu & Wilson, 2009), we hypothesized that Taiwanese students will report less memorization than American students, and that Taiwanese students will report more elaboration or control strategies than American students.

Research question 3: To what extent are the relationships between self-efficacy and learning strategies the same across countries? Given that self-efficacy functions equally across cultures (Bandura, 1997; 2002; Liu, 2009; Stankov & Lee, 2017), we assumed that the relationships between self-efficacy and learning strategies are similar across cultures. Furthermore, based on the mechanism of SRL (Zimmerman, 2001) and empirical studies (Berger

& Karabenick, 2011; Diseth, 2011; Liem et al., 2008), we expected that across cultures, there will be negative relationships between self-efficacy and memorization strategies, positive relationships between self-efficacy and elaboration strategies, and positive relationships between self-efficacy and control strategies.

The data used for all statistical analyses in this study were from PISA 2012 due to several advantages. First, PISA 2012 included a sufficient and representative sample of 15-year-old students in Taiwan and USA, which can provide a more precise population estimation for each educational system. Second, the items for measuring students' mathematics learning strategies and self-efficacy from PISA 2012 were well-designed and based on several educational psychology theories (Bandura, 1977; Weinstein & Mayer, 1986). Third, students' reported learning strategy use survey in PISA 2012 applied the forced-choice format to avoid response style, which is a more effective design (OECD, 2014a).

Method

Participants and Procedure

Participants in this study were 15-year-old students in Taiwan and USA derived from PISA 2012. In the PISA data collection process, students were told that participation was voluntary and confidential, and they did not receive feedback on their performance afterwards (Baumert & Demmrich, 2001). PISA adhered to the regulation of anonymity; thus, the data were de-identified. The sampling design in PISA 2012 was a two-stage stratified sample design (OECD, 2014a). In the first stage, 150 schools were systematically sampled based on probabilities proportional to the school size. Once schools were selected, at least 35 students within a school were randomly selected. During the data collection, it is possible that not all students may not have completed all measures within a school. Each school was required to have a minimum student response rate of 50% to be considered as participating (OECD, 2014a). There were 2,013 students from Taiwan and 1,654 students from USA. Approximately 52% and 51% of Taiwanese and American students were female, respectively [2]. We chose to examine Taiwan and USA in this study because their education systems are structurally similar yet culturally different.

Measures

Mathematics Learning Strategy Use. There were three mathematics learning strategies, including two cognitive strategies, memorization and elaboration, and one metacognitive strategy, control (OECD, 2013). These three learning strategies were measured by four items each, using a forced-choice format. As shown in Table 1, each item included three mutually exclusive statements that describe students' learning behavior (i.e., memorization, control, or elaboration). These forced-choice items allowed students to choose only one of three learning strategy statements. Due to the forced-choice format for the mathematics learning strategy use items, we were unable to provide the reliability, as there was a violation of independent errors between items (Brown & Maydeu-Olivares, 2013).

Mathematical Self-efficacy. The mathematical self-efficacy survey measured the extent to which students identify their mathematics ability given a specific mathematics task. Students were asked about how confident they felt about eight mathematics tasks (see Table 2) using a 4-point Likert scale with "very confident" (1), "confident" (2), "not very confident" (3), and "not at all confident" (4). All items were reverse coded in PISA 2012 and the scores of mathematics self-efficacy were scaled with a mean of 0 and a standard deviation of 1 (OECD, 2014a). The

[2] PISA 2012 adopted a rotated-design for the student questionnaire. In other words, not every student answered self-efficacy and learning strategies items. In this study, Form A was used to conduct analyses, because only Form A included self-efficacy and learning strategy use items.

reliabilities of the mathematics self-efficacy survey were .91 and .85 for Taiwan and USA, respectively (OECD, 2014a).

Validity issues (e.g., construct validity, cross-cultural validity) of the surveys used in PISA 2012 have been checked regularly across all participating countries. Those existing and any newly-developed surveys were kept in PISA 2012 only when testing results were satisfactory (OECD, 2014a). In other words, construct validity and cross-cultural validity of the two surveys used in the study were acceptable. All of the validity information is available in the PISA 2012 Technical Report (OECD, 2014a).

Covariates

Gender. In the analyses, female was coded as 0 and male was coded as 1.

Economic, Social, and Cultural Status. In PISA, the economic, social, and cultural status (ESCS) index was used to measure a student's family socioeconomic status (SES). The ESCS was derived from the highest occupational status of parents, the highest educational level of parents, and home possessions including family wealth, cultural possessions, home educational resources, and number of books in the home. The ESCS index was scaled with a mean of 0 and a standard deviation of 1 (OECD, 2014a).

Statistical Analyses

Multiple-group Latent Class Analysis. The measurement invariance of the survey is a prerequisite of making quantitative comparisons of latent classes (such as class sizes or the survey scores of latent classes) across groups (Collins & Lanza, 2010). In this study, multiple-group latent class analysis (MGLAC) was conducted to examine the measurement invariance of mathematics learning strategy use survey across Taiwanese and American students. We examined whether the number of latent classes and the category-response probabilities for each item were equivalent across the two countries in order to consider the measurement invariance of the survey, suggesting that the characteristics and interpretations of latent classes are the same across both countries (Collins & Lanza, 2010).

Aligned with Collins and Lanza's (2010) recommendations, we took the following steps to examine the measurement invariance of the learning strategy use survey. The first step was to determine the number of latent classes. Three single-group latent class analyses (LCAs) were conducted for the combined sample (i.e., including Taiwanese and American students together) and two individual country samples. In addition, an MGLCA was conducted with no constraints across two countries. One to four-class solutions were used to fit the data for these LCA analyses. Information criteria, such as Akaike's information criterion (AIC; Akaike, 1974), Bayesian information criterion (BIC; Schwarz, 1978), and adjusted BIC (a_BIC; Sclove, 1987), were applied to select the best fit solution for each sample. Research indicated that the BIC has the best performance among information criteria to choose the number of latent classes (Nylund, Asparouhov, & Muthén, 2007). In this study, the selection of the number of latent classes was based on the lowest BIC. In addition, we also took the meaningful interpretations of latent classes into consideration.

If the number of latent classes is consistent and meaningful across single-group and multiple-group LCA analyses, the next step is to investigate whether category-response probabilities are invariant across groups. We conducted the unconstrained and the constrained MGLCA models with the best fit solution from the first step. The unconstrained model involved freely-estimated both category-response probabilities and class sizes across Taiwanese and American students. The constrained model included equally-constrained category-response probabilities but freely-estimated class sizes across two countries. Information criteria mentioned earlier were used to choose the best model. If the constrained model is selected, the measurement invariance of the survey is held and equal class sizes across two countries will be tested.

Multinomial Logistic Regression. The relationship between self-efficacy and mathematics learning strategy was examined using multinomial logistic regression. The dependent variable was the latent classes of learning strategy use, and the predictor variable was mathematics self-efficacy. Gender and economic, social, and cultural status (ESCS) were covariates in the multinomial logistic regression. The multinomial logistic regression analyses were conducted for Taiwanese and American samples separately. All analyses were conducted with student weights in Mplus 7.4 (Muthén & Muthén, 2015).

Results

Latent Class Analyses

Of interest was whether the items for measuring learning strategy use were invariant in terms of the number of latent classes and the category-response probabilities for Taiwanese and American students. Table 3 presents the fit indices (i.e., AIC, BIC, and A_BIC) for each model for the combined sample, two individual country samples, and multiple-group latent class analysis. The lowest BIC value occurred in the 3-class solution for all tested samples. Thus, the best fit solution of latent classes was the 3-class model for both countries, indicating the structure of latent classes was the same across two countries.

Table 4 presents the class sizes and the conditional category-response probabilities for the unconstrained and constrained models with the 3-class solution using multiple-group latent class analysis. The unconstrained model has freely-estimated class sizes and category-response probabilities while the constrained model includes freely-estimated class sizes and equally-constrained category-response probabilities across Taiwanese and American students. As shown at the top of Table 4 for the unconstrained model, students in Class 1 had the highest conditional probabilities for the category of memorization across four blocks. Thus, Class 1 was characterized as the "memorization" class. In Class 2, three out of four items, except for Item 2, had the highest conditional probabilities on the category of elaboration for both countries, which was characterized as the "elaboration" class. In Class 3, three out of four items, except for Item 4, had the highest conditional probabilities on the category of control for both countries, which was characterized as the "control" class. Therefore, Taiwan and USA had the same interpretations of the latent classes, namely the Memorization, Elaboration, and Control classes for Classes 1 to 3, respectively.

To examine the measurement invariance of the use of mathematics learning strategies across Taiwanese and American students, we compared the constrained and unconstrained models with 3-class solution using the multiple-group LCA analyses. In addition to two models shown in Table 4, we added one constrained model with equally-constrained both class sizes and category-response probabilities across the two countries. Table 5 presents fit indices for the three MGLCA models with the 3-class solution. Two constrained models (M2 and M3) had a lower BIC than the unconstrained model (M1). The best fit model between two constrained models occurred in the model with equally-constrained category-response probabilities but freely-estimated class size. Thus, measurement invariance of the strategy use survey was held across the two countries in terms of category-response probabilities, but the class sizes were different between Taiwan and USA.

The category-response probabilities and class sizes for the best fit model are shown at the bottom of Table 4. The characteristics of three latent classes for the best model were Memorization, Elaboration, and Control for Classes 1 to 3 (Table 4), respectively. Regarding the distributions of three latent classes, few Taiwanese students were classified in the Class 1, compared with American students. More Taiwanese students were classified in the Class 2, whereas a large proportion of American students were classified in the Class 3.

Multinomial Logistic Regression

Table 6 presents means and standard errors (SE) of students' self-efficacy scores across three latent classes for Taiwanese and American students. The lowest self-efficacy means for Taiwanese and American students were in the memorization class and elaboration class, respectively. The highest self-efficacy means appeared in the elaboration class for Taiwanese students and in the control class for American students.

To understand the relationship between students' self-efficacy and their learning strategy use, the multinomial logistic regression was conducted with students' economic, social, and cultural status (ESCS) and gender as covariates for each country. The control class was used as the reference group, which enabled us to compare it with the deep-level cognitive strategy (i.e., elaboration) and the surface-level cognitive strategy (i.e., memorization). Table 7 shows the unstandardized coefficients of each predictor for two comparisons of learning strategy use (i.e., memorization versus control and elaboration versus control) in both countries. As shown in Table 7, after controlling for ESCS and gender, Taiwanese students' self-efficacy was significantly negatively related to memorization use compared to control use, indicating that high self-efficacy students were less likely to report using the memorization strategy than the control strategy. Taiwanese students' self-efficacy was not significantly related to the use of elaboration or control strategy. For American students, self-efficacy was not significantly related to the use of memorization compared with control strategy. American students' self-efficacy was significantly related to elaboration use, compared to control use strategy, meaning that high self-efficacy students were less likely to report using the elaboration strategy than the control strategy.

As for the relations of gender with mathematics learning strategy use after controlling for self-efficacy and ESCS, Taiwanese male students were more likely to report using the elaboration strategy but were equally likely to report using the memorization strategy, compared to the control strategy use, in relation to Taiwanese female students (Table 7). American male students were more likely to report memorization or elaboration compared to the control strategy use, in relation to American female students (Table 7).

Regarding the relations of ESCS with mathematics learning strategy use after controlling for self-efficacy and gender, ESCS was not related to the memorization strategy and the elaboration strategy for Taiwanese students, compared to the control strategy use. The finding demonstrates that Taiwanese students with different ESCS levels had equivalent chances to report using the memorization or control strategies as well as the elaboration or control strategies. However, ESCS was significantly negatively related to the use of memorization and elaboration strategies, compared to the control strategy use for American students. This indicates that American students who possessed high ESCS status were less likely to report using the memorization strategy or the elaboration strategy than the control strategy. In other words, American high ESCS students tended to report using the control strategy.

Discussion

The present study aligns with and extends prior research examining the generalizability of the Self-Regulated Learning theory in the East Asian context. This cross-cultural study extended the literature by examining measurement invariance of learning strategy use across Taiwan and the USA. Additionally, the study examined the relative frequency of learning strategy use and examined the relationships between students' self-efficacy and their learning strategy use for Taiwan and American students separately.

The results indicated that items measuring students' learning strategy use were measurement-invariant across Taiwanese and American students. American students reported using memorization strategies more than Taiwanese students. A majority of Taiwanese students reported using elaboration strategies, whereas most American students reported using control strategies. Taiwanese students with higher mathematical self-efficacy were less likely to report using memorization strategies than control strategies. However, American students with higher mathematical self-efficacy were less likely to report using elaboration strategies, compared to control strategies. A more detailed discussion about the findings in this study is presented below. Implications for classroom instruction are discussed.

Perceptions of Learning Strategies

The same number of three latent classes in terms of students' learning strategy use across Taiwan and America were found in this study, denoting memorization, elaboration, and control classes. The probability of endorsing three types of learning strategies on the four items were the same across the two samples. These findings indicated that measurement invariance of the items measuring students' reported mathematics learning strategy use was held across Taiwanese and American students. In other words, Taiwanese and American students had the same perceptions of memorization, elaboration, and control strategy use from a quantitative perspective. This finding is in contrast with the findings from qualitative research indicating different perceptions of memorization between Eastern and Western cultures (Dahlin & Watkins, 2000; Kember, 2000; Sachs & Chan, 2003). A plausible reason might be that qualitative research is able to discern subtle differences in perceptions of memorization across cultures. For example, Berger and Karabenick (2016) conducted a cognitive interview to understand whether or not students have similar interpretations of self-report items for monitoring, regulating, and planning strategies. They found that students had different concepts of planning strategies. Given that qualitative research allows researchers to validate constructs examined in quantitative methods, additional qualitative studies are needed to supplement the psychometric validity of the learning strategy use survey in cross-cultural research.

Use of Learning Strategies

As expected, Taiwanese students were less likely to report memorization than American students, and most Taiwanese students reported elaboration. When comparing the latent prevalence, a larger proportion of American students reported using the memorization learning strategy compared to Taiwanese students. These findings are consistent with previous PISA research indicating that East Asian students are less likely to report the memorization strategy than Western students (Chiu et al., 2007; Liu, 2009). Similarly, Liu and Wilson (2009) indicated that American students outperformed Hong Kong students on reproduction items in PISA 2003. They argued that American students may use more memorization strategies than East Asian students (Liu & Wilson, 2009). According to the findings in the current study and existing literature, it is evident that American students are more likely to report using memorization to learn mathematics compared to Taiwanese students.

Relations between Students' Self-efficacy and Their Learning Strategy Use

Our results were partially in accord with the SRL theory. As expected, students with higher self-efficacy reported deep-level cognitive or metacognitive strategies in Taiwan and USA, respectively. However, it was unexpected that the results indicated that elaboration was negatively associated with self-efficacy in the USA. In Taiwan, students with high mathematical self-efficacy tended to report the use of elaboration or control strategies, whereas students with low mathematics self-efficacy tended to report the use of memorization strategies. These findings for Taiwanese students are consistent with previous studies, indicating that students with high self-efficacy are likely to use time-consuming, deep-level learning strategies such as elaboration and control strategies (Liem et al., 2008; Zimmerman & Martinez-Pons, 1986). These findings also align with the SRL theory, as students with higher confidence in their abilities are likely to regulate their behavior to achieve their goals, thereby using effective and appropriate learning strategies (Zimmerman, 2001).

Self-efficacy has been shown to be a positive predictor of control strategies in the USA. Similar to their Taiwanese counterparts, when American students were confident in their mathematics abilities, they tended to apply control strategies, but not elaboration strategies. However, it is surprising that American students with low self-efficacy tended to apply elaboration strategies, which was not the case with Taiwanese students who reported low self-efficacy. Further research on learning strategy use for low self-efficacy American students is warranted.

Conclusions, Implications, and Future Research

The findings support self-regulated learning theory and research by examining students' perceptions of learning strategies and the frequency of learning strategy use as well as examining the relationships between learning strategies and self-efficacy in the mathematics domain across cultures. Specifically, this study contributes to research examining learning strategies in East Asian contexts by confronting the typical view of East Asian students as engaging in rote learning and using memorization strategies in mathematics. The findings provide a more nuanced understanding of East Asian student learning strategy use in comparison to their

Western counterparts. Specifically, more American students reported memorization than Taiwanese students, and most Taiwanese students reported elaboration whereas most American students reported control strategies. The findings have theoretical implications for cross-cultural understanding of the self-regulation learning process, including the extent to which learning beliefs and learning strategies are similar across Eastern and Western cultures. Furthermore, students with high self-efficacy were likely to use elaboration or control strategies in Taiwan and America, respectively. The findings might inform future cross-cultural research investigating the roles of self-efficacy and learning strategies in promoting mathematics performance.

Results have important practical implications regarding students' mathematical self-efficacy and learning strategy use in Eastern and Western countries. In past decades, educational researchers have believed that East Asian students may rely on memorization strategies extensively; however, the current study provides a different picture. The findings demonstrated that American students reported memorization strategies more than Taiwanese students; this may have implications for classroom instruction. From a Western perspective, classrooms are often teacher-centered and examination-focused in Taiwan (Hung, 2014), which may encourage students to use memorization frequently. However, Biggs (1998) argued that Taiwanese teachers often ask students higher-level questions rather than lower-level questions even though the classroom environment remains teacher-centered. Higher-level questions often involve substantial cognitive and psychological investment as these questions cannot be solved immediately or solved with an alternative, expedited procedure (Baumert et al., 2010; Paris & Paris, 2001). Consequently, such questions encourage students to think more deeply to search for an answer and find a potential method that helps them to reach answers, which simulates students' higher-order cognition and motivation. In order to understand how teaching practices can foster students' self-regulated learning behavior and to shed light on SRL theory, future research should consider the quality of questions in teaching practices.

Additionally, the findings have implications for better understanding students' mathematical self-efficacy and learning strategy use. Specifically, self-efficacy had a negative relationship with memorization among Taiwanese students, whereas self-efficacy had a negative relationship with elaboration among American students. These findings indicate there may be meaningful learning and instruction differences among Taiwanese and American classrooms that warrant additional investigation. For example, future research is needed to investigate possible reasons why American students with low self-efficacy use elaboration strategies, and why this was not the case with Taiwanese students. This may have important implications in terms of how teachers can provide explicit and tailored instruction to help students effectively use deep-level cognitive learning strategies.

The findings should be understood within the context of limitations and future directions. First, the current study did not take instructional characteristics into account. Variations of the classroom environment and teaching styles could potentially influence students' self-regulated learning. For example, supportive and caring learning environments may improve students' self-efficacy and encourage students to use deep-level cognitive learning strategies (Fredricks, Blumenfeld, Friedel, & Paris, 2005; Young, 2005). Cognitive engagement is also important for students' learning. Hattie (2009) suggested that teachers using cognitive strategies, summarizing, questioning, and clarifying can foster students' cognitive activities. Furthermore, teachers providing challenging and deep problems may help students to make connections between mathematical facts, procedures, and ideas (Hiebert & Grouws, 2007).

The second limitation is that we investigated the influence of students' mathematical self-efficacy on their learning strategy use. However, how students use learning strategies may affect their self-efficacy, that is, successful use of learning strategies could increase students' confidence. Considering another directional relationship by examining learning strategies to predict self-efficacy may provide a clearer picture of the negative relationship between self-efficacy and elaboration – whether the successful use of elaboration could decrease students' self-efficacy – in an American context.

Lastly, although we found the measurement invariance of learning strategy use across Taiwanese and American students based on their perceptions, researchers might cast doubt on whether or not the items in PISA 2012 measure students' true learning strategies. Given that some cross-cultural qualitative studies question the meanings of memorization in East Asian contexts, future research can investigate the items of learning strategies from PISA. For instance, future research may include conducting cognitive interviews to understand whether students from East Asian and Western cultures translate the items of learning strategies consistently, and whether their response choices are in agreement with their interpretations. This approach could provide PISA with the data necessary to modify learning strategy items and the guidance for PISA in further operationalizing the construct of learning strategies. Additionally, self-reported learning strategies are often questioned as items may be perceived as subjective and limited to a few types of learning strategies (Winne, Jamieson-Noel, & Muis, 2002). Considering that learning is a dynamic process, the items of learning strategies in PISA may only roughly reflect students' learning behavior, as students often use a diverse range of strategies during learning. Future research could consider using observational approaches that allow researchers to identify a more detailed and dynamic learning strategy use.

Despite the limitations, this study contributes to self-regulated learning theory and research by documenting the measurement invariance of learning strategies on PISA 2012 in Taiwan and the USA, as well as examining the relationships between learning strategies and self-efficacy in the mathematics domain. The findings call attention to learning strategies as being measurement-invariant between Taiwan and USA and indicate the need for further consideration of cross-cultural comparisons of the associations among self-efficacy and learning strategies in order to better understand mathematics performance in East Asian and Western cultures.

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Table 1

Three Strategy Use Statements of Learning Strategy Use Survey

Strategy	Statement
	Item 1
Control	When I study for a mathematics test, I try to figure out what are the most important parts to learn.
Elaboration	When I study for a mathematics test, I try to understand new concepts by relating them to things I already know.
Memorization	When I study for a mathematics test, I learn as much as I can by heart.
	Item 2
Control	When I study mathematics, I try to figure out which concepts I still do not understand completely.
Elaboration	When I study mathematics, I think of new ways to get the answer.
Memorization	When I study mathematics, I make myself check to see if I remember the work I have already done.
	Item 3
Control	When I study mathematics, I start by working out exactly what I need to learn.
Elaboration	When I study mathematics, I try to relate the work to things I have learned in other subjects.
Memorization	When I study mathematics, I go over some problems so often that I feel as if I could solve them in my sleep.
	Item 4
Control	When I cannot understand something in mathematics, I always search for more information to clarify the problem.
Elaboration	I think about how the mathematics I have learned can be used in everyday life.
Memorization	In order to remember the method for solving a mathematics problem, I go through examples again and again.

Table 2

Stem and Mathematics Tasks of the Self-Efficacy Survey with a 4-point Likert Scale

Stem	How confident do you feel about having to do the following mathematics tasks?
	Mathematics Tasks
(a)	Using a train schedule to figure out how long it would take to get from one place to another.
(b)	Calculating how much cheaper a TV would be after a 30% discount.
(c)	Calculating how many square feet of tile you need to cover a floor.
(d)	Understanding graphs presented in newspapers.
(e)	Solving an equation like 3x+5= 17.
(f)	Finding the actual distance between two places on a map with a 1:10,000 scale.
(g)	Solving an equation like 2(x+3) = (x + 3) (x - 3).
(h)	Calculating the gas mileage of a car.

Note. Four-point Likert scale for each task: Very confident (1 point), Confident (2 points), Not very confident (3 points), Not at all confident (4 points). All items were reverse recoded in the 2012 PISA (OECD, 2014a).

Table 3

Fit Indices for the LCA and MGLCA Analyses with the 1 to 4 Solutions

Model	AIC	BIC	A_BIC
Combined Sample			
1-class	28896.0	28945.6	28920.2
2-class	28602.7	28708.0	28654.0
3-class	28450.7	**28611.7**	28529.0
4-class	28407.2	28623.9	28512.7
Single Group: Taiwan			
1-class	16470.2	16515.0	16489.6
2-class	16280.0	16375.2	16321.2
3-class	16199.8	**16345.4**	16262.8
4-class	16157.5	16353.4	16242.2
Single Group: USA			
1-class	12845.1	12888.2	12862.7
2-class	12720.0	12811.5	12757.5
3-class	12664.4	**12804.5**	12721.9
4-class	12653.3	12841.8	12730.6
MGLCA: Freely-estimated Probability			
1-class	30785.1	30890.3	30836.3
2-class	30496.5	30713.2	30602.0
3-class	30367.0	**30695.1**	30526.7
4-class	30334.3	30773.9	30548.3

Note. The bold represents the lowest BIC. LCA = Latent class analysis; MGLCA = Multiple-group latent class analysis.

Table 4 *Class Sizes and Category-response Probabilities for the Multiple-group Latent Class Analyses across Taiwan and America*

			Item 1			Item 2			Item 3			Item 4		
Class	Country	Size	C	E	M	C	E	M	C	E	M	C	E	M
						Freely-estimated class size and probability model								
1	Taiwan	.10	.17	.23	**.60**	.10	.15	**.76**	.23	.32	**.45**	.19	.19	**.62**
1	USA	.17	.00	.33	**.68**	.37	.13	**.50**	.40	.06	**.54**	.37	.11	**.52**
2	Taiwan	.29	.33	**.61**	.06	**.47**	.36	.16	.36	**.55**	.08	.42	**.44**	.14
2	USA	.27	.33	**.42**	.26	**.44**	.36	.20	.38	**.46**	.16	.26	**.41**	.33
3	Taiwan	.59	**.60**	.28	.12	**.62**	.05	.33	**.62**	.25	.14	.30	.16	**.54**
3	USA	.57	**.61**	.20	.20	**.79**	.05	.16	**.70**	.12	.18	.28	.05	**.67**
						Freely-estimated class size and equally-constrained probability model								
1	Taiwan	.05	.00	.31	**.69**	.36	.16	**.48**	.39	.08	**.53**	.35	.14	**.51**
1	USA	.19	.00	.31	**.69**	.36	.16	**.48**	.39	.08	**.53**	.35	.14	**.51**
2	Taiwan	.63	.36	**.44**	.21	**.46**	.32	.22	.39	**.48**	.13	.28	**.40**	.31
2	USA	.23	.36	**.44**	.21	**.46**	.32	.22	.39	**.48**	.13	.28	**.40**	.31
3	Taiwan	.32	**.61**	.20	.20	**.78**	.05	.17	**.70**	.12	.19	.28	.05	**.67**
3	USA	.57	**.61**	.20	.20	**.78**	.05	.17	**.70**	.12	.19	.28	.05	**.67**

Note. C = Control category; E = Elaboration category; M = Memorization category.

Table 5

Fit Indices for Model Selection of Three MGLCA Models with the 3-class Solution

Model	AIC	BIC	A_BIC
M1: Freely-estimated both class size and probability	**30366.99**	30695.12	30526.72
M2: Freely-estimated class size and equally-constrained probability	30378.50	**30558.04**	**30465.89**
M3: Equally-constrained both class size and probability	30418.41	30585.57	30499.78

Note. The bold represents the lowest BIC across three models.

Table 6

Means and Standard Deviations of Students' Self-Efficacy for Three Latent Classes

	Memorization Mean (SE)	Elaboration Mean (SE)	Control Mean (SE)
Taiwan	-.38 (.12)	.25 (.06)	.20 (.04)
USA	.07 (.07)	-.03 (.07)	.16 (.03)

Note. The value in the parenthesis is standard error.

Table 7

The Unstandardized Coefficients in the Multinomial Logistic Regression

	Memorization vs. Control (Log odds ratio/Odds ratio)	Elaboration vs. Control (Log odds ratio/Odds ratio)
Taiwan		
Intercept	**-2.09 / .12**	**.45 / 1.56**
Male	.28 / 1.32	**.62 / 1.85**
ESCS	-.28 / .76	.05 / 1.05
Self-efficacy	**-.36 / .70**	0/ 1.00
USA		
Intercept	**-1.18 / .31**	**-1.17 / .31**
Male	**.27 / 1.30**	**.65 / .19**
ESCS	**-.20/ .82**	**-.17 / .85**
Self-efficacy	-.06 / .94	**-.19/ .83**

Note 1. The control category is fixed as 0 for model identification.
Note 2. The bold represents significance at .05; ESCS = Economic, social, and cultural status.

8.4. Appendix D: Manuscript 3: Wu, Kiefer, Chen, & Carstensen (2018, revised)

Exploring Learning Strategy Use and Its relationships with Motivation and Mathematics Performance among East Asian Students

Abstract

This study explored latent classes of learning strategy use, the relationships between learning strategy use and motivation as well as moderation effects of learning strategy use on the relations between motivation and mathematics performance among East Asian students in Shanghai, Singapore, Honk Kong, Taiwan, Korea, Macau, and Japan. We applied latent class analysis (LCA), one-way analysis and variance (ANOVA), and a 3-step LCA method on data from the Progamme of International Student Assessment (PISA) 2012. The results showed that students reported using more control strategies and fewer memorization and elaboration strategies. When students used elaboration, control, or a combination of these strategies, intrinsic motivation was positively related to mathematics performance, which means that learning strategy use moderated relations between motivation and mathematics performance. Implications for research on learning strategy use, motivation, and performance are discussed.

Keywords: Learning strategies; Motivation; Mathematics performance; PISA; Latent class analysis

Motivation and learning strategy use are essential components of the self-regulated learning (SRL) process and provide insight into understanding student performance (Pintrich, 1999, 2000; Pintrich & De Groot, 1990; Zimmerman, 2001). SRL describes how students monitor, regulate, and control their motivation and behavior to achieve their goals (Pintrich, 2000; Zimmerman, 2001). Zimmerman (2001) defined self-regulated learning as consisting of three phases: forethought, performance/volition, and self-reflection. Motivation plays an important role in the forethought phase because it influences how much effort students are willing to exert. In the performance phase, students regulate their behavior to focus on their performance by choosing appropriate learning strategies – actions to gain information – to achieve the desired level of performance. In the self-reflection phase, students evaluate their performance. Thus, a high self-regulated learner usually possesses high motivation and a clear goal as well as adopts effective learning strategies to achieve goals.

The present study makes a unique contribution to the field by examining the associations of motivation and learning strategy use with mathematics performance as well as the moderation effects of learning strategy use on the relations between motivation and mathematics performance among East Asian students. Despite a global focus on understanding factors that influence student performance, only a few studies have distinguished between separate types of motivation (i.e., intrinsic and extrinsic) and learning strategy use (i.e., memorization, elaboration, and control), and have examined these factors simultaneously (Artelt, 2005; Walker, Greene, & Mansell, 2006; Yildirim, 2012). Although recent research suggests learning strategies may mediate links between motivation and achievement (Artelt, 2005; Metallidou & Vlachou, 2007; SoriĆ & PalekčiĆ, 2009; Yildirim, 2012), there is much we do not know about how learning strategy use may serve as an underlying mechanism to better understand relations between motivation and mathematics performance. Additionally, understanding the outstanding mathematics performance of East Asian countries in the Progamme of International Student Assessment (PISA) study has attracted Western and Eastern researchers' attention. There may be cultural differences in students' learning strategy use and motivation, and additional research is needed to understand the self-regulated learning processes of East Asian students.

The current study had two main aims: (a) to explore students' learning strategy use (i.e., memorization, elaboration, and control) and its relationships with motivation (i.e., intrinsic and extrinsic), and (b) to explore learning strategies as moderating associations of motivation and mathematics performance among East Asian students in Shanghai, Singapore, Honk Kong, Taiwan, Korea, Macau, and Japan. Data in this study were from PISA 2012, which provided several advantages over other existing data such as Trends in International Mathematics and Science Study (TIMSS) and previous PISA data. Latent class analysis (LCA) and a 3-step LCA were used to detect qualitatively different types of learning strategies and to examine moderating effects of learning strategy use within each East Asian education system.

Learning Strategy Use

Prior research indicates that learning strategy use plays an important role in students' performance and is a key component of the SRL process (Greene, Miller, Crowson, Duke & Akey, 2004; Metallidou & Vlachou, 2007; Pintrich, 1999; Wolters & Pintrich, 1998; Zimmerman & Pons, 1986). For instance, students with high achievement are more likely to report deep learning strategies or a combination of various learning strategies. Many researchers have attempted to classify students' learning behaviors into different categories and label them as specific learning strategies (Pintrich, Smith, García & McKeachie, 1993; Weinstein & Mayer, 1986; Zimmerman & Martinez-Pons, 1986). For instance, PISA 2012 includes three types of learning strategies, including memorization, elaboration, and control strategies (OECD, 2013).

PISA adopted Weinstein and Mayer's taxonomy (1986) to have two categories: cognitive and metacognitive strategies. Memorization and elaboration strategies belong to the cognitive category and control strategies belong to the metacognition category. Memorization has been criticized as a surface-level learning strategy because students use rote or rehearsal learning to reproduce information. Elaboration, on the other hand, is a deep-level learning strategy as students connect prior and new knowledge to deepen their knowledge in the long term. Control is also a deep-learning metacognitive strategy that allows students to plan, set, and monitor their learning. Studies have examined how the type of learning strategies is related to motivation and found students may apply multiple learning strategies in a specific context. For instance, East Asian students believe memorization can boost understanding (Kember & Gow, 1990; Marton, Dall'Alba, & Tse, 1996; Watkins & Biggs, 1996). From this view, memorization could be accompanied by other learning strategies, and adopting multiple strategies might reflect the students' true learning behavior.

Motivation

Motivation refers to students' willingness to do tasks intrinsically or extrinsically (Ryan & Deci, 2000) and has a significant influence on learning strategy use (Sansone & Thoman, 2005). According to SRL, students need to adopt effective learning strategies and have sufficient motivation to achieve the desired level of performance (Boekaerts, 1999; Pintrich & De Groot, 1990). Having effective learning strategies is not enough; students also need motivation to trigger them to adopt learning strategies to achieve their level of performance. Given that using deep-level learning strategies take considerable time and effort, students are more likely to adopt elaboration and control strategies when they have strong interests in a subject or perceive it as beneficial. In contrast, when students are less interested in a subject or perceive little benefit, they are more likely to select surface-level learning strategies such as memorization strategies as they take less time and effort. Research indicates that motivation is highly related to learning strategy use (Lau & Chan, 2003; Lau & Ho, 2016; Law, 2009; Schiefele, Schaffner, Möller, & Wigfield, 2012; SoriĆ & PalekčiĆ, 2009; Wolters & Pintrich, 1998; Yildirim, 2012). Metallidou and Vlachou (2007) found that students who reported high motivation intended to use elaboration and control strategies in mathematics. Similarly, the findings from Berger and Karabenick's (2011) longitudinal study revealed that motivation was positively related to learning strategies in students' mathematics performance.

Motivation can be viewed as a continuum, including intrinsic and extrinsic motivation (Ryan & Deci, 2000). Intrinsic motivation refers to students enjoying doing an activity for its own sake, without any rewards or constraints, whereas extrinsic motivation refers to students doing an activity for instrumental or other reasons, such as the importance of a goal, rewards, or avoidance of punishment (Pintrich & Schunk, 2002; Wigfield, Fredricks, Simpkins, Roeser, & Schiefele, 2015). Motivational research indicates that intrinsic motivation results in high-quality learning and is an enabler for academic success, whereas some types of extrinsic motivation have detrimental effects on learning and performance (Linnenbrink & Pintrich, 2002; Pintrich & Schunk, 2002; Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2006). In the PISA 2012 study, intrinsic motivation indicated is operationalized as students' interests (e.g., 'I enjoy doing') and extrinsic motivation indicated utility (e.g., 'having a good job in the future').

Most studies have either investigated the relationship between intrinsic motivation and learning strategies (SoriĆ & PalekčiĆ, 2009), or examined intrinsic motivation and extrinsic motivation as one construct (Berger & Karabenick, 2011; Metallidou & Vlachou, 2007;

Schiefele et al., 2012; SoriĆ & PalekčiĆ, 2009; Wolters & Pintrich, 1998). It is difficult to understand the relative effects between intrinsic motivation, extrinsic motivation, and learning strategy use when only using intrinsic motivation or a combination of intrinsic and extrinsic motivation (Schiefele et al., 2012). Motivation is multifaceted; intrinsic and extrinsic motivation should be examined separately rather than as one combined construct (Pintrich & Schunk, 2002; Wigfield et al., 2006; Wigfield et al., 2015). Students can be motivated both intrinsically and extrinsically; the effect of motivation on the use of learning strategies may be underestimated when only one type of motivation is included. Moreover, intrinsic and extrinsic motivation play important roles in selecting learning strategies (Artlet, Baumert, Julius-McElvany, & Peschar, 2003), especially for East Asian students. There are several studies (d'Ailly, 2003; Moneta & Siu, 2002; Zhu & Frederick, 2010) that find extrinsic motivation has a significant positive effect in East Asian educational systems, suggesting intrinsic and extrinsic motivation are essential in East Asian students' learning behavior. It seems that East Asian students' learning behavior is unlike Western students who are initiated to learn because of enjoyment and interest. Taken together, it is necessary to take extrinsic motivation into account to have a deep understanding SRL in East Asian educational systems.

Learning Strategy Use and Motivation among East Asian Students

There is a need to further explore learning strategy use and motivation as factors that influence East Asian students' mathematics performance. The outstanding performance of East Asian countries in the PISA study has attracted the attention of Western and Eastern researchers. According to the PISA 2012 report (OECD, 2014), Shanghai, Singapore, Hong Kong, Taiwan, Korea, Macau, and Japan were ranked in the top 10. These high-performing East Asian education systems have a similar Confucian culture, and their educational systems share similar characteristics. The most visible characteristic is an examination system that has substantial impact on teacher instruction and student learning behavior. This examination system plays a vital role in East Asian countries, especially those with a strong Confucian cultural heritage such as Japan, Korea, Taiwan, Hong Kong, and Singapore (Watkins & Biggs, 1996). Students invest a lot of time and effort, and experience high levels of stress, preparing for an examination. The importance of examination encourages a teacher-centered instruction and the promotion of rote learning (Birenbaum, Tatsuoka, & Xin, 2005; Ramakrishnan, 2000; Shen, 2005). Therefore, there may be cultural differences in students' learning strategy use, as teachers encourage rote learning and memorization and researchers claim its effectiveness in East Asian cultures (Chiu, Chow, & Mcbride-Chang, 2007; Gow, Balla, & Hau, 1996).

In addition, learning is pragmatic-oriented in Confucian culture (Tweed & Lehman, 2002), because East Asian students tend to be motivated by family expectation and potential benefits for a group (Markus & Kitayama, 1991; Walker & Debus, 2002). Consequently, East Asian students are likely extrinsically motivated due to meeting others' needs. However, this is contradicted by the expectancy-value theory (Wigfield & Eccles, 2000), which states that students who have a greater value tend to exert more effort and perceive the likelihood of success (Pintrich & Schunk, 2002). Research conducted in Western countries indicates that students with higher intrinsic motivation are likely to exert greater effort and time to learn, resulting in higher performance. Yet, in Confucian culture (especially in the Chinese context), intrinsic and extrinsic motivation occur simultaneously, as external goals are positively related to mastery goals (Salili, Chiu & Lai, 2001; Tweed & Lehman, 2002; Volet, Renshaw & Tietzel, 1994). In other words, when students have high intrinsic motivation, they tend to have high extrinsic motivation. Students with greater extrinsic motivation have lower achievement in the U.S.A. (Ryan & Deci, 2000), yet in other cultures such as Taiwan and Hong Kong, students with greater extrinsic motivation tend to perform well (d'Ailly, 2003; Moneta & Siu, 2002). Given the different patterns of East Asian students' learning behavior and motivation from Western students, this study explored relations of learning strategy use and motivation with mathematics performance among Eastern Asian students using data from PISA 2012.

Learning Strategy Use as a Moderator

Few studies have examined associations between intrinsic motivation, extrinsic motivation, and learning strategy use simultaneously (Artelt, 2005; Yildirim, 2012). Artelt (2005) found that extrinsic motivation had a negative effect on performance whereas intrinsic motivation had a positive effect on performance when taking into account learning strategies. In contrast, Yildirim (2012) found that intrinsic and extrinsic motivation had a slight impact on performance when controlling for learning strategies. An additional study found that learning strategies mediated the relations between motivation and achievement, although results were small (Artelt & Schneider, 2015). Due to less study investigating the relationship between intrinsic and extrinsic motivation simultaneously with learning strategy use and the small effect of learning strategies use as a mediator when considering learning strategy as a mediator between motivation and students' performance, the present study explored the relative effect of intrinsic and extrinsic motivation on mathematics performance moderated by learning strategy use.

Conceptualizing learning strategies as moderating the relationship between motivation and performance is consistent with the SRL model (Pintrich, 2000; Zimmerman, 2001). Self-motivation is instrumental in activating the forethought phase by shaping one's self-efficacy, learning goals, and outcome expectations, which in turn shape performance (Zimmerman, 2001). Learning strategies (i.e., memorization, elaboration, and control) have direct associations with performance as they help students monitor and regulate their learning and behavior. Learning strategies may also serve as an underlying mechanism for understanding the links between motivation and performance. For instance, an individual with intrinsic motivation may be more successful in achieving their goals by adopting deep-level learning strategies compared to surface-level learning strategies. This moderating association of learning strategy use may differ based on the type of motivation (i.e., intrinsic, extrinsic, or both) and cultural context (i.e., East Asian countries). Given the lack of existing research that examines intrinsic and extrinsic motivation and multiple learning strategies simultaneously, especially among East Asian students, no specific hypotheses were made in the current study. Thus, relations among learning strategies use, motivation, and mathematics performance, as well as learning strategy use as a moderator, were examined on an exploratory basis.

The Present Study

In the current study, we applied the LCA to investigate latent classes of students' regarding learning strategy use within each educational system in East Asia. After obtaining the latent classes, we investigated the relationships between motivation and learning strategy use. Finally, by applying a 3-step approach for LCA with covariates, the moderation effects of learning strategy use on the relations between students' motivation and mathematics performance were explored. The research questions are specified in detail as follows. First, do we obtain latent classes for learning strategy use with the same interpretations among educational systems in the East Asia? Second, to what extent are intrinsic and extrinsic motivation related to learning strategy use? Finally, to what extent are the moderation effects of learning strategy use on the relations between motivation and mathematics performance?

More specifically, this study has the following strengths. First, it provides a deeper examination of East Asian students' self-regulated learning and may provide insight into the outstanding mathematics performance of East Asian students. Second, this study utilizes several methodological advantages in the PISA 2012 report (OECE, 2013). The PISA 2012 includes the use of a forced-choice format for learning strategy items, which allowed students to choose one option in a block. The advantage of the forced-choice format is that it avoids response distortions such as extreme responses or acquaintance responses in Likert-scale (Brown & Maydeu-Olivares, 2013). A second advantage of the PISA 2012 is the inclusion of several East Asian educational systems which allows for the exploration of convergent and divergent student learning behavior in the East Asian countries. Prior research has mainly focused on investigating one educational system such as Hong Kong (Lau & Chan, 2003; Law, 2009), but less is known about other East Asian educational systems. A more comprehensive understanding of self-regulated learning within and across multiple East Asian educational systems is needed. A third advantage is that the PISA 2012 combines various motivational and self-regulated theories (Boekaert, 1995; Pintrich, 2000; Zimmerman & Schunk, 2001) to design the self-regulation framework. Thus, PISA provides comprehensive self-regulated learning and motivational data and allows researchers to investigate mechanisms of self-regulation as well as the influence of intrinsic and extrinsic motivation simultaneously, in each educational system.

Lastly, this study utilizes latent class analysis (LCA) and a 3-step approach for LCA with covariates (Asparouhov & Muthén, 2014; Vermunt, 2010). Researchers using international large-scale assessments often consider the populations of interest as homogenous and seldom explore if subpopulations exist (Oliver, Ercikan, Zumbo, & Lawless, 2014). Under the assumption of population homogeneity, conventional models such as hierarchical linear modeling (HLM) and structural equation modeling (SEM) are applied in many studies but may yield biased estimates if subpopulations exist. Population heterogeneity may exist due to several reasons, such as different curriculum or different types of learning strategies. Therefore, in this study, we advocate LCA and a 3-step approach LCA. Note the details of LCA and a 3-step approach of LCA are illustrated in the method section.

Method

Participants

Participants in this study were 15-year-old students from PISA 2012. The sampling design in the PISA 2012 was a two-stage stratified sample design (OECD, 2014). In the first stage, schools were systematically sampled based on probabilities proportional to the school size. Once schools were selected, students within the schools were randomly selected. The present study examined seven East Asian education systems, namely Shanghai (N = 1,713), Singapore (N = 1,861), Taiwan (N = 2,013), Macau (N = 1,784), Hong Kong (N = 1,582), Korea (N = 1,669), and Japan (N = 2,103).

Measures

There were three measures used in this study from the 2012 PISA: motivation, learning strategy use, and mathematics performance. Only form A of students' questionnaire for learning strategy use and motivation was used in this study[3].

Learning Strategy Use. In PISA, an instrument that measured three learning strategies (i.e., memorization, elaboration, and control) was used to indicate students' learning behavior. The 2012 PISA adopted a forced-choice format for learning strategy items (OECD, 2013), which allowed each student to choose only one strategy to best describe their learning behavior. There

[3] PISA2012 adopted a rotated-design in a student questionnaire. Only form A has motivation and learning strategy use items.

were four blocks in the questionnaire, and each block included three mutually exclusive items (see Table 1).To interpret the reliability of the forced-choice format is not recommended, due to a violation of a basic assumption of independent errors between items (Brown & Maydeu-Olivares, 2013; Cornwell & Dunlap, 1994). Thus, we do not provide reliability estimates for the learning strategy items.

Motivation. PISA measured intrinsic motivation and extrinsic motivation using a 4-point Likert scale (see Table 1). Intrinsic motivation was measured by four items, as was extrinsic motivation. The average reliability of intrinsic motivation among educational systems is .90(Max = .91 and Min = .86); the average of reliability of extrinsic motivation among educational systems is .89 (Max = .92 and Min = .84). These items were reverse scored (i.e., higher scores indicated higher motivation). The sum scores for intrinsic and extrinsic motivation were obtained for each student as continuous variables.

[Insert Table 1]

Mathematics Performance. In PISA, each student was randomly assigned to one of thirteen booklets containing the partial items in the item bank due to limited time. Thus, there are missing data in item responses. To solve this problem, PISA used the multiple imputation approach to estimate each student's mathematics proficiency thereby generating five plausible values for each student (OECD, 2013). According to recommendations (von Davier, Gozalez, & Mislevly, 2009), we used the five plausible mathematics values simultaneously in this study to obtain unbiased estimates of students' mathematics performance.

Statistical Analyses

LCA can detect heterogeneity of a sample and split a sample into two or more subgroups where subgroups' memberships are obtained by analyzing the response patterns. In other words, population heterogeneity is explained by underlying subgroups called latent classes. Individuals with similar response patterns have a high probability to be classified into the same latent class. The top part of Figure 1 represents the LCA model. I_1 to I_4 refer to four items, and the relationships between items are explained by c, latent classes.

There are three steps in the 3-step approach for LCA with covariates. Firstly, the LCA is conducted without any covariates, that is, the items of learning strategies are fitted in to LCA without including intrinsic motivation, extrinsic motivation, and mathematics performance. Secondly, the most likely class memberships are obtained and the uncertainty rate of classification is calculated. In other words, the proportions of the class membership within each latent class are fixed, so that the proportions of the class membership within each latent class remain the same as in the first step, when we include intrinsic motivation, extrinsic motivation, and mathematics performance in the final step. Finally, a linear regression with latent classes is estimated using the most likely class memberships and the uncertainty rate of classification fixed in the second step (Asparouhov & Muthén, 2014). In other words, intrinsic motivation, extrinsic motivation, and mathematics performance are included as a linear regression part, and the relationships are varied across latent classes. The bottom part of Figure 1 presents this linear regression model. The effects from the predictors X_1 (i.e., intrinsic motivation) and X_2 (i.e., extrinsic motivation) on the outcome variable Y (i.e., mathematics performance) are different across latent class c (i.e., type of learning strategy use). The linear regression model can be expressed mathematically as follows:

$$Y = \beta_{0c} + \beta_{1c}X_1 + \beta_{2c}X_2 + \epsilon$$

where β_{0c} represents the intercept for class c; β_{1c} and β_{2c} represent the class-specific slopes; X_1

and X_2 refer to two predictors; c refers to latent class; Y is the outcome variable.

The following analyses were conducted in this study. First, to explore latent classes in each educational system, LCA models with one, two, three and four classes were fitted to each data of the seven education systems separately. LCA models with different numbers of classes on the items of learning strategies were not nested within each other so that we used information criteria, AIC (Akaike, 1987), BIC (Schwarz, 1978), and adjusted BIC (a_BIC) (Sclove, 1987), to select the optimal number of latent classes. The solution with the lowest BIC was considered the best-fitting model because the BIC performed best, compared to AIC and a_BIC (Nylund, Asparouhov, & Muthén, 2007).Once the number of latent classes was obtained, the characteristics of each class would be based on the conditional probabilities of four individual items that measure learning strategy use. The interpretations of latent classes were based on the maximal number of the highest conditional probabilities of the respective type of learning strategies. For example, if three or four out of four items had the highest conditional probabilities on the "Control strategy" option within one class, that class was labeled as the "Control-Use" group with respect to learning strategies. If one latent class had two items with the highest probabilities on two different strategy options, that class was classified as the "Combination-Use" group of the two learning strategies.

Second, to examine the relations of motivation and learning strategy use, a one-way ANOVA was conducted within each education system with intrinsic or extrinsic motivation as a dependent variable and latent classes as independent variables. The Tukey test for unequal sample size as the post hoc analysis was conducted. Third, a newly-proposed three-step LCA approach was applied to explore whether the relations between motivation and mathematics performance were affected by latent class. Using this approach, all five mathematics plausible values as students' performance were dependent variables; intrinsic and extrinsic motivation were two predictors; latent class of learning strategy use was a moderator. All analyses were conducted with Mplus 7.4 (Muthén & Muthén, 2015).

Results

Latent Classes of Learning Strategy Use

Table 2 shows three information indices for one-, two-, three-, and four-class solutions for each educational system. As seen in Table 2, Shanghai, Singapore, Taiwan, and Macau showed the lowest BIC values with the three-class solution whereas Hong Kong, Korea, and Japan showed the best-fitting solution for two- class solution. The characteristics of the latent classes of learning strategies were defined based on the number of highest endorsement probabilities of the three types of item options (i.e., control, elaboration, and memorization) for four items. Tables 3 and 4 present endorsement probabilities of options for educational systems with three and two class-solutions, respectively. Figure 2 presents class sizes for latent classes in each educational system.

As seen in Table 3, three educational systems (i.e., Shanghai, Singapore, and Taiwan) had the same characteristics for three latent classes, namely memorization, elaboration, and control classes. In these educational systems, students in the control class, for instance, had three out of four control options with the highest endorsing probabilities whereas those in the memorization class had three or four highest probabilities endorsing on the memorization options (see Table 3). Although Macau also had three latent classes, it showed the same control and memorization classes as well as the combination class of control and elaboration. As seen in Table 3, students from Macau in the combination class had two highest probabilities with the control options and two with the elaboration options. As shown at the bottom of Table 3, in these four educational systems, more students (45% - 78%) were classified into the control class and fewer students (10% - 15%) were in the memorization class except for students from Shanghai (30%). Few students from Singapore (12%) reported to use elaboration, but more students from Taiwan and Shanghai (30% and 25%, respectively) reported to use it. Approximately 20% of students in Macau reported the combination use of control and elaboration strategies.

[Insert Table 2 and Table 3]

Hong Kong, Korea, and Japan had only two classes: a control class and a combination class of various strategies as shown in Table 4. Among these education systems, students in the control class had three out of four highest probabilities on the control options. The combination classes for Hong Kong and Korea included control and elaboration strategies as well as elaboration and memorization strategies, respectively. In Japan, students in the combination class had two highest probabilities with memorization, one with elaboration, and one with control. As shown in the last row of Table 4, in these educational systems, most students were classified in the control class (77% - 86%) and fewer students reported to use the combination of strategies (23% - 14%).

[Insert Table 4]

The Relationship between Learning Strategy Use and Motivation

The relationships between learning strategy use and motivation were examined in each educational system. Table 5 presents results of ANOVA analyses for intrinsic and extrinsic motivation comparisons across latent classes of learning strategy use in each educational system. All educational systems showed statistically significant differences of intrinsic and extrinsic motivation across latent classes of learning strategy use except for Japan. Table 6 presents the means of intrinsic and extrinsic motivation for each class in each educational system. The results of Tukey's post hoc tests indicated that students in the memorization class had significantly lower intrinsic and extrinsic motivation than students in another two classes in Shanghai, Singapore, Taiwan, and Macau.

[Insert Table 5]

Table 6 shows mean levels of intrinsic and extrinsic motivation for each type of learning strategy in each educational system. In Shanghai, students in the elaboration class had significantly higher intrinsic and extrinsic motivation than students in the control class. Students from Singapore and Taiwan in the elaboration class had significantly higher intrinsic motivation than those in the control class, but there was no significantly difference for students who were extrinsically motivated in the elaboration and control classes. In Macau, students in the combination class of elaboration and control had significantly higher intrinsic and extrinsic motivation than those in the control class.

In the educational systems where we found two latent classes, Korean students in the control class reported significantly higher intrinsic and extrinsic motivation than those in the combination class of elaboration and memorization. However, Hong Kong students in the control class reported higher intrinsic but lower extrinsic motivation than those in the combination class of elaboration and memorization. Japan students in the control and combination classes had relatively equivalent levels of intrinsic and extrinsic motivation.

[Insert Table 6]

The Relationships between Motivation and Mathematics Performance Moderated by Latent Class of Learning Strategy Use

The LCA 3-step approach was used to explore the relationships between motivation and mathematics performance moderated by latent classes of learning strategy use. Table 7 presents the estimated coefficients of predictors after controlling for the other predictors, intrinsic or extrinsic motivation. Intrinsic and extrinsic motivation did not have a significant impact on mathematics performance for these educational systems, with the exception of Singapore. The findings indicate that for students from Singapore, intrinsic motivation had a positive impact whereas extrinsic motivation had a negative impact on mathematics performance.

Shanghai, Singapore, and Taiwan possessed the latent class of elaboration. All three educational systems showed that intrinsic motivation had a significantly positive impact on mathematics performance. However, only Taiwanese students showed a significantly positive impact of extrinsic motivation on mathematics performance. In all educational systems, we found the latent class of control. All except for Shanghai and Singapore had a significantly positive impact of intrinsic motivation on mathematics performance. Students from Taiwan, Korea, and Japan also showed a positive impact of extrinsic motivation. Extrinsic motivation of Singaporean students had a negative impact on mathematics performance.

Macau, Hong Kong, Korea, and Japan showed a combination class of various learning strategies. As shown in Table 7, intrinsic motivation had a significantly positive impact on mathematics performance in these educational systems except for Korea. Even though intrinsic motivation had a non-significant impact on mathematics performance, Korea was the only educational system showing a positive impact of extrinsic motivation on mathematics performance.

Discussion

The present study aligns with and extends prior research examining associations of learning strategy use and motivation with mathematics performance. Specifically, this study extended the literature by exploring the latent classes of learning strategy uses (i.e., memorization, elaboration, control, and combination), examining whether students with different learning strategies uses display different mean levels of intrinsic and extrinsic motivation, and how learning strategy use moderates the relationship of motivation with mathematics performance among East Asian students. The results indicated that students reported using more control strategies and less memorization and elaboration strategies. Students reporting elaboration strategy use had the highest levels of intrinsic and extrinsic motivation whereas students in the memorization class had the lowest levels. For students who reported using elaboration, control, or a combination of these strategies, intrinsic motivation was positively related to mathematics performance. In other words, learning strategy use moderated the relations between motivation and mathematics performance, but associations differed by East Asian educational systems. Implications for research on learning strategy use, motivation, and performance are discussed.

Associations of Learning Strategy Use and Motivation with Mathematics Performance

Four educational systems (i.e., Shanghai, Singapore, Taiwan, and Macau) had a memorization class, and approximately 10% of students in these educational systems except for Shanghai (30%) were classified in this class. It is surprising that students from East Asian educational systems reported less use of memorization, as this is in contrast with the stereotype of East Asian learners (Leung, 2006; McInerney, 2011; Purdie & Hattie, 1996; Watkins & Biggs, 1996). However, this finding was consistent with studies indicating that East Asian students were less likely to report memorization use in PISA data (Areepattamannil & Caleon, 2013; Chiu et al, 2007).When students reported the use of memorization in these four educational systems, they had the lowest levels of intrinsic and extrinsic motivation, compared to students reporting the use of other learning strategies. In addition, the findings showed that for students in the memorization class, intrinsic and extrinsic motivation had a non-significant impact on mathematics performance in Shanghai, Taiwan, and Macau, but not in Singapore. The findings suggest that the self-regulated learning behavior for Singaporean students is inconsistent with theory, as intrinsic motivation had a significant impact on mathematics performance when students reported memorization use. The current study may provide an important implication for teaching and learning in Singapore, in that students who are intrinsically motivated may not choose the most appropriate learning strategies to perform at their best. Therefore, the findings suggest Singaporean teachers may consider providing students with explicit instruction and support in understanding when, why, and how to use learning strategies to help facilitate more effective learning strategy selection and implementation (Carr, Alexander, & Folds-Bennett, 1999; Carr, Taasoobshirazi, Stround & Royer, 2011; Kuhn, Garcia-Mila, Zohar, & Anderson, 1995).

Among East Asian educational systems, few students reported the use of elaboration. Elaboration strategies were only found in Shanghai, Singapore, and Taiwan (12% - 30%). Elaboration strategies may be used less frequently as connecting and transferring information between prior and new knowledge requires a lot of effort and time (Chiu et al, 2007; Garner, 1990; Murayama, Pekurn, Lichtenfeld, & vom Hofe, 2013). The findings indicated that students in Shanghai, Singapore, and Taiwan who reported elaboration use had the highest intrinsic and extrinsic motivation. Furthermore, intrinsic motivation of all students in the elaboration class had a statistically significant, positive impact on mathematics performance. Only Taiwanese students had a positive impact of extrinsic motivation on mathematics performance, but the impact of extrinsic motivation was relatively smaller than that of intrinsic motivation.

Control strategies were among the most frequent strategies used among East Asian students in all seven educational systems. Intrinsic and extrinsic motivation of students in the control class were higher than those of students in the memorization class, but lower than those of students in the elaboration class in Shanghai, Singapore, and Taiwan. Regarding the moderation effect of learning strategy use, students in the control class displayed a statistically significant, positive impact of intrinsic motivation on mathematics performance in all educational systems except for Shanghai and Singapore. Extrinsic motivation had a statistically significant, positive impact only among students in Taiwan, Korea, and Japan, whereas Singaporean students displayed a negative impact of extrinsic motivation. Thus, findings from the present study reinforce the idea that intrinsic motivation plays an important role in the control class as they are deep-level learning strategies that involve substantial time and effort to effectively implement.

Combination strategies were found in Macau (elaboration and control), Hong Kong (elaboration and control), Korea (elaboration and memorization), and Japan (memorization, elaboration/memorization, and control). Regarding the moderation effect of combination strategy use, the findings differed by educational system as to whether intrinsic and extrinsic motivation for students in the combination class were higher or lower than those of students in the control class. Students in Macau with multiple learning strategies had higher intrinsic motivation than those in the control class, whereas students in Hong Kong and Korea had lower intrinsic motivation. As for extrinsic motivation, students in Macau and Hong Kong with multiple strategy use had higher extrinsic motivation than those with the control use, but Korean students had significantly lower extrinsic motivation. As for Japanese students, there were no significant differences regarding intrinsic and extrinsic motivation between the control and combination classes. Among the four educational systems where students reported multiple strategy use, intrinsic motivation had a positive impact on mathematics performance for students in Macau, Hong Kong, and Japan. In contrast, extrinsic motivation had a positive influence on mathematics performance only for Korean students. Given the exploratory nature of the current study and the differing patterns of findings, further investigation is needed to replicate the moderating effect of multiple strategy use, especially among East Asian educational systems. The findings align with previous research that suggests it is not clear whether multiple learning strategies are more effective than the single strategy use (de Boer, Donker-Bergstra, & Konstons, 2012; Dignath & Büttner, 2008; Haller, Child, & Walberg, 1998).

In conclusion, the current study demonstrates that intrinsic motivation has a substantial influence in SRL for East Asian students, suggesting intrinsic motivation might be universal irrespective of culture. In contrast, extrinsic motivation is rather important in SRL for some East Asian educational systems, including Taiwan and Korea. The findings indicate that extrinsic motivation plays an important role for Taiwanese and Korean students, when Taiwanese students reported elaboration and control strategies and Korean students reported control and combination strategies. These findings are in line with Zhu and Frederick (2010) and d'Ally (2003). Zhu and Frederick (2010) found that extrinsic motivation displays an additive pattern in Taiwan and Korea by using the 2003 Trends in International Mathematics and Science (TIMSS). In addition, d'Ally (2003) noted that extrinsic motivation has a substantial positive effect for Taiwanese students. These findings may suggest that Taiwanese and Korean educators should be aware of whether extrinsic motivation is an essential component in learning, and which types of extrinsic motivation are beneficial to students' learning (Ryan & Deci, 2000). Thus, the findings from the current study may provide Taiwanese and Korean educators a better understanding of how to design motivationally supportive learning environments.

Implications, Limitations, and Future Directions

The findings support and advance research examining associations of motivation and learning strategy use with mathematics performance. Specifically, this study examined intrinsic and extrinsic motivation simultaneously in order to demonstrate their relative effects on learning strategy use and mathematics performance. This study contributes to our understanding of individual differences in learning strategy use and the relationship between learning strategies and motivation in high-performing East Asian educational systems. This study is unique in that it utilized LCA to investigate the heterogeneity of the sample population. The findings indicated that each of the East Asian educational systems have subpopulations classified by the type of learning strategy use. Although there may be different numbers of latent classes and interpretations for each educational system, an alternative explanation is that elaboration and memorization strategies may not be measured similarly among all East Asian educational systems, because only control strategies exist in each East Asian educational system. Further research should conduct a qualitative study to investigate the perception of learning strategies and the possibility of adopting multiple strategies for East Asian students. Integrating quantitative and qualitative studies might help researchers to develop an appropriate learning strategies instrument. Further, the 3-step LCA model used the type of learning strategy use (i.e., latent class) to identity the effects of motivation on mathematics performance in subpopulations. These models have the potential to inspire researchers to assess mechanisms of multiple strategy use in the self-regulation theory and open new possibilities to address sample heterogeneity.

Results help to better understand learning strategy use, motivation, and mathematics performance among high-performing East Asian educational systems and may have implications for supporting mathematics performance at a global level. Prior research indicates that motivation and learning strategies differ by context (Marton et al., 1996; Wigfield et al., 2015). A recent school-based intervention indicates that educators can modify students' motivation, self-regulatory skills, and mathematics achievement (Cleary, Velardi, & Schnaidman, 2017). However, many motivational interventions in science, technology, engineering, and mathematics (STEM) have shown mixed results (Rosenzweig & Wigfield, 2016); future research is needed to examine moderating variables such as learning strategy use as well as consider contextual and cultural variables.

According to our findings, control strategies were the dominant strategies among East Asian students. These results align with prior research indicating deep-level learning strategy use (i.e., elaboration, control, or combination) are linked to higher intrinsic and extrinsic motivation than surface-level strategy use (i.e., memorization; Berger & Karabenick, 2011; SoriĆ, I., & PalekčiĆ, 2009). It is evident that intrinsic motivation had a significant impact on mathematics performance when students reported deep-level learning strategies in most educational systems, whereas extrinsic motivation had less of an impact on mathematics performance. Thus, deep-level learning strategies and intrinsic motivation might provide a plausible explanation of why East Asian students performed well in PISA. However, it is not clear if intrinsic and extrinsic motivation were higher when students used the control strategies or multiple strategies. Therefore, further research should investigate the level of intrinsic and extrinsic motivation when students use only one type of deep-learning strategy or multiple learning strategies.

Nevertheless, despite these contributions, this study has several limitations. First, it is unclear whether self-reported learning strategies reflect students' actual learning behavior. In this study, we used students' responses to infer their actual use of learning strategies. Situated and cultural approaches to studying motivation and learning in context (Artelt, 2005; King &

McInerney, 2015; Nolen, Home, & Ward, 2015; Turner & Nolen, 2015) may avoid a retrospective bias as well as better examine and explain how associations among variables vary across context and population. Collecting data during or immediately following an event through the use of personal digital assistants, videotaping, or interviews may more accurately assess motivation and learning strategies. Second, this cycle of PISA used a forced-choice item instead of a Likert-scale to measure the frequency of learning strategies. Students may have been forced to choose one learning strategy that might not be completely true for them. Third, this study focused on the mathematics domain. Prior research showed that students use different learning strategies across domains (de Boer, et al., 2012; Hopfenbeck, 2009; Wolter & Pintrich, 1998). Thus, the findings from the present study should not be generalized to other domains. Furthermore, although the present study provided information about the relationship of multiple strategy use and motivation (i.e., intrinsic and extrinsic) with mathematics performance, additional research is needed to better understand whether multiple strategies are more effective than a single strategy as well as the relationship between motivation and multiple learning strategies. Lastly, this study was cross-sectional; longitudinal research is needed in order to examine causal relationships between motivation, learning strategy use, and mathematics performance.

Despite its limitations, the current study contributes to understanding of learning strategy use and its relations with motivation and mathematics performance among East Asian students. The findings call attention to learning strategy use as moderating associations among motivation and mathematics performance, and as a potential factor for promoting mathematics achievement. The findings also indicate a need for situated and cultural approaches to understand differing patterns among East Asian educational systems.

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Table 1

Items of Learning Strategy Use and Motivation

Item Content	Type
Learning Strategy Use	
Block 1	
When I study for a mathematics test, I try to figure out what are the most important parts to learn.	Control
When I study for a mathematics test, I try to understand new concepts by relating them to things I already know.	Elaboration
When I study for a mathematics test, I learn as much as I can by heart.	Memorization
Block 2	
When I study mathematics, I try to figure out which concepts I still do not understand completely	Control
When I study mathematics, I think of new ways to get the answer.	Elaboration
When I study mathematics, I make myself check to see if I remember the work I have already done.	Memorization
Block 3	
When I study mathematics, I try to relate the work to things I have learned in other subjects.	Elaboration
When I study mathematics, I start by working out exactly what I need to learn.	Control
When I study mathematics, I go over some problems so often that I feel as if I could solve them in my sleep.	Memorization
Block 4	
In order to remember the method for solving a mathematics problem, I go through examples again and again.	Memorization
I think about how the mathematics I have learned can be used in everyday life.	Elaboration
When I cannot understand something in mathematics, I always search for more information to clarify the problem.	Control
Motivation	
I enjoy reading about mathematics	Intrinsic
I look forward to my mathematics lessons	Intrinsic
I do mathematics because I enjoy it	Intrinsic
I am interested in the things I learn in mathematics	Intrinsic
Making an effort in mathematics is worth it because it will help me in the work that I want to do later on.	Extrinsic
Learning mathematics is worthwhile for me because it will improve my career prospects.	Extrinsic

Mathematics is an important subject for me because I need it for what I want to study later on.	Extrinsic
I will learn many things in mathematics that will help me get a job.	Extrinsic

Table 2

Fit Index for Model Selection in Each Educational System

Educational System	Class	AIC	BIC	a_BIC
Shanghai	1	14184.067	14227.592	14202.177
	2	13861.269	13953.761	13899.754
	3	13792.795	**13934.254**	13851.655
	4	**13772.177**	13962.603	**13851.412**
Singapore	1	13902.53	13946.68	13921.26
	2	13772.6	13866.42	13812.41
	3	13698.6	**13842.1**	**13759.5**
	4	**13697.04**	13890.22	13779.02
Hong Kong	1	11337.65	11380.37	11354.95
	2	11098.13	**11188.91**	**11134.9**
	3	11079.58	11218.41	11135.82
	4	**11072.57**	11259.45	11148.27
Taiwan	1	16436.92	16481.69	16456.28
	2	16246.59	16341.72	16287.71
	3	16166.03	**16311.53**	16228.92
	4	**16123.95**	16319.81	**16208.61**
Korea	1	13286.17	13329.44	13304.03
	2	13169.91	**13261.86**	13207.86
	3	**13132.69**	13273.33	**13190.73**
	4	13133.37	13322.69	13211.5
Macau	1	13052.39	13096.1	13070.69
	2	12823.68	12916.58	12862.57
	3	12760.59	**12902.67**	**12820.07**
	4	**12749.9**	12941.16	12829.97
Japan	1	15232	15277	15251.58
	2	15128.23	**15223.85**	15169.84
	3	15096.4	15242.64	**15160.03**
	4	**15091.33**	15288.19	15177

Note. The value with boldness indicates the lowest value for each fit index.

Table 3

	Class Interpretation											
	Control Class				Elaboration Class			MS Class	Memorization Class			
Items	Shanghai	Singapore	Taiwan	Macau	Shanghai	Singapore	Taiwan	Macau	Shanghai	Singapore	Taiwan	Macau
Block 1												
Control	**.501**	**.559**	**.601**	**.686**	.255	.271	.332	.288	.314	.054	.169	.383
Elaboration	.225	.270	.281	.221	**.684**	**.554**	**.607**	**.703**	.192	.020	.232	.087
Memorization	.275	.171	.119	.092	.061	.175	.061	.010	**.494**	**.927**	**.600**	**.530**
Block 2												
Control	**.868**	**.741**	**.621**	**.788**	.348	**.443**	**.473**	**.502**	.000	.115	.095	.439
Elaboration	.132	.044	.045	.046	**.470**	.358	.363	.416	.002	.161	.148	.089
Memorization	.000	.215	.334	.166	.182	.199	.164	.083	**.998**	**.724**	**.756**	**.472**
Block 3												
Control	**.673**	**.692**	**.617**	**.823**	.310	.361	.363	**.484**	**.597**	.423	.228	**.609**
Elaboration	.183	.147	.244	.119	**.568**	**.498**	**.555**	.413	.115	.099	.323	.048
Memorization	.144	.162	.138	.058	.122	.141	.082	.104	.288	**.477**	**.450**	.344
Block 4												
Control	.355	.29	.302	.386	**.444**	.192	.421	.396	.257	.305	**.444**	.203
Elaboration	.102	.044	.156	.183	.369	**.456**	**.441**	**.441**	.111	.050	.369	.119
Memorization	**.543**	**.665**	**.541**	**.431**	.186	.353	.138	.192	**.632**	**.645**	.186	**.678**

Note 1. MS represents multiple strategies- the combination of elaboration and control- in Macau
Note 2. The bold represents the highest probability on an option in a block
Note 3. The probability is round off to three decimal digits

Table 4

Endorsement Probability for Each Option in the 2-class Solutions

	Class Interpretation					
	Control			Multiple strategies		
Items	Hong Kong	Korea	Japan	Hong Kong	Korea	Japan
Block 1						
Control	**.695**	**.458**	**.679**	.359	.130	.357
Elaboration	.173	.421	.228	**.582**	.408	**.413**
Memorization	.132	.121	.092	.059	**.462**	.231
Block 2						
Control	**.614**	**.512**	**.681**	**.490**	.335	.184
Elaboration	.023	.180	.042	.406	.286	.339
Memorization	.363	.308	.276	.104	**.379**	**.478**
Block 3						
Elaboration	.082	.194	.160	**.490**	**.491**	.301
Control	**.807**	**.647**	**.699**	.372	.381	**.447**
Memorization	.111	.160	.141	.138	.128	.252
Block 4						
Memorization	**.639**	**.612**	**.557**	.292	.189	**.408**
Elaboration	.128	.056	.057	.320	**.581**	.243
Control	.233	.332	.386	**.388**	.230	.350

Note 1. MS represents multiple strategies- the combination of elaboration and control in Hong Kong; the combination of memorization and elaboration in Korea; the combination of memorization, elaboration, and control in Japan.
Note 2. The bold represents the highest probability on an option in a block.
Note 3. The probability is rounded off to three decimal digits.

Table 5

The ANOVA Results for Intrinsic and Extrinsic Motivation Comparisons across Latent Classes in Each Educational Systems

	Intrinsic Motivation		Extrinsic Motivation	
	F-test	Eta-Square	*F*-test	Eta-Square
Shanghai	*F*(2,1694) = 89.44*	0.095	*F*(2,1694)=32.89*	0.037
Singapore	*F*(2,1836) = 7.44*	0.008	*F*(2,1839)=5.57*	0.006
Taiwan	*F*(2,1974) = 26.46*	0.026	*F*(2,1974)=11.22*	0.011
Macau	*F*(2,1726) = 95.50*	0.100	*F*(2,1735)=30.85*	0.034
Hong Kong	*F*(1,1530) = 82.08*	0.051	*F*(1,1534)=39.58*	0.025
Korea	*F*(1,1645) = 74.85*	0.044	*F*(1,1647)=100.04*	0.057
Japan	*F*(1,2030) = 0.26	0.000	*F*(1,2041)=1.65	0.001

Note. * means that the *F*-test is significant at the 0.05 level.

Table 6

Means of Intrinsic and Extrinsic Motivation for Each Class in Each Educational System

	Control	Elaboration	Memorization	Multiple Strategies
Intrinsic				
Shanghai	10.58 (2.88)	11.87 (2.69)	9.49 (2.48)	
Singapore	11.84 (2.70)	12.22 (3.09)	11.18 (2.81)	
Taiwan	9.43 (2.85)	10.07 (3.24)	8.39 (2.67)	
Macau	9.44 (2.74)		8.47 (2.85)	11.46 (2.74)
Hong Kong	11.42 (3.15)			9.76 (2.98)
Korea	8.89 (3.00)			7.08 (2.72)
Japan	8.49 (3.08)			8.58 (3.39)
Extrinsic				
Shanghai	12.03 (2.63)	12.60 (2.43)	11.24 (2.72)	
Singapore	13.10 (2.22)	13.18 (2.49)	12.53 (2.64)	
Taiwan	11.01 (2.76)	11.22 (3.00)	10.16 (2.60)	
Macau	11.00 (2.67)		10.33 (2.87)	12.02 (2.50)
Hong Kong	10.96 (2.80)			12.03 (2.90)
Korea	10.87 (3.16)			8.62 (3.32)
Japan	10.26 (3.25)			10.01 (3.52)

Note 1. Multiple strategies are elaboration and control in Macau and Hong Kong; elaboration and memorization in Korea; memorization with either elaboration or control in Japan.
Note 2. The standard deviation is in the parenthesis.

Table 7

The Coefficients of Two Predictors for Each Class in Each Educational System

	Shanghai	Singapore	Taiwan	Macau	Hong Kong	Korea	Japan
Control Class							
Intrinsic motivation	3.15 (2.07)	-0.07 (1.46)	**4.44** (1.94)	**7.08** (1.87)	**7.62** (1.36)	**7.95** (1.24)	**4.73** (1.09)
Extrinsic motivation	2.089 (2.139)	**-3.51** (1.71)	**9.46** (2.02)	0.82 (2.03)	3.12 (1.60)	**7.58** (1.09)	**5.38** (1.18)
Elaboration Class							
Intrinsic motivation	**6.70** (3.19)	**12.91** (3.91)	**15.91** (2.94)				
Extrinsic motivation	-0.51 (3.28)	2.50 (4.10)	**6.34** (2.84)				
Memorization Class							
Intrinsic motivation	4.718 (2.46)	**18.96** (4.10)	10.86 (7.96)	-0.67 (4.08)			
Extrinsic motivation	2.91 (2.54)	**-15.97** (5.09)	8.44 (8.35)	-3.97 (4.21)			
Combination Class							
Intrinsic motivation				**13.36** (4.13)	**14.63** (2.54)	-1.76 (5.17)	**10.80** (2.94)
Extrinsic motivation				-3.44 (4.68)	-2.79 (2.89)	**10.52** (3.30)	4.357 (3.20)

Note 1. The dependent variable is mathematics performance.
Note 2. The value in the parenthesis is standard error of estimate.
Note 3. The value with boldness indicates significant at the 0.05 level.

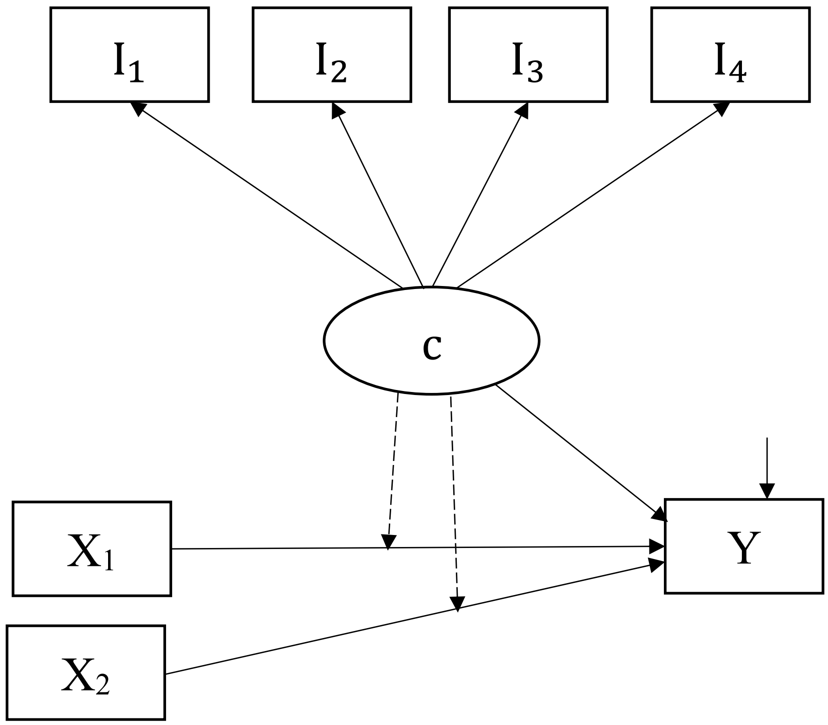

*Figure 1.*Latent class modeling with covariates: A 3-step approach

Note. c is a discrete latent class; X is a predictor; Y is an outcome

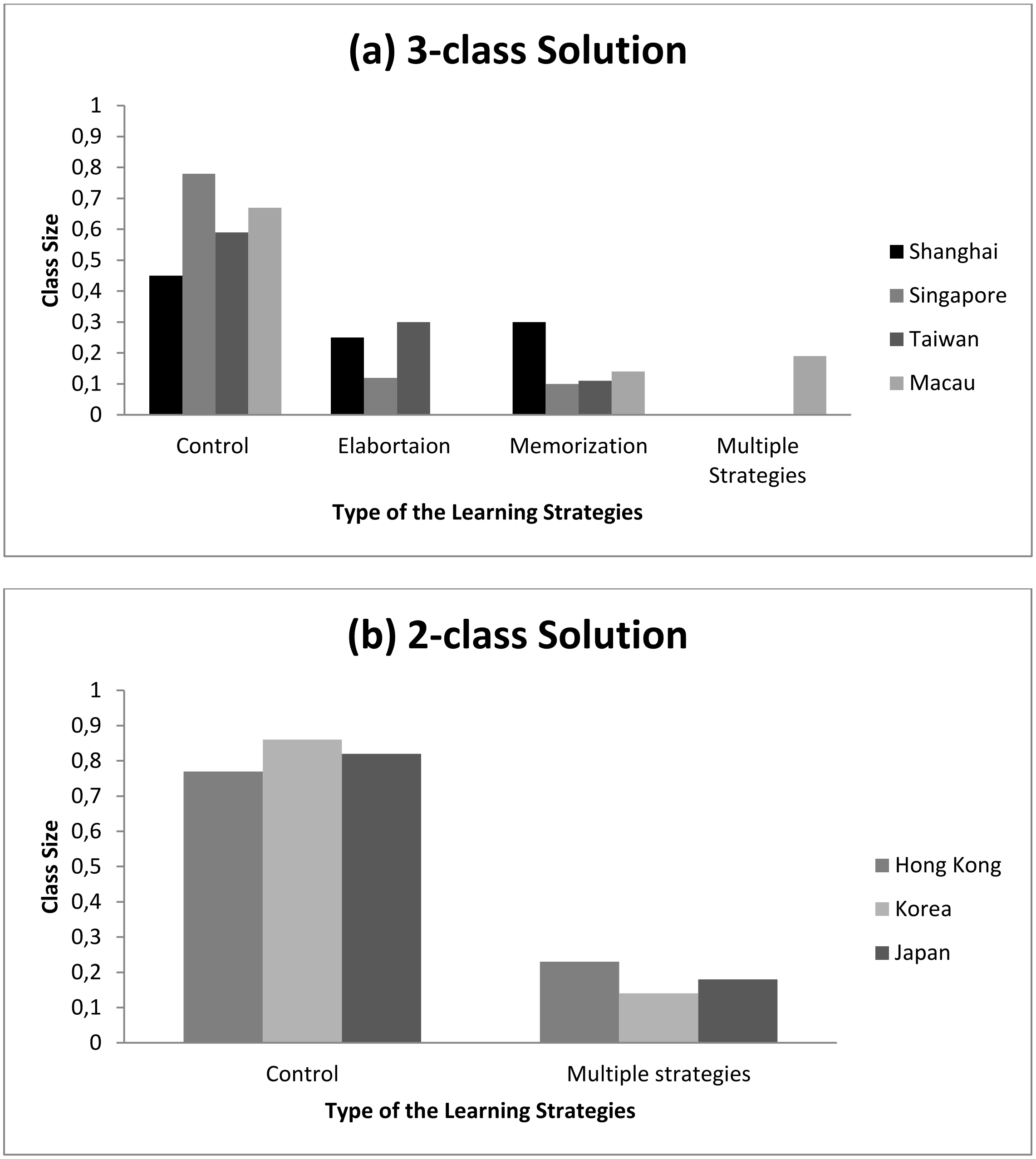

Figure 2. Class label and class size for each class in each education system

Note. Multiple strategies are elaboration and control in Macau and Hong Kong; elaboration and memorization in Korea; memorization with either elaboration or control in Japan.

Erklärung gemäß § 9 (3) der Promotionsordnung der Fakultäten Humanwissenschaften und Geistes- und Kulturwissenschaften

Ich erkläre, dass ich die vorgelegte Dissertation selbständig angefertigt, dabei keine anderen Hilfsmittel als die im Quellen- und Literaturverzeichnis genannten benutzt, alle aus Quellen und Literatur, einschließlich des Internets, wörtlich oder sinngemäß entnommenen Stellen als solche kenntlich gemacht und auch die Fundstellen einzeln nachgewiesen habe.

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