Relationship among High School Students' Science Academic Hardiness, Conceptions of Learning Science and Science Learning Self-Efficacy in Singapore

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Abstract

This study used three previously validated instruments, namely Science Academic Hardiness (SAH), Students' Conceptions of Learning Science (COLS) and Science Learning Self-Efficacy (SLSE) on 431 Singaporean students. Using Structural Equation Modeling, results showed that the "Commitment" dimension of SAH is a positive predictor explaining both the "reproductive" (such as science learning as memorizing or testing) and "constructivist" (such as science learning as understanding or seeing in a new way) conceptions of science learning as well as all dimensions of students' self-efficacy among high school students in Singapore. It was also found that the "Control" dimension in the SAH is a positive predictor for explaining the "science communication" dimension of SLSE, but a negative predictor for explaining "reproductive" COLS. Finally, only students with constructivist COLS has statistically significant associations with all the dimensions of SLSE. These findings suggest that students' personal commitment to learning science is an important aspect to cultivate since it has the ability to predict conceptions of science learning and self-efficacy. Further, creating opportunities for students to be engaged in learning through constructivist ways such as designing tasks to help students understand and see phenomena in new ways, and occasions for students to apply their science knowledge to solve science problems is likely to lead to positive self-efficacy in practical science work, science communication and everyday application of scientific knowledge. Additionally, students' engagement in reproductive ways of learning science such as memorization, testing, and calculating and practicing could be reduced since these do not contribute to building students' science learning self-efficacy.

Keywords: Commitment in Science Learning; Conceptions of Science Learning; Science Academic Hardiness; Science Learning Self-Efficacy

Introduction

In this research, we aim to better understand the relationship amongst Singaporean high school students' science academic hardiness (SAH), conceptions of learning science (COLS) and science learning self-efficacy (SLSE) to improve understanding of science learners. These students present a compelling case study for understanding the complexity of science learning in the Singapore context — (1) Students' excellent performance in science as revealed by international comparative studies such as PISA or TIMSS, and (2) a unique education landscape where students take national standardized tests at the ages of 12, 16 and 18. We argue here that the familiarly that Singaporean students have with taking standardized tests could have possible effects on COLS, SAH and SLSE. The main research question that guided this study is "What is the relationship among high school students' science academic hardiness, conceptions of learning science and science learning self-efficacy in Singapore?

The latest released results for PISA 2015 revealed that Singaporean students outperformed all other participating countries/economies in science with 24% (average of 8% across OECD countries) being top performers (OECD, 2018). Several factors such as investment in good teachers, readily available resources for science learning, strong governmental support, parental involvement and motivated students could have all contributed to the students' PISA performance. As a city state, Singapore places great emphasis on education as evidenced by the generous government investment in education to develop and maintain a skilled workforce and vibrant economy. In 2017, the government spent an equivalent of about US$17.8 billion on education despite decreasing student cohorts. This amount was the second largest expenditure after spending on defense (Ministry of Communication and Information, 2018). This investment in education translates to a societal expectation and accountability of education to produce a high quality workforce for economic progress. The meritocratic system in Singapore allows for students who perform well in national examinations to progress up the academic ladder and to enjoy recognition in the form of social acceptance. Consequently, teachers in schools work hard to ensure that students enjoy academic success. While it is clear from the 2015 PISA results as well as research published on science education in Singapore (see Tan, Poon, & Lim, 2016) that students are well supported in their science learning pursuits, what remains unclear is how the science learning experiences of Singaporean students shape their individual traits such as personal conceptions of science learning, science academic hardiness and self-efficacy in science learning.

Literature Review

Conceptions of learning science (COLS)

The knowledge base for the research questions in this study rests at the nexus of the three key constructs of COLS, SAH and SLSE. COLS refer to students' ideas about what constitutes science learning. Put in another way, COLS refer to the constructions of personal representations of the learning environment and process of learning (Pinto, Bigozzi, Vettori, & Vezzani, 2018). Lee, Johanson, and Tsai (2008) developed a COLS questionnaire with the factors of (1) memorizing, (2) testing, (3) calculating and practicing, (4) increasing one's knowledge, (5) applying, and (6) understanding and seeing in a new way. Generally, a high score in areas such as memorizing, testing, and calculating and practicing suggests that students perceive science learning from a more reproductive manner and hence are more likely to engage in more surface approaches of learning. A high score in the areas of increasing one's knowledge, applying, and understanding and seeing in a new way is likely to indicate that students perceive science learning beyond the immediate need to pass examinations. These students are also more likely to adopt deep learning approaches (see for example Chiou, Liang & Tsai, 2011).

Earlier research on conceptions of learning science included examining young children's conceptions of learning (Hsin, Liang, Hsu, Shih, Sheu, & Tsai, 2018), understanding university students' conceptions of memorizing and understanding (Lin, Liang, & Tsai, 2015a), establishing the relationship between conceptions of learning science to scientific epistemic beliefs and self-efficacy of science learning (Tsai, Ho, Liang, & Lin, 2011), and understanding more specifically, the relationship between self-efficacy and conceptions of learning science (Lin & Tsai, 2013). The findings from research studies (for example Tavakol & Dennick, 2010) on conceptions of learning have established links between students' conceptions of learning and their approaches to learning – constructivist conceptions of learning lead to deep learning. As such, reproductive conceptions of science learning related to "testing" and "calculate and practice" lead to surface learning, while constructivist conceptions such as "applying" and "understanding and seeing in a new way" are related to deep approaches to learning science (Chiou, Lee, & Tsai, 2013). For instance, in Singapore, science classrooms are strongly teacher-fronted and science inquiry is also enacted with assessment requirements in mind (Kim, Tan, & Talaue, 2013, Tan, 2018); hence it is logical to claim that there is a prevalence of reproductive learning experiences in Singapore science classrooms. These traditional learning experiences could possibly translate to reproductive conceptions of learning among Singaporean students.

Science Academic Hardiness (SAH)

Besides students' COLS, SAH is also considered by the current study. Academic hardiness (AH) is a personality trait and has the potential to differentiate students who avoid challenging academic learning experiences from those who are willing to engage with academic challenges. AH is likely to be dependent on different life stages and cultural settings as well. (Kamtsios & Karagiannopoulou, 2012). Hardiness is a composite of attitudes that provides both the courage as well as motivation to persevere with hard work to change stressful circumstances into growth opportunities (Maddi, 2002). AH comprises three components of "Commitment," "Challenge" and "Control" (Maddi, 2002; Kamtsios & Karagiannopoulou, 2012). Research studies carried out on AH include those by Benishek and Lopez (2001) who established a positive relationship between AH and perceptions of academic self-worth. This finding was also confirmed again later by Maddi, Harvey, Khoshaba, Fazel, and Resurreccio (2009) who established that AH is associated with academic self-efficacy.

The concept of AH is aligned to the practice of science since scientists are required to preserve in their pursuit of knowledge of the natural world. Learning science will thus also require that learners be hardy. Hence, in science, SAH refers to students' commitment to learning science, their abilities to face challenges during the science learning process as well as the level of "Control" that they exert in their learning (Wang & Tsai, 2016). The concept of SAH is one that should be nurtured and among science learners.

With respect to instrumentation, the first AH questionnaire was originally developed by Creed, Conlon, and Dhaliwal (2013) and was subsequently modified by the Wang and Tsai (2016) to measure specifically SAH. Wang and Tsai (2016) related students' science learning science efficacy with their SAH. They found that teachers' SAH fostered students' SAH, which in turn positively influenced the students' science learning self-efficacy.

Science Learning Self-Efficacy (SLSE)

Self-efficacy stems from the seminal work of Bandura in 1977. The construct of self-efficacy can be defined as individuals' perceived confidence in their abilities to succeed in a given task (Bembenutty, 2007). Self-efficacy has been recognized as a powerful predicator of students' motivation and subsequent learning and academic achievements. Students with high self-efficacy usually tend to show positive orientations towards academic work. SLSE is therefore defined as an individual's perceived confidence in their ability to learn and practice science. The SLSE was adopted from related instruments on students' self-efficacy that contained four factors (Baldwin, Ebert-May, & Burns, 1999; Uzuntiryaki & Capa Aydin, 2009) by Tsai et al. (2011) with the addition of one more factor in science communication. In the current study, the resultant SLSE questionnaire by Wang and Tsai (2016) was used. This version of questionnaire was clustered under the headings of (1) conceptual understanding, (2) higher-order cognitive skills, (3) practical work, (4) everyday application, and (5) science communication. The items of SLSE can be categorized into Cognition (consisting of conceptual understanding and higher-order cognitive skills) and Application (practical work, everyday application and science communication) (Wang & Tsai, 2016). By comparing SLSE to students' Approaches to Learning (ALS), Wang and Tsai found that students who engage with deep learning strategies were more likely to have higher SLSE. Of particular interest was the fact that "Practical work" in SLSE could only be predicted by the deep strategy of ALS.

Research in self-efficacy carried out in higher education by Wang, Liang, and Tsai (2017) compared the self-efficacy of university students in Taiwan and the United States and found that American students' confidence in their ability to apply higher order cognitive skills also tended to stimulate their confidence to accomplish their practical work and in the process, strengthened their academic self-efficacy. Such a trend was not observed among the Taiwanese university students.

The researchers attributed the difference to cultural variances. In another study, Lin, Liang and Tsai (2015b) established the relationship between university students' physics learning profiles and their self-efficacy. They found that only students who sought understanding of physics concepts rather than depending on memorization, learning routine calculations and practicing tutorial questions possessed stronger self-efficacies.

The relationships among SAH, COLS and SLSE

Research has been carried out to examine the relationships between different combinations of the three constructs of SAH, COLS and SLSE. For instance, Tsai et al. (2011) examined the relationship between the COLS, SLSE and scientific epistemic beliefs of Taiwanese students and found that absolutist scientific epistemic beliefs led to reproductive conceptions of learning and were also negatively associated with their science learning self-efficacy. On the other hand, sophisticated scientific epistemic beliefs were more likely to trigger constructivist conceptions of learning that promoted students' science learning self-efficacy. From their study, they found that students with reproductive conceptions of learning science decreased self-efficacy in science learning. The relationship between SLSE and COLS was further explored by Lin and Tsai (2013a) and their findings concurred with those of Tsai et al. (2011), namely that students with constructivist conceptions of science learning were generally more self-efficacious compared with those holding reproductive conceptions of science learning. The association of constructivist conceptions of learning with higher learning self-efficacy was again shown by the study examining university biology majors' conceptions of memorizing and understanding in learning (Lin, et al., 2015a). Wang and Tsai (2016) sought to understand the relationship between SLSE and SAH using hierarchical linear modeling, and found that science hardiness is associated with science learning self-efficacy. Cheng, Tsai, and Liang (2019) further verified the construct of SLSE and the role of science academic hardiness using a multilevel model approach and showed that there was a statistically significant relationship between the constructs. In another study, Zheng, Dong, Huang, Chang, and Bhagat (2018) revealed that students with high levels of COLS have a positive influence on deep approaches to learning science and in turn, these deep approaches to learning science have played a positive role in both low and high levels of self-efficacy in science learning. As seen from research with SAH, COLS, SLSE, and other constructs related to science learning, there are currently few studies that explicitly examine the relationship between the three constructs of SAH, COLS and SLSE.

Research Hypothesis

In this study, we hypothesize that hardiness to science learning is the single most statistically significant predictor (based on earlier research and Singapore education context) of students' willingness to engage in both reproductive as well as constructivist forms of learning. When students are committed to academic challenges, they would be eager to spend time memorizing facts and also spend time working on practice papers (these refer to routinue worksheets that students work on that are similar to examination questions). At the same time, if they have strong science learning hardiness, they would also be willing to engage with more open-ended tasks to research on solutions to problems rather than to avoid challenges academic learning experiences presented to them. We predict a direct positive relationship between "Commitment" and reproductive as well as constructivist conceptions of learning.

We also hypothesize that reproductive (memorization, testing, calculating and practicing) conceptions of learning will be negatively correlated to students' self-efficacy in project work, science communication and everyday applications (Maddi et al. 2009). Complementary to this, engagement in constructivist learning (increasing one's knowledge, application, understanding and seeing in a new way) would be positively correlated to higher science learning self-efficacy.

The Science Learning Context in Singapore

Science learning in Singapore closely adheres to the learning outcomes stated in the national science curriculum (see CPDD, 2008). While inquiry forms the core of the science curriculum framework, the adoption and practices of science inquiry are uneven (Kim et al., 2013). The approaches to science learning are also varied. For instance, students are inclined to memorize keywords in science so that they are able to reproduce them in the examination to be given full credits (Teng & Lee, 2015). Consequently, there is a reliance on the use of memorization for learning science. While memorization is a form of the reproductive conception of learning, the distinction between memorization and learning with understanding (a constructivist conception) is often not clearly distinguished in the science learning in Singapore. For instance, in Singapore classrooms, students are taught the multiplication tables in grades 2 and 3 together with addition and subtraction. There is an expectation that students memorize these multiplication tables as their mental arithmetic is often tested in class. It is often unclear if a child truly understands the concept of multiplication when he/she is able to recite the multiplication tables (Lau, 2019). It is hence difficult to tell if students' learning in Singapore is "understanding before memorization" or "understanding replacing memorization" (Marton, Watkins, & Tang, 1997).

To date, there is little research on the SAH, COLS and SLSE of Singaporean students. Lin, Tan, and Tsai (2013) examined the science learning self-efficacy of Singaporeans students and found that Singaporean eighth grade students had higher SLSE than their Taiwanese counterparts.

Further, Singaporean male students had higher SLSE compared to female students except for the Practical Work (PW) dimension. Lau (2019) studied students' approaches to learning science in secondary schools in Singapore and compared the students' learning motivation. He found that students' approaches to learning science statistically significantly correlated with their achievement goals. These findings and observations about science learning in Singapore suggest that students' motivation to learn science is driven by a desire to succeed, and in order to succeed, they engage in various ways of learning science. Singapore students' indicator for success in learning is varied and includes good results on tests and examination and getting into programmes and schools of their choices (Davie, 2017).

Methods

This study adopts a case study method consisting of a survey of students' COLS, SAH, and SLSE. A detailed description and analysis of the Singapore context and students enables understanding of how context can possibility affect students' conceptions in the three keys areas.

Participants

Four schools across the different parts of Singapore were randomly sampled and invited to participate in the study. There were two junior colleges (grades 11 and 12) and two secondary schools (grades 9 and 10) involved in the study. Junior colleges in Singapore are two-year programmes for prepare students to take the General Certificate of Education (GCE) Advanced level examination before they enter the university, while secondary schools typically offer four-year programmes to prepare students to enter the junior college or polytechnics (institute of higher learning leading to a diploma). The age of the 431 students who participated in the study ranged from 15 (grade 9) to 17 (grade 12) years old. After informed consent was obtained from the students and their parents, the students were presented with a questionnaire comprising the SLSE, COLS, and SAH. The students were given about 40 minutes to respond to the questionnaire.

Instruments

Science Academic Hardiness (SAH)

The three key factors in SAH are "Commitment", "Control" and "Challenge" which were adopted from Wang and Tsai (2016) and Cheng et al. (2019). Examining the three components of science academic hardiness closely, Sheard (2009) found that "Commitment" was the most statistically significantly correlated compared with "Challenge" and "Control" of academic performance in graduate degrees since it was found that "Commitment" was able to statistically significantly predict final degree performance and dissertation grades. Given the importance of "Commitment" (Sheard, 2009) as a predictor of self-efficacy, this study hypothesized the component of "Commitment" as a predictor of self-efficacy among Singaporean students. The second component that this research examined for SAH is that of "Control". Given that the science curriculum in Singapore focuses on science as inquiry (CPDD, 2008) and teachers are encouraged to work towards creating opportunities for greater student self-direction in the aspects of questions, evidence, explanation, connections and communication (CPDD, 2008, pp. 12-13), it was meaningful to examine students' perceptions of the notion of the "Control" that they are able to exert in their science learning.

The expert validity for this measure showed the appropriateness of the content. For validation by experts, two researchers who are experienced with instrumentation and science education went through the questions through discussions using existing literature on students' SAH. According to the previous study results (Cheng et al., 2019), the internal consistency reliability coefficient (Cronbach's alpha) for "Commitment" was .89, for "Control" was .71 and for "Challenge" was .59. This meant that the factors had sufficient reliability and validity to assess SAH (Cheng et al., 2019).

Science Learning Self-Efficacy (SLSE)

In this study, we focus on the components of "Practical work", "Everyday application" and "Science communication" of science learning self-efficacy. Practical work is an important feature in the science curriculum in Singapore to enable students to understand the empirical nature of science. The use of everyday applications in science teaching and learning is also encouraged in the Singapore science curriculum as can be seen from the statement "It is important to use *real life situations*, where possible, as the starting point for the development of scientific ideas through inquiry" (CPDD, 2008, p. 13). Finally, the focus on science communication is also deliberate since under the 21st century competencies and scientific literacy vision for the science curriculum, information and communication skills is one of the three overarching goals that science education needs to strive to achieve (CPDD, 2008, p. 4). The other two components of SLSE, higher order cognitive skills and conceptual understanding, are not discussed in this analysis for two reasons. Firstly, Lin et al., (2013) had earlier shown that Singaporean students have statistically significantly higher SLSE compared with Taiwanese students for all dimensions of SLSE. Secondly, higher-cognitive skills and conceptual understanding are relatively more constant in science teaching and learning when compared to practical work, everyday application, and science communication. The development of higher cognitive skills and conceptual understanding follows the learning outcomes stated in the syllabus documents and the enactment is routine. In general, a high mean score for all factors of self-efficacy is desirable and indicative of high-level ability in learning (Usher & Pajares, 2008). Conversely, a low mean score for self-efficacy suggests that attention needs to be paid to the development of helping students see links between concepts of science and applications in their everyday life.

In an earlier study by Lin and Tsai (2013a), the SLSE has been validated using exploratory factor analysis (with factor loadings ranging from .50 to .82) and the Cronbach's alpha values for each factor were in the range from .83 to .94. The overall Cronbach's alpha value of .97 indicates satisfactory reliability to measure students' science learning self-efficacy. Using these analyses, it is suggested that the factors in SLSE had highly sufficient reliability and validity in assessing science learning self-efficacy.

Conceptions of Learning Science (COLS)

The COLS questionnaire was developed by Lee, Johnson, and Tsai (2008) and was based on Tsai's (2004) study which used a hierarchical order to address the possibility of mixed COLS. The COLS has a total of 31 items under the factor headings of (1) memorizing [5 items], (2) testing [6 items], (3) calculating and practicing [5 items], (4) increasing one's knowledge [5 items], (5) applying [4 items], and (6) understanding and seeing in a new way [6 items]. In Lee et al. (2008), the COLS structure was confirmed with a reasonable model fit and maintained sufficient reliability (ranged from .84 to .91, overall alpha = .91).

Data Analysis and Procedure

For the verification of the validity and structure of the three surveys, the Confirmatory Factor Analysis (CFA) was conducted to verify the construct validity of the SAH, COLS and SLSE dimensions. Earlier studies have revealed that the three surveys, SAH, COLS and SLSE, used in this study were validated by exploratory factor analysis (EFA) (see for example Lin & Tsai, 2013a;

Wang & Tsai, 2016). In this current study, a single Confirmatory Factor Analysis (CFA), which has all of the factors with selected items in the three surveys merged into one model, was conducted to clarify both the reliability and validity of the three surveys simultaneously in one construct. Finally, 51 items were kept in this final version model (i.e., 10 items in SAH, 25 items in COLS and 16 items in SLSE). The results of the CFA for the three surveys with all of the selected items in one model, as well as the descriptive statistics for each dimension, are shown in Appendix 1. Four to seven items remained in each dimension except for the "Application" dimension (two items) in COLS. However, the dimension of "Challenge" was omitted in this study due to low factor loadings (all < .5) and low Cronbach's alpha value (.58). In addition, the structure of the model was not positively defined while the "Challenge" dimension was included in the model structure. The validation results indicated that the "Challenge" dimension did not qualify for further examination of Singapore students' SAH. As a result, the "Challenge" dimension was omitted. In terms of the validity of the model, all the measured item factor loadings for each dimension are significant ($p < .001$) and the factor loading values are .55 and higher (ranging from .55 to .92). Regarding the reliability of the model, the Cronbach's alpha (α) values for all the remained dimensions ranged from .82 – .88, the composite reliability (CR) coefficients exceeded .80 (.81 – .87), and the AVE values ranged from .47 – .70. In addition, the fit indices of the CFA for this model, Chi-square=2252.07, $P < .001$, degree of freedom= 1169, Chi-square/degree of freedom = 1.93, GFI = .83, IFI = .91, TLI = .90, CFI = .91, and RMSEA = .046, indicated that the CFA results of this model showed a sufficient fit (Burkell et al., 1990). The results then confirmed the convergent and construct validity of the model designed for the three surveys.

In addition, the Pearson's correlation was performed to explore the potential relationships between the dimensions of the three surveys. Subsequently, the structural relationships between all the dimensions of the three surveys were further evaluated through the Structural Equation Modeling (SEM) analysis.

Results

Correlational relationships among dimensions of the three surveys

The Pearson's correlation results among the dimensions of the three surveys, including SAH, COLS and SLSE, are shown in Table 1. Students' SAH was associated with their COLSs (reproductive and constructivist COLSs) and their SLSE. Specifically, the "Commitment" dimension in SAH was positively correlated with all of the dimensions in COLS ($r = .28 – .39$, $p < .001$) except for the "Testing" dimension, as well as being positively correlated with all the dimensions in SLSE (.40 -.46, $p < .001$). On the other hand, the "Control" dimension in SAH was negatively correlated with the only one dimension, "Testing," in COLS ($r = -.25$, $p < .001$), and was positively correlated with two dimensions, "Practical work" ($r = .11$, $p < .05$) and "Science communication" ($r = .14$, $p <.01$) in SLSE. In terms of the relationships between COLS and SLSE, the results indicated that most of the dimensions in COLS ($r= .14 – .52$, $p < .01$ or $< .001$) were positively correlated with all the dimensions in SLSE. However, the "Testing" dimension in COLS was negatively correlated with "Everyday application" ($r = -.11$, $p < .05$) and "Science communication" ($r = -.12$, $p <.05$) in SLSE.

Students' average score of reproductive COLS, such as the "Memorizing," "Testing" and "Calculating and practicing" dimensions, was positively correlated with the "Commitment" dimension ($r = .24$, $p < .001$) in SAH and all the dimensions in SLSE ($r = .14 – .17$, $p < .01$ or .001). In addition, students' average score of reproductive COLS was negatively correlated with the

"Control" dimension in SAH ($r = -.17$, $p < .001$). Furthermore, students' average score of constructivist COLS, such as the "Increase one's knowledge," "Application," and "Understanding and Seeing in a new way" dimensions, was positively correlated with the "Commitment" dimension ($r = .41$, $p < .001$) in SAH and all the dimensions in SLSE ($r = .44 – .56$, $p < .001$). However, the correlation between their average score of constructivist COLS and the "Control" dimension in SAH was not significant. However, it is worth noting that the p-value and the correlation coefficient value are influenced by the sample size. The relatively small correlation coefficients (e.g. $r = -.11$, $p < 0.05$; $r = -.12$, $p < 0.05$) revealed the statistical significance due to the relative large sample size ($n = 431$) in this current study. Hence, based on the results of the correlation analysis, the relationships among all the dimensions of the three surveys were further evaluated using Structural Equation Modeling (SEM) analysis.

Insert Table 1 here

The structural relationships among the three surveys, SAH, COLS and SLSE, are shown in Figure 1. To reduce the complexity of the structure, based on the suggestions of Lee et al. (2008) study, the six COLS dimensions were divided into Reproductive and Constructivist COLSs by a second-order analysis of SEM. The Reproductive COLSs (RC) include "Memorizing," "Testing," and "Calculating and practicing," while the Constructivist COLSs (CC) consist of "Increase of knowledge," "Applying," and "Understanding and seeing in a new way." The results of the path analysis with statistical significance ($p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively) are shown in the figure. The fit indices for this structure, Chi-square = 2636.37, $P < .001$, degree of freedom = 1201, Chi-square/degree of freedom = 2.20, GFI = .80, IFI = .88, TLI = .87, CFI = .88, and RMSEA

= .053, indicated that this structural model adequately explained the data in this study (Jöreskog & Sörbom, 1993). In addition, the standardized factor loadings of all the dimensions in the three surveys were between 0.58 and 0.92 and reached the statistical significance level, suggesting that the items and the dimensions were effective in expressing the dimensions among the learners. Furthermore, the standardized factor loadings of both the second order dimensions, RC and CC, to the six first-order dimensions were between 0.39 and 0.96 and also reached the statistical significance level, suggesting this second-order model was exhibited reasonable fit and adequately supported.

Regarding to the path analysis, the results indicated that the “Commitment” dimension in SAH was positively correlated with both second-order dimensions, RC and CC, in COLS (path coefficient = .35 and .48, $p < .001$), as well as positively correlated with all the dimensions in SLSE (path coefficient =.23-.30, $p < .001$). The “Commitment” dimension in SAH was the positive predictor for explaining both second order dimensions, RC and CC, in COLS and all the dimensions in SLSE. Moreover, the “Control” dimension in SAH was positively correlated with the “Science communication” dimension in SLSE (path coefficient = .11, $p < .05$), and negatively correlated with the second-order dimension, RC, in COLS (path coefficient = -.12, $p < .05$). The “Control” dimension in SAH was the positive predictor for explaining the “Science communication” dimension, and the negative predictor for explaining the RC. In addition, only students’ CC had statistically significant associations with all the dimensions in SLSE (path coefficient = .40-.60, $p < .001$). Students’ CC was the positive predictor for explaining all the dimensions in SLSE. However, it should be noted that students’ RC had no significant relationship with the dimensions in SLSE.

Insert figure 1 here

Based on the results of the structural relationships among the three surveys (Figure 1), the detailed relationships between students' Constructivist COLSs (Increase of knowledge, Applying, and Understanding and seeing in a new way) and their SLSE (Practical work, Everyday application and Science communication) were further examined and shown in Figure 2. The fit indices, Chi-square=723.94, $P < .001$, degree of freedom= 287, Chi-square/degree of freedom = 2.52, GFI = .88, IFI = .93, TLI = .92, CFI = .93, and RMSEA = .060, showed that this model adequately explained the data (Jöreskog & Sörbom, 1993). The results indicated that both of students' "Applying" and "Understanding and seeing in a new way" dimensions in Constructivist COLSs were positively correlated with all the dimensions in SLSE (path coefficient =.17-.57; $p < .05$). Both of students' "Applying" and "Understanding and seeing in a new way" dimensions in Constructivist COLSs are the positive predictors for explaining all the dimensions in SLSE. However, students' "Increase of knowledge" dimension in Constructivist COLSs had no significant relationship with any of their SLSE dimensions.

Insert figure 2 here

Discussion and Conclusion

Referring to the research question of how Singaporean science students' conceptions of science learning relate to their SAH and SLSE, our results showed that the "Commitment" dimension of SAH is a positive predictor for explaining both the reproductive and constructivist conceptions of science learning as well as all dimensions for students' self-efficacy among high school students in Singapore. This finding suggests that personal commitment in learning is an important factor in fostering positive self-efficacy in learning. Possessing an intrinsic interest and having a commitment to science serve as motivation to pursue the discipline in depth. Interest is central in determining how an individual "select and persist in processing certain types of information in preference to others. Thus interest plays a major role in the course and outcome of our mental activities" (Hidi, 1990, p. 549). As such, personal interest in learning (commitment to learning) helps students with their willingness to pay extra attention to and focus on their learning in order to pursue excellent performance and progress in their studies (Sheard & Golby, 2007). This is especially true in the context of Singapore since academic success is viewed as an important outcome of schooling (Davis, 2017). Singaporean students are willing and committed to learn and do whatever it takes for them to perform well in their tests and examinations and use multiple ways to do that, including memorizing and doing practice papers before examinations.

Taking this finding together with earlier findings (for example Tavakol & Dennick, 2010) that suggested links between students' conceptions of learning and their approaches to learning, it could be suggested that the "Commitment" dimension of SAH could lead to students adopting approaches (both deep and traditional) to learning that will help them achieve their educational goals. Pinto et al. (2018) found in their study that students' conceptions of learning affect their motivation that in turn guide their learning approaches and choices of learning strategies, then leading to different learning outcomes. Watters (2000) found that to learn biology successfully, students need to develop complex problem-solving, innovation and adaptability. These constructivist ways of learning hence need to exist in partnership with the way students are taught in mass lectures. Mass lectures as a teaching method is popular but it might establish a context that fosters learning through memorization. (Watters, 2007). Students hence need to be able to commit themselves to learn through both memorization as well as to learn to apply their knowledge to solve meaningful problems. In order to do that, students need to be committed to learning. Students with higher commitment tend to have higher confidence in learning science and foster their science learning through fostering higher science learning self- efficacies (Zheng et al., 2018). When students are committed to science learning, they would embrace appropriate and specific approaches to learn in different contexts. For instance, when engaged in open-ended science problem solving, students might explore in detail the different variables affecting the problem. This way of learning leads to greater comprehension, understanding and different ways to solve problems (characteristics of constructivist conceptions of learning). In contrast, should students encounter learning contexts where they are required to supply chemical formulae, they would adopt the more traditional way of memorizing the valences of the different elements. Students hence learn through a combination of deep and traditional approaches depending on the demands that the learning tasks make on them.

It was also found that the "Control" dimension in the SAH was a positive predictor explaining "Science communication" but was a negative predictor explaining "Reproductive" COLS. "Control" in SAH refers to students' ideas and their abilities to exert influence over their own learning process and achievements and to use them to reach their academic goals, even when conditions are unfavourable (Sheard & Golby, 2007). For this group of students, having control of their learning of science helped them to be confident in their science communication but did not necessarily mean that they did not adopt memorizing, testing, and calculating and practicing as their way of learning. It is likely that this group of students prefers engagement in constructivist learning rather than traditional memorization, testing and practicing.

Finally, only students with constructivist COLS had statistically significant associations with all the dimensions of SLSE. Constructivist COLS include seeking to increase one's knowledge, opportunities to apply science knowledge and engaging in activities that help learners to understand and see things in a new way. Such COLS describe activities that have been advocated in standards and reforms documents as good science inquiry practices and activities both in Singapore and internationally (Ministry of Education, 2008; NRC, 2000; NRC 2012). For instance, the practices advocated by the Next Generation Science Standards (NRC, 2012) encourage getting students to plan and carry out investigations, an approach that is aligned with the activities that help learners understand and see things in a new way in COLS. When students' self-efficacy is stronger, their commitment to learning is also higher (Bandura, 1986). Further, when students have higher self-efficacy, they are also better able to apply appropriate strategies to execute learning tasks to meet their goals (Muhammed, 2011). As such, when students' are more oriented to constructivists COLS, they are likely to be more proficient in working on projects, applying their knowledge to solve problems as well as to communicate their understandings.

In this study, the decision to exclude the component of "Challenge" was made based on both contextual factor as well as statistical factors. Contextually, there is a national science curriculum in Singapore that all schools follow. The science curriculum is outcome-based and spiral in nature — similar concepts are revisited at different grade levels with increasing complexities. As such, scientific concepts and materials presented to students at each grade level are assumed novel on first encounter and hence is equally challenging for them. Statistically, the structure of the model was not positively defined while the "Challenge" dimension was included in the model structure. The validation results indicated that the "Challenge" dimension did not qualify for further examination among Singapore students' SAH. Despite the two factors, we recognize the importance of understanding "Challenge" in science learning, further work could be carried out to develop instruments that are able to measure "Challenge" in SAH that could be applied to students who learn science under a common national curriculum.

Implications

These findings suggest that students' personal commitment to learning science is an important aspect to cultivate in Singapore since it influences aspects of hardiness and self-efficacy. This is aligned with Choy, Deng, Chai, Koh and Tsai's (2016) finding that students in Singapore are generally motivated in learning and are also positive about self-directed learning and collaborative learning. Further, creating more opportunities for students to be engaged in learning through constructivist ways such as designing meaningful tasks to help students understand and see phenomena in new ways, and occasions for students to engage in solving science problems could lead to positive self-efficacy in practical science work, science communication and everyday application of scientific knowledge. Choy et al (2106) showed that self-directed learning and collaborative learning are two popular approaches adopted by primary and secondary school students in Singapore. Further, since students' motivation to learn is fueled by self-confidence and appreciating the value of learning tasks rather than their pursuit of receiving good grades and praise from others, engagement with meaningful learning experiences become even more important. Students' engagement in reproductive ways of learning such as memorization, testing, and calculating and practicing could be reduced since these do not contribute to building students' science learning self-efficacy and are likely to be poor in motivating students.

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table

Table 1: The correlations among the dimensions of the SAH, COLS and SLSE surveys (n=431).

	Commitment	Control	Practical work	Everyday application	Science communication
Memorizing	.28***	-.09	.14**	.15**	.16**
Testing	-.05	-.25***	-.08	-.11*	-.12*
Calculating and practicing	.32***	.01	.30***	.36***	.30***
Increase one's knowledge	.36***	.07	.36***	.45***	.44***
Application	.33***	.09	.38***	.48***	.45***
Understanding and seeing in a new way	.39***	.05	.41***	.52***	.47***
Reproductive COLS	**.24*** **	**-.17*** **	**.15** **	**.17*** **	**.14** **
Constructivist COLS	**.41*** **	**.08**	**.44*** **	**.56*** **	**.52*** **
Practical work	.40***	.11*	-	-	-
Everyday application	.45***	.02	-	-	-
Science communication	.46***	.14**	-	-	-

Notes: *p<.05, **p<.01, ***p<.001. **Reproductive COLS: Mean scores of Memorizing, Testing and Calculating and practicing; Constructivist COLS: Mean scores of Increase one's knowledge, Application and Understanding and seeing in a new way.**

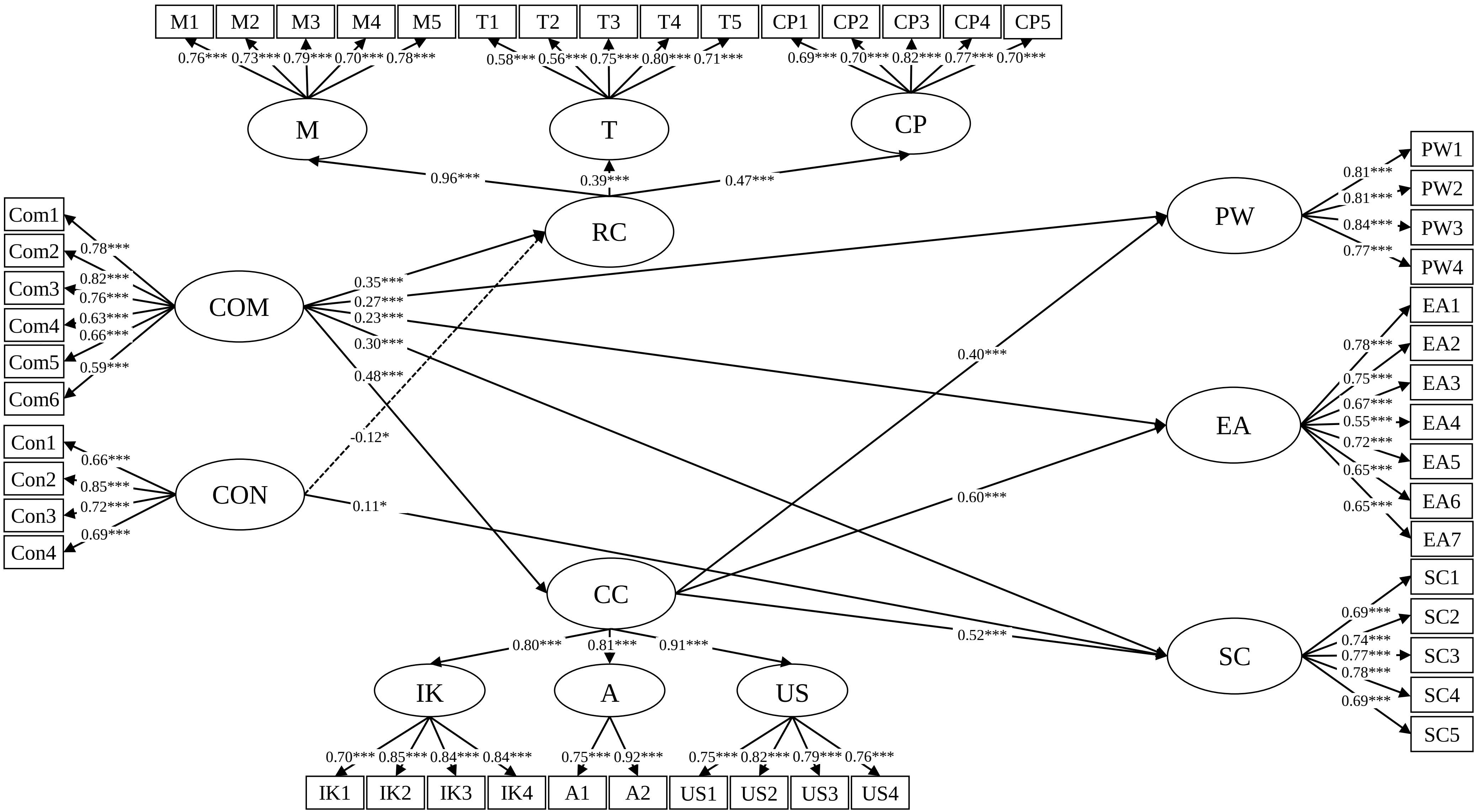

Figure 1. The structural relationships among the three surveys, SAH, COLS and SLSE. COM: Commitment; CON: Control; M: Memorizing; T: Testing; CP: Calculating and practicing; IK: Increasing one's knowledge; A: Application; US: Understanding and seeing in a new way; RC: Reproductive Conceptions of learning science; CC: Constructivist Conceptions of learning science; PW: Practical work; EA: Everyday application; SC: Science communication. Note: *p<0.05; ***p<0.001.

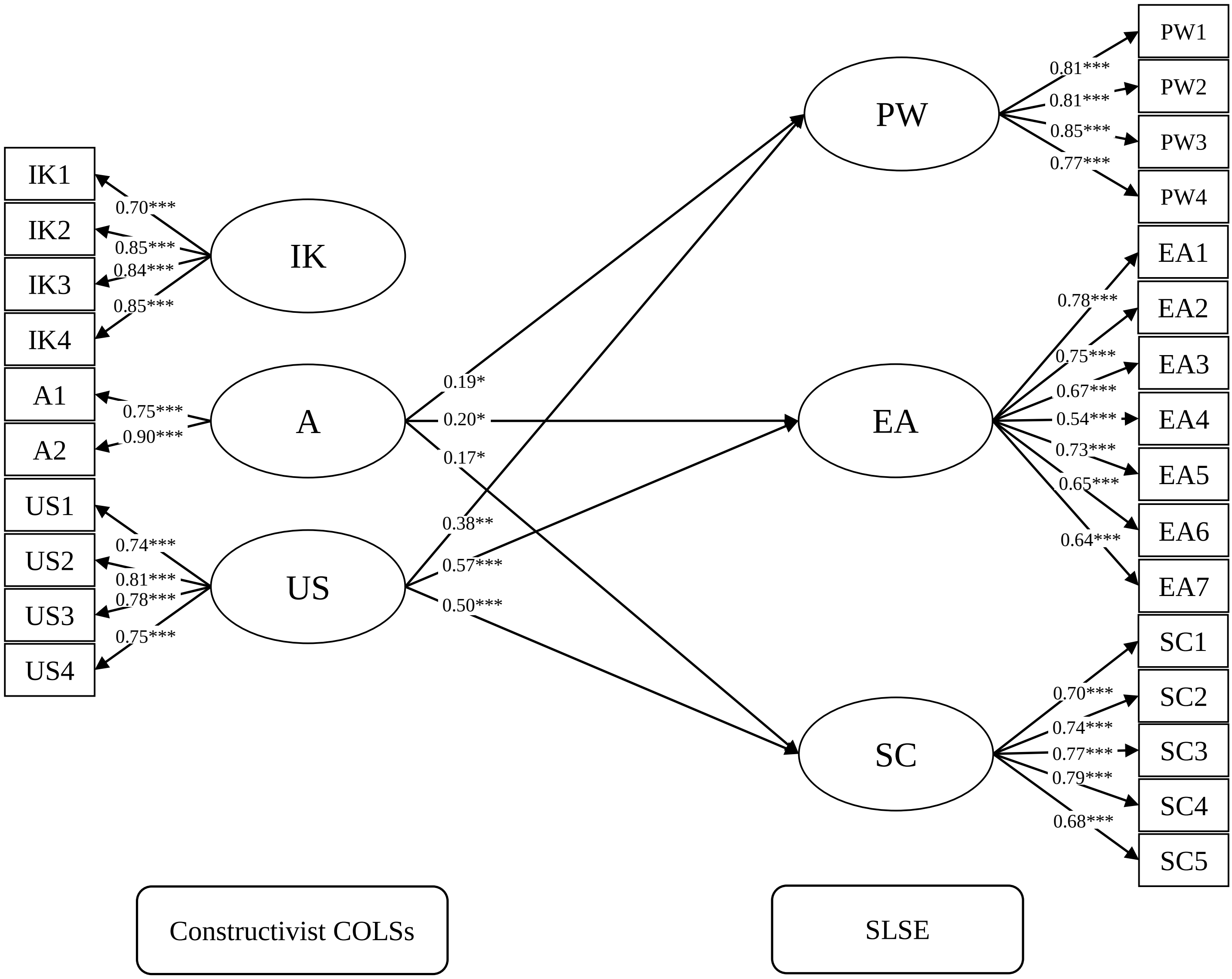

Figure 2. The structural relationships among students' constructivist COLSs and their SLSE. IK: Increasing one's knowledge; A: Application; US: Understanding and seeing in a new way; PW: Practical work; EA: Everyday application; SC: Science communication. Note: *p<0.05; **p<0.01; ***p<0.001.

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