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STRENGTHENING STRATEGIC APPLICATIONS OF PROBLEM-SOLVING SKILLS FOR TAIWAN STUDENTS' CHEMISTRY UNDERSTANDING

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Abstract. *This study better research aimed at strategic applications for exploring students' learning performances with conceptual understanding and algorithmic proficiency by problem-solving maps and six major learning activities. A quasi-experimental method was employed to detect the outcomes of students' compared intervention, together with two learning groups, the experimental group and control group. All results demonstrated that the experimental group students who used the strategic applications showed better learning performances than those of the control group students. The experimental group students with more cognitive competency presented significant achievements and larger effect sizes after their two module executions of gas chemistry program. Moreover, these demonstrations were predominated with students' conceptual and algorithmic learning developments in chemistry. The experimental group students witnessed a new advancement of self-performed modules to promote their feedback and intelligent analyses.*

Key words: *algorithmic proficiency, conceptual understanding, gas chemistry, problem-solving.*

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Introduction

As the major multi-functional approaches for academic learning, problem-solving skills (PSS) had been inspired by science educators for college students' engagement of dynamic education objectives. This study embedded in strengthening students' strategic PSS applications of concepts analyses and intelligent understanding presented more approachable science competency in gas chemistry. Specifically, these strategic PSS applications would link students' individual proficiency of inference competence with their learning development of chemistry activities (Barak, 2012; Chandrasegaran *et al.*, 2007; Funke, 2010; Hwang *et al.*, 2011; Overton *et al.*, 2013; Sevian *et al.*, 2015; Selvaratnam & Canagaratna, 2008; Simons & Klein, 2007). The immediate goal of strategic applications asked for students to develop comprehensive understanding of chemistry concepts by means of more illuminating module programs in keeping up with today's global challenges and competitive environment (Sevian *et al.*).

Accordingly, this study would inspire Taiwan college students to get involvements of six gas learning activities for strategic applications in chemistry. Meanwhile, the modified texts implicated with the problem-solving maps shed new insight on cognition learning of density solution map from researchers (Selvaratnam & Frazer, 1982; Selvaratnam & Canagaratna, 2008). The illustrated exploration of students' problem-solving maps was through their encounters with the step-by-step tactic access in three deductive stages for the appropriative ideal gas equation which could be calculated from unknown quantities to the known quantities (shown in Figure 1, students' formative understanding of problem-solving maps for the gas pressure calculation). Based on the above conceptualized insights, this study set up two module programs of problem-solving maps and six major learning activities for strengthening students' strategic PSS applications in gas chemistry.

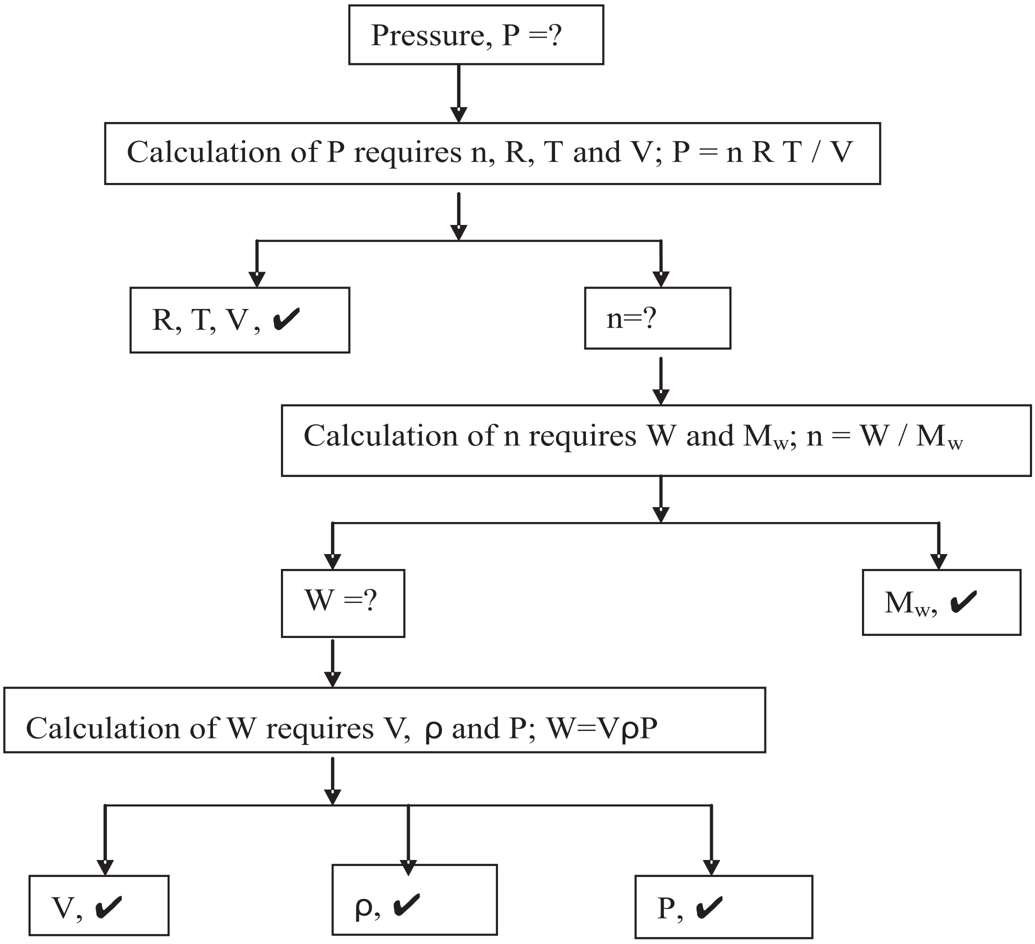

Figure 1: **Students' formative understanding of problem-solving maps for the gas pressure calculation; the symbol ✔ is an indication of the known figure. From the known data of the base level, we can infer the data relationship between the upper levels. Fig. 1 is derived from the revised charts of Selvaratnam & Frazer (1982).**

Dilemma of Chemistry Learning

At the first sight of their encounters with important chemistry terminologies, college students would often feel puzzled for individual difficulties in solving abstract or complicated problems, such as gas chemistry (Sanger et al., 2013), electrochemistry (Cheung, 2011), stoichiometry (Davidowitz et al.; 2010 Sanger, 2005), chemical equilibrium (Cheung et al., 2009) and stereochemistry (Abraham et al., 2010). Scholars attributed students' primary dilemma of chemistry learning to their lack of authentic access for integrating cognitive skills with their fundamental understanding of chemistry concepts (Sanger, 2005; St Clair-Thompson *et al*., 2012). Although many researchers (Harper, 2006; Nakhleh, 1992; Siburt *et al*., 2011) had pointed out that students might have done all the exercises and assignments for traditional requirements of chemistry learning, they still failed to get high grades on their exams. The traditional learning with mechanical exercises and monopolistic class lectures might be insufficient for the different levels of college students to set up their conceptual understanding in gas chemistry. A lack of strategic PSS applications could be a serious obstacle for novice learners, who approached chemistry exams only as a recitation task, thinking that what would be necessary to pass exams was being able to regurgitate the knowledge they had been given, rather than establishing a cognitive learning process for building up a basis of coherent concepts.

In the educational perspective of strategic PSS applications, Salt and Tzougraki (2011) demonstrated that though students could have solved algorithmic-type chemistry problems, they still had difficulty answering conceptual-type problems on the same topics, especially if these conceptual problems were given in detailed description of the particulate nature level (also Özmen, 2013). To look for more cognitional features of conceptual changes, researchers emphasized that students had to integrate clear conceptions with strategic PSS applications for individual learning (Pickering, 1990; Cracolice *et al.*, 2008; Sanger *et al.*, 2013), to avoid students' inability to answer algorithmic versus particulate conceptual questions during the initiated process of chemistry reasoning skills.

Many scholars proposed that students' alternative and complicated conceptions included the properties of gas, gas particulate nature of matter and kinetic molecular theory of gases (Kautz et al., 2005; Lin et al., 2000; Nurrenbern & Pickering, 1987; Pickering, 1990; Sanger et al., 2013). To elaborate clear cognitive learning of gas chemistry, this study summarized several scholars' academic resources. Most of scholars' critical implementations aimed at facilitating college students' learning cognition, especially strengthening their comprehensive conception of PSS (Lazakidou & Retalis, 2010). The strategic PSS applications provided an available learning platform for more effective experimental approaches that could arise students' interest, allowing them to new access of gas chemistry knowledge; to take two functional examples, multimedia technologies have been used to develop animations (Su, 2008a, 2008b) and problem-solution map (Selvaratnam & Frazer, 1982; Selvaratnam & Canagaratna, 2008) to promote college students' conceptual learning in chemistry.

Instructional Assessments and Techniques

To set for learning efficiency, students' study motivation should be largely dependent on well-prepared course designs (Sperling *et al.*, 2003; Yang & Andre, 2003). In an important joint research, Sanger *et al.* (2013) proposed that the dynamic key point to assess instructional techniques for particulate gas chemistry should ask students in response to answering more conceptual questions correctly. The juxtaposed list of students' conceptual misunderstanding versus algorithmic problem-solving in this study served to illustrate their learning competence and assessed cognitive skills in gas chemistry (Salt & Tzougraki, 2011). For this reason, a well-designed program had contributed to students' identifiable advancements for different aspects of sufficient conceptual constructions integrated with strategic PSS applications of gas chemistry.

Next for the discussion of learning environment, students could put constructive modules within the scope of the following underlying premises in PSS implementations of gas chemistry. Students' understanding of constructive modules results in their search for more meaningful learning than they would perform in other ways. The perspective of students 'constructivism lies in the fact that knowledge is constructed in the mind of the learners. Here is a good example from scientific scholars (Ausubel, 1968; Calik *et al.*, 2010), who designed the fundamental constructivism with the principle priority of assessing what students know as the dominant force to learn and then instructing them to adjust cognitive knowledge correspondingly step by step. As an effective theory of formative learning, constructivism posits a fundamental procedure to construct knowledge for students' learning achievement. Also, two constructivist scholars Yore and Treagust (2006) maintained that most constructive knowledge could be traced back to the results of students' thinking abilities because they found that consequent ideas were separately constructed from the learners' existing-knowledge and from their social and cultural backgrounds. Consequently, the constructive principles had been developed into several interpretations of constructivism ranging from information processing, interactive-constructivist, and social constructivist to radical constructivist approaches (Yore, 2001), all of which offered students' favorable learning opportunities to think, develop more complex ideas, and reconstruct their conceptions. More knowledge could be seen as the constructive result of the way students think and construct new ideas from prior knowledge and new experiences in a socio-cultural context (Trumper, 1997; Yore & Treagust, 2006).

Table 1. Students' tentative understanding for gas chemistry between alternative conceptions (the wrong concepts in italicized words) and corrected ideas (the right concepts in bold-faced words).

The properties of gas A gas is a substance that is normally in a gaseous state at *all* temperatures and pressures (**suitable**). Gases are *not more easily* compressible than liquids (**more easily**). Gases have *higher* density than liquids and solids **(lower**). Gases occupy *a partial* volume of the container in which they are placed (**full**). There is a *smaller* distance between molecules in gases than in liquids or solids (**larger**).
Gas and the particulate nature of matter Particle ideas can be used to explain gas phenomenon in *macroscopic* terms (**microscopic**). The behaviors of gas particulate in motion or trajectory will *be not* affected by temperature (**be**). The behaviors of gas particulate in motion or trajectory will *be* affected by tank (**be not**).
Kinetic molecular theory of gases *Macroscopic* properties of gases are related to the kinetic motion of molecules (**microscopic**). The theoretic assumption for ideal gas molecules will be continuous in motions, with totally random and *imperfectly* elastic collisions (**perfectly**). Attractive *and* repulsive forces between gas molecules are negligible (**or**). The average kinetic energy of the molecules is proportional to the *Celsius* temperature (**absolute**).

One of the notable features for the fulfillment of strategic PSS applications, many innovative curricula have been developed to avoid learners' alternative scientific conceptions and to modify their pre-conception (Chambers & Andre, 1997; Mayer, 2013). This study develops a well-designed program of strategic PSS applications for accessing students' six functional learning activities and modifying conceptual changes in gas chemistry. To take an inquiry of students' conceptual changes, Cracolice *et al.* (2008) emphasized that students had different levels of chemistry reasoning and conceptual skills that enlarged the gap between conceptual understanding and algorithmic questions. Thus, a well-designed program of strategic PSS applications in gas chemistry would decrease these gaps, facilitate conceptual construction, and promote problem-solving abilities. Integrating strategic PSS applications with constructive gas chemistry learning would promote reasoning skills, conceptual understanding and algorithmic proficiency.

Problem of Research

We may an impersonal style should be used notice that it would be appropriate for exploring students' improvement of learning performances and validation of learning activities design as exemplified in strategic PSS applications. The development of this study is illustrated in two major purposes of strategic PSS applications: to make appropriate estimations of students' learning achievement and to find effective evaluation of students' learning attitude for building up and clarifying their individual conceptual understanding and algorithmic proficiency in gas chemistry.

Based on the above purposes, this study builds up two fundamental research questions:

(1) Will developments of strategic PSS applications for two group students' individual conceptual understanding and algorithmic proficiency more effective learning performances justify students' problem-solving performances in gas chemistry?

(2) To what extent will these strategic PSS applications upgrade the experimental group students' learning attitudes after their comprehensive practices and feedbacks?

Research Focus

The specific designs of students' learning performances accord both with problem-solving map for the calculation of gas pressure (seen in Figure 1) and with six major learning activities in the field of gas chemistry. This study adopted strategic PSS applications in six learning activities for operated-mind and cognitive learning in order to make comparisons of students' problem-solving skills with higher-order cognition and lower-order cognition (Zoller & Dori, 2002; Bark, Ben-Chaim & Zoller, 2007). Also for facilitating students' target learning, Table 2 presented their feedback of individual conceptual understanding and algorithmic proficiency in accordance with developments of six major learning activities.

Table 2. **Learning activities about gas laws chemistry developed in this study and their target concepts.**

Learning activity	Target concepts
1. What is the correct pressure?	• Pressure in open systems. Effects on pressure: • Force (F)effect • Area (A) effect
2. Measuring gas volume with an open-ended J tube?	• the temperature and quantity are held constant • pressure (P) effect • volume (V) effects • gas is easily compressible
3. A kinetic molecular theory	• the molecules or atoms are supposed to be ideal gases (because scientists held that ideal gases got attributes in motion continuously, totally and perfectly random for elastic collision.) • motions are continuous and totally random • perfectly elastic collisions with each other
4. Dalton's law of partial pressures	• each gas expands to fill the container • independent gases and no chemical reaction • each gas exerts its own partial pressure
5. Charles' law effect of temperature on volume	• the pressure and gas quantity are held constant • volume (V) effects • absolute temperature (T) effects • gas expends
6. Force of atmospheric pressure	• gas is dissolved in the water • pressure (P) effects

Methodology of Research

General Background of Research

We assume that both learning environment and module units are inseparable from the applications of PSS implementations. According to Selvaratnam and Canagaratna (2008), PSS implementation functionally helps students clarify concepts, promotes their intellectual skills and increases efficacy in chemistry learning. The conceptual understanding of constructivist learning would be employed to link the major theoretical framework with module units in this study; therefore, college students could construct cognitive knowledge in terms of six functional student-oriented activities in a favorable learning environment and integrate interactions between ideas and performance in gas chemistry.

Students' constructive conceptions of quantitative measures have been elaborated by many researchers (Tenenbaum et al., 2001; Loyens et al., 2009; Harrington & Enochs, 2009; Mensah, 2015). They took the functional examination of students' constructive engagement with the influential learning environment, such as dealing with arguments, discussions, debates; meeting conceptual conflicts and dilemmas; sharing ideas with others; measuring targeted materials toward solutions; organizing reflections and conceptual investigations; fitting students' needs; and making meaningful, real-life examples. The constructive PSS learning environment highlights students' dynamic and active knowledge in learners' minds step-by-step. In a research for the learning perspective, the constructive environment has facilitated students' attainment of learning achievements, which created the suitable learning programs by chemistry educators (Clark & Estes, 1998, 1999; Estes & Clark, 1999; Suaalii & Bhattacharya, 2007).

In this study, students were encouraged to recognize continuous conceptual changes between new knowledge and prior knowledge where they activate, evaluate, and modify their alternative or misconceptions. This PSS constructive development became an influential perspective on students' learning environment and activities in gas chemistry. In contrast to the traditional learning, there had been significant recent academic studies focused upon PSS applications in gas chemistry (Sanger & Phelps, 2007; Cracolice *et al.*, 2008). Two critical subjects, conceptual understanding and algorithmic proficiency in gas chemistry, had been proposed for functional PSS assessments by scientific researchers (Sanger & Phelps, 2007; Cracolice *et al.*, 2008). Cracolice *et al.* (2008) investigated different levels of conceptual reasoning skills in order to reduce the gap between algorithmic and conceptual questions of problem-solving abilities. To train students with well-developed reasoning skills would lower their reliance on rote learning in chemistry and upgrade their conceptual constructions. This study explored fundamental conceptual and algorithmic understanding with six learning activities in gas laws chemistry needed to develop a strategic PSS learning. Strategic PSS applications of conceptual maps involved conformity, clarity, and visualization; all these applications could help students organize, classify, analyze, and promote critical thinking, which was not only as a useful tactic, but also as a major interaction between students' conceptual understanding and learning environment (Schultz, 2008; Selvaratnam & Canagaratna, 2008). Students' participations upon learning activities through brain-storming presentations constituted the better environment for their cognitive understanding and application in gas chemistry.

All the above constructive modules and the suitable learning environment were designed to clarify students' conceptual understanding and algorithmic learning for the PSS applications of gas chemistry. Four effective characteristics of strategic PSS applications were illustrated as follows: firstly, to explore students' difficulties in comprehending the PSS relationship between conceptual understanding and algorithmic learning; secondly, to solve problems encountered by students in strategic PSS applications during the whole learning process of gas chemistry; thirdly, to corroborate students' understanding and performance in gas laws chemistry through six major learning activities; fourthly, to promote students' feedback for making links between critical thinking and intelligent analyses in gas chemistry.

Since the PSS implementations had become the new trends of recent innovative design, the focus of this study examined several current approaches in terms of functional strategic PSS applications with more conceptual understanding and algorithmic learning in gas chemistry for researchers (Cracolice *et al.*, 2008; Overton & Potter, 2008, 2011). In the target for the extended activities of strategic PSS applications and learning results, this study explored the accuracy of students' individual conceptual understanding and algorithmic proficiency and responses of their learning attitude in gas chemistry.

Sample of Research

All participants were Taiwan college students (ages from 17 to 19 years) selected from the first stage of overview of 165 members with pre-knowledge of basic gas laws chemistry. All students attending this class were required that empirical work would not do any harm for their ethical precaution and gave full informed consent in agreement with the process of experimental study (Taber, 2014). Before their enrollment for a general chemistry courses in a Taiwan technological college, students had to pass an entrance examination in order to register for courses in college. 165 college students with prior knowledge of general chemistry had to take the next intermediate qualification test for attending empirical study. Through two stages of qualification tests, minimum one third of students had passed the second trial of accumulated knowledge in general chemistry. At the end of final qualification test, 47 students with high cognitive skills who received full prior knowledge in average grade scores 70-80 could respond to more advanced chemistry performances for this research requirement. As for the formalization of group division, participants were assigned from the same 47 students of final qualification test after random stratification of classroom learning. For the research purpose of quasi-experimental approach in this study, participants were divided into two groups: the experimental group (24 students) instructed with the strategic PSS applications (including solution map for calculation of gas pressure, seen in Fig. 1 and six major learning activities with the timespan of six hours), and the control group (23 students) taught with traditional text teaching methods without any assistances of strategic PSS applications. All participants had to take pre-tests before they joined the experimental teaching. This study took a quasi-experimental approach for strategic PSS in gas laws chemistry. Both groups of students used the same syllabus of gas laws chemistry during the same semester and had the same instructor.

After completing the whole class, the experimental group students were asked to take post-tests and answer the learning attitude questionnaire. On the other hand, the control group is an independent variable counterpart the experimental group; the control group students who did not attend the experimental teaching of strategic PSS applications were only required to carry out the post-tests without doing any questionnaire.

Instrument and Procedures

Research design 1. Students' involvement of learning activity: Several underlying PSS principles had been proposed for activating the experimental group students' understanding of gas chemistry and their interactions with six learning activities as the main research designs. These strategic PSS applications and developments of target concepts were listed in Table 2 and discussed in the following six gas laws learning activities. Students should give their answers in traditional multiple-choice items instead of ordered multiple-choice items. The traditional multiple-choice items were suitable for assessing students' learning achievements in contrast to ordered multiple-choice items which gave specific statements in allotment with students' selected items for different scores to evaluate students' understanding levels (Briggs, Alonzo, Schwab & Wilson, 2006; Alonzo & Steedle, 2009; Hadenfeldt et al., 2013). In the first learning activity for the experimental group students, "What is the correct pressure?" it was asked to activate the gravity force (F) on the heel of a spiked shoe (seen Appendix 1 Q1) for the given force area (A) to find the correct pressure (P=F/A). Students were required to make correct answering of pressure measurement for three-fold PSS cognition in relation to pressure (P), area (A) and gravity force (F). In the second learning activity "How to measure gas volume with an open-end J tube," this instruction gave students more responses for adjusting suitable amounts of mercury into the apparatus which would be manifested in the increased pressure on the trapped gas (seen Appendix 1 Q 2). In their new recognition of chemistry knowledge to testify Boyle's law, students gradually came up with an inverse relationship between the pressure exerted on a quantity of gas and its volume in case of the temperature in a constant state. In the third learning activity "What is the kinetic molecular theory of Boyle's law?" this instruction made students get involved in explicit understanding about the kinetic theory during their experimental operation and observations. The compression of He atoms would decrease in volume and increa**s**e in pressure at the same time. This phenomena accounted for the change while He atoms bounced off the container walls with a certain frequency, they created a particular pressure (seen Appendix 1 Q 3), because the attribution of He atoms for container walls was closely link with perfect elasticity collision.

Research design 2. Students' fulfillment of learning activity: As for the fourth learning activity "How to apply Dalton's law of partial pressures," students should turn to the definition which states that in a mixture of independent gases, each gas expands to fill the container and exerts its own pressure (seen Appendix 1 Q 4). Thus the individual gas pressure could be called the partial pressure. This application provided students to assume their abilities for actual correct calculation of the partial pressure. In case of the fifth learning activity "What is the effect of temperature vs volume according to Charles' Law?" students developed their notion one step further to identify Charles' Law with the volume of a fixed amount of a gas at a constant pressure as being directly proportional to its absolute temperature (seen Appendix 1 Q 5). There is considerable validity for students to follow changes of balloon volume in accord with the increased temperature as long as the gas molecules begin to move faster. To take the sixth learning activity "Why does gas create a fountain effect when dissolved in water?" as an example, students got the impression to note when a small amount of water was introduced into a round-bottom flask by the rubber dropper, most of the HCl gas was dissolved into the water, which created a partial vacuum. This interesting phenomenon occurred because most gases obey Henry's law to render students' discoveries of the fountain effects sights (seen Appendix 1 Q 6).

All the above research designs of six gas laws learning activities highlighted the overall strategic PSS applications in the detailed course designs. Students' achievement test was compiled to include algorithmic and conceptual pair questions taken from Sawrey (1990), Nakhleh (1993) together with the final test designed by five chemistry professors to assess the validity of the achievement test. The Cronbach's α coefficient obtained for the total achievement tests was 0.790. After all students had finished studying the gas laws learning activities, they were asked to respond to 6 algorithmic and conceptual paired items (see Appendix 1, in all questions * represent correct answer).

Students' attitude questionnaire: For confirming the content validity, this study assessed students' attitude questionnaire with the advice of two eminent chemistry educators, two science philosophers and two educational psychologists to preview the survey and revise the final versions. Furthermore, in terms of the constructive validity, 165 copies of pre-tests were taken into consideration for factor analyses. The first result of factor analyses for the Kaiser-Meyer-Olkin (KMO) data (0.895) and χ^2 data (3377.928) of Bartlett spherical investigation proved to be significant, so factor analyses were deemed suitable for the attitude questionnaire. There were five aspects considered in main component analyses of the questionnaire. The initial Eigenvalue obtained was above 1.0 with an accumulative explanation variation of 71.85%. These Eigenvalues of five aspects were 1.247, 1.369, 2.089, 1.620, and 15.615. All findings of factor analyses were classified into five dominating dependent variables of learning attitude: Qa_1 (toward problem-solving map courses), Qa_2 (toward science instructors), Qa_3 (toward students' interests of participation), Qa_4 (toward self-evaluation), and Qa_5 (toward statistical results), and these five variables were designed for further PSS analytical developments. There were total 29 test items and their loading factor in this questionnaire (see Appendix 2). The Cronbachs' α values could be corresponded to 0.856, 0.835, 0.910, 0.884 and 0.924 as shown by internal consistency inspections. The total scale score of the Cronbach's α 0.917 reached the satisfactory degree of internal consistency in accordance to students' attitude. According to the research of Gay's reliability (1992), the result of coefficient reliability over 0.900 gave better indication of learning scale which confirmed the high internal consistency of this questionnaire.

Data Analysis

Students were assigned for scoring 6 pairs of achievement test items, with 16 points for correctly answering each paired test item, in case of 8 points for correctly answering half of each paired test item a or b, with 96 points for the total scoring. All statistical information acquired before and after the classes was carried on the file of SPSS 12.0 Windows software, to do the strategic PSS applications for students' analyses of learning achievement and attitude in t-test, covariance and one-way ANOVA.

Results of Research

During the process of strategic PSS applications, this study made quantitative results and their interpretation for students' learning performance. Quantitative results involved students' covariance analyses of achievement tests, accurate pairwise answering rates, and learning attitude. In case of responsive and answering results, students' interactions of 6 gas laws learning activities corresponded to their performances of conceptual understanding and algorithmic paired items. After students' involvements and practices of 6 gas laws learning activities, students would find out both quantitative and responsive understanding and assessments are complementary, not separate entities in their strategic PSS applications.

Covariance Analyses of Achievement Tests

From development of quantitative discussions, students' pre-test data were treated as covariate variables, post-test data as dependent variables, and divided groups as independent variables. An important quantitative result presented the homogeneity examination of the regression slopes to indicate that there existed no significant differences (*p*=.108) between the two groups of students through strategic PSS learning applications in relation to either independent or dependent variables. Because two group students expanded their assumptions of covariate variables analyses in response to the homogeneity examinations of the regression slope, all covariance were available for students to advance further analyses and to get final results of achievement tests. Table 3 showed that results of covariant analyses which displayed significant differences in post-test achievements between the experimental group and control group. It was noted that Cohen's (1988) experimental *f* value of 0.464 indicated a higher effect size. The adjusted mean scores of post-tests supplied that post-test scores of the experimental group students (72.00) were superior to those of the control group students (32.00), which confirmed the research assumption that experimental strategic PSS applications were better than those of traditional teaching which were in shortage of practices for cognitive skills and students' involvements of learning activities. All results of achievement t-tests clearly demonstrated that there were significant differences (t=3.008, *p*=.004) in the post-test achievements of the experimental group students in contrast to those of the control group students. Based on the above results for research question 1, different group students might have different learning proficiency for the same 6 pair-wise algorithmic and conceptual questions in their response of gas chemistry problem-solving performances.

Table 3. Summary of *F*-ratios, *p*-values, and effect sizes (*f*) for gas laws showing learning achievement in ANOVAs of post-tests.

Source	SS	df	MS	F –ratio	p-value	f
Group	656.338	1	1154.059	9.485**	0.004	0.464
Error	5353.744	44	121.676			

*** p< 0.01*

Students' Accurate Answering Rates

In order to follow the results of statistical analyses in Table 4, the experimental group students had more correct pairwise answering rates and average numbers (Ns) of PSS learning performances than the control group students in gas laws chemistry. As mentioned before, the experimental group students' correct conceptual answering rate (4/6) and average numbers (4Ns) in post-tests were superior to those of the pre-tests (2/6 and 2Ns). Meanwhile students' correct algorithmic answering rate (5/6) and average numbers (5Ns) in post-tests were also superior to those in the pre-tests (2/6 and 2Ns). In examining the control group students' correct conceptual and algorithmic answering rates and average numbers, both their pre-tests and post-tests made no significant differences (2/6 and 2Ns, shown in Table 4).

Table 4. Comparisons of correct answering rate in proportion to six pairwise items.

	Experimental group				Control group			
Correct pairwise	Pre-test		Post-test		Pre-test		Post-test	
comparisons	C	A	C	A	C	A	C	A
Rate	2/6	2/6	4/6	5/6	2/6	2/6	2/6	2/6
Pairwise Ns	2	2	4	5	2	2	2	2
Total score	32		72		32		32	

After taking into consideration all finding results from learning achievement tests and accurate pairwise answering rates, this study demonstrated that the strategic PSS learning applications proved to encourage more effective learning performances as demonstrated in students' post-test score analyses. As for the strategic PSS learning applications of the experimental group students, there were more significant differences shown between the pre-tests and post-tests in gas laws chemistry. The reason for the differences lay in the fact that the PSS strategic implements in conjunction with learning environment not only facilitated students' conceptual recognitions, but also built up correct algorithmic learning for gas chemistry. The PSS strategic implements of gas laws chemistry accorded available resources for students to analyze, provide and receive feedback, solve problems, compare, criticize, and link symbols and abstract conceptual relationships for accurate recognizable analyses.

Table 5. Mean scores (M), standard deviations (SD), and Cronbach's α for the experimental group students' learning attitude.

Subscales	**M**	**SD**	**Cronbach's α**
Q a_1	3.71	0.554	0.868
Q a_2	3.67	0.837	0.873
Q a_3	3.65	0.505	0.875
Q a_4	3.62	0.494	0.872
Q a_5	3.71	0.453	0.850
Total scale	3.67	0.537	0.917

Statistical Analyses of One-way ANOVA

The overall summary of students' learning attitude with F-ratios, *p*-values, and *f* values from ANOVA post-tests was proposed for assessing experimental group students' performances in Table 6. The basic feature required that all the experimental group students had to complete the same learning attitude survey after their performances in gas laws chemistry. The blocking variable for students' disposition toward chemistry learning stemmed from a series of ANOVA and combined samples. Most significant factors were fit together in determining students' learning disposition toward gas laws chemistry. The Cohen's (1988) effect size (*f*) was related to the dominant index for different variants in students' learning behavior after strategic PSS applications. The effect sizes with the range between .30 and .49 demonstrated different levels from medium to large in Table 6. The dependent variables Qa_1, Qa_3 and Qa_4 in Scheffe's post hoc comparisons indicated students had expressed more learning attitudes in "positive" orientations than those in "neutral" or "negative" ones, and more "neutral" than those in "negative" ones.

Table 6. Summary of *F*-ratios, *p*-values, and *f* value for learning attitude in ANOVAs post-tests.

Experimental Course	Blocking Variable	Analysis of Variance	Attitude				Measure
			Qa_1	Qa_2	Qa_3	Qa_4	Qa_5
Gas laws chemistry	Disposition toward Chemistry (positive, neutral, negative)	*F-ratio*	5.183	2.035	5.029	3.445	2.756
		p-value	0.010*	0.143	0.011*	0.041*	0.075
		f	0.49	0.30	0.48	0.40	0.35
		Scheffe	1>3, 2>3		1>3, 2>3	1>2, 1>3	

$p < 0.05$

Students' Responsive Results

The correct distribution of pairwise answering was presented for both experimental group students' conceptual and algorithmic items in Table 7. All students in the experimental group gave correct answers for Item 1 and Item 2 in pre-tests and post-tests as shown in Table 7. They could clearly understand conceptual and algorithmic items related to gas pressure and Boyle's law. A correct response to Item 3 assumed that the He atoms were ideal gases whose motions were in continuous, totally random and perfectly elastic collision. The key notion for He atoms were very difficult to liquefy, so these atoms bounced off the container walls with a certain frequency, to create a particular pressure. While the volume of the atoms He was decreased from 2L to 0.5 L at 25 , the pressure increased the amount 33% in more collision frequency with the container walls indicated by the kinetic molecular theory. Consequently, the correct answer for Item 3a was A (4 atm, consistent with the new volume of 0.5L) and the correct answer for Item 3b was B. Not up to one tenth students in the total number gave correct answers for Item 3a and 3b in the pre-test. These correct answers of Item 3a and 3b proved that students did not have any full conception of the kinetic molecular theory. However, the experimental group students understood the applications of ideal gases and correctly answered items 3a and 3b in the post-tests after their strategic PSS learning.

Table 7. Distribution of experimental group students' correct answers for both conceptual and algorithmic items.

Item	Pre-test		Post-test	
	Algorithmic(a)	Conceptual(b)	Algorithmic(a)	Conceptual(b)
1	V	V	V	V
2	V	V	V	V
3	X	X	V	V
4	X	X	X	X
5	X	X	V	V
6	X	X	V	X

Note: V is correct answer; X is incorrect answer.

Item 4 gave the partial pressure tests of Dalton's law, in which each gas could exert its own pressure and behave independently of other gases. The idea that any component (He, N_2, O_2 or CO_2) of gases in a mixture filled the container while expanding and exerts a distinctive partial pressure was illustrated in Appendix 1 Q4. Not up to one sixth of the students qualified in number could correctly answer 4a and 4b in Item 4, because the most frequent misconception in Item 4 was most students failed to recognize that the total pressure was equal to the each partial pressure exerted by the separate gases. Hence, for the system in equilibrium as shown in Appendix 1 Q4, the total pressure was 1.0 atm. The correct response to 4a in Item 4 was (D), and 4b in Item 4 was (A). Not up to one tenth of the students in the total number correctly responded to 4a and 4b in Item 4 in their pre-test and post-test. Most students' responses for conceptual chemistry problems confused with blurry algorithmic answers could be traced back to their misconceptions of Dalton's law of partial pressure.

According to Charles' Law in Item 5, the volume of a fixed amount of gas at a constant pressure is directly proportional to its absolute temperature. The correct answer for 5a in Item 5 was (B) and the correct answer for 5b in Item 5 was (A). Very few students correctly answered 5a and 5b in Item 5 in pre-tests. These responses showed that students did not have deep existing knowledge of Charles' Law. However, after integration of PSS applications, the students in the experimental group could comprehend Charles' Law. This accounted for their understanding of the relationship between balloon volume and absolute temperature by the kinetic molecular model. Therefore, students could correctly answer 5a and 5b in Item 5 in the post-tests.

To answer Item 6, students found that the dissolving of hydrogen chloride gas in water caused a decrease in the pressure in a round-bottom flask. The same result was demonstrated in water as for NH_3 gas (Lin, Cheng and Lawrenz, 2000). Thus, the brilliant fountain existed into being when the pressure was lower than the one in the Erlenmeyer flask, as shown in Appendix 1 Q6. Very few students could correctly answer 6a and 6b in Item 6 in the pre-test. These responses manifested that students did not have profound concepts of atmospheric pressure, at the time the HCl gas was dissolved in the water the round-bottom flask could create a partial vacuum. However, after the strategic applications in Item 6 of the post-tests, the experimental group students could correctly answer 6a and 6b in their response for the understanding of the partial vacuum.

All above students' responsive results of Item 1 to Item 6 were related to their conceptual understanding and algorithmic proficiency for the research question1 of gas chemistry. In view of assisting students' problem-solving, the time spent is worthwhile because it ensures mental effort by students, and also illustrates the clear comprehension of six pair questions on the algorithmic and conceptual problem solution. It is functional to help improve problem-solving abilities of students and to build their gas chemistry knowledge and self-confidence. With the text designs of problem-solving maps and six major learning activities, students not only have learned much theoretical knowledge but also practiced step by step in formulating clear conceptions of gas chemistry and substantial understanding of problem-solving skills.

The impact of strategic PSS applications presents multi-advantages for college students' gas chemistry learning. Functional utilization of strategic PSS applications designed with six major learning activities would upgrade students to develop problem-solving skills and clarify their conceptual understanding and algorithmic learning in response to kinetic molecular theory for both Boyle's law and Charles' Law. The more strategic PSS applications college students attained, the better implementations learning achievements and attitudes would be manifested in their problem-solving skills of the effective chemistry approach.

Discussion

This research analyzed Taiwan college students' gas chemistry understanding for the strategic applications of problem-solving skills with two module designs of problem-solving maps and six major learning activities. It was critical to be noted that not only traditional teaching methods should be included in students' concept understanding but also more implementations should have done for the consequent guidance of literature analyses. Scholars found that students' primary dilemma of chemistry learning might be attributed to their authentic access without integrating cognitive skills with their fundamental understanding of chemistry concepts (Sanger, 2005; St Clair-Thompson *et al*., 2012). Gas particulate nature of matter and kinetic molecular theory of gases were all related to complicated conceptions which often widened students' identification for more alternative learning (Kautz et al., 2005; Lin et al., 2000; Nurrenbern & Pickering, 1987; Pickering, 1990; Sanger et al., 2013). To make students' effective learning access and involvements, this study incorporated major extended learning texts with two module designs for the substantial understanding of gas chemistry. With the aim to facilitate college students' learning cognition, this study strengthened especially their comprehensive PSS conception which provided an available learning platform for more effective experimental approaches (Lazakidou & Retalis, 2010). Two prototypes as functional examples, multimedia technologies to develop animations (Su, 2008a, 2008b) and problem-solution map to conduct conceptualizations (Selvaratnam & Frazer, 1982; Selvaratnam & Canagaratna, 2008) contributed students' advancements of new access of gas chemistry knowledge and conceptual learning of strategic PSS applications.

This study analyzed that the link of two group students' integration with the same pre-knowledge backgrounds as variant gave a distinctive perspective of learning performances. Thus it was significant that the initiative learning texts for both two group students had played the crucial role in their formative understanding of gas chemistry. Two group students' diverse acquisition of learning texts determined their comprehensive dexterity of strategic applications. On the whole, the control group students who were instructed with traditional teaching methods without strategic applications had made little impact upon the subsequent understanding and performances of gas chemistry. The final results of these strategic PSS applications justified the imprint of understanding and performances of gas chemistry in favor of the experimental group students rather than the control group students. Although the discussion of Chung (2015) and Uzuntiryaki Kondakci and Senay (2015) referred to students' learning strategies would result in higher levels of chemistry learning self-efficiency for more performance of cognitive skills, the previous findings of strategic PSS applications in this study placed much emphasis on students' step-by-step encounters of individual conceptualization and algorithmic proficiency.

Researchers of chemistry education had reported the same responsive learning results for functional learning activities of these PSS strategies (Sanger & Phelps 2007; Sanger *et al.*, 2013). For example, Sanger et al. conducted two experimental activities with the goal of activate schema designed in students' responsive results of the behavior and properties of gases (Sanger *et al.*, 2013). Subsequently, these results came up with the responsive learning results of strategic PSS applications for assisting students' individual conceptual understanding and algorithmic proficiency in gas chemistry. They felt that strategic PSS applications linked with problem-solving maps and six functional learning activities could be beneficial for their understanding of chemical concepts and up to more high-level algorithmic learning followed by these scholars' demonstrations (Zoller & Dori, 2002; Barak *et al.*, 2007; Salt & Tzougraki, 2011).

Furthermore, major results of students' achievement t-tests clearly demonstrated significant differences in the post-tests of the experimental group students in contrast to those of the control group students. After taking into consideration all finding results from learning achievement tests and accurate pairwise answering rates, this study demonstrated that the strategic PSS applications proved to encourage more effective learning performances as demonstrated in students' post-test score analyses. Based on both the statistical analyses of learning attitude questionnaire, the experimental group students witnessed that they had taken a more active participation of learning attitude in gas chemistry. The advocative dominance of learning attitude has been an important role in science teaching and learning. According to many research studies (Zahorec et al., 2014; Nasr & Soltani, 2011) some attitude factors would make students' learning achievement more positive. Many learning advantages presented in this study could link strategic PSS applications with gas chemistry texts which could be fully embedded in the above six functional learning activities and problem-solving maps for assessing college students' learning achievement and attitude. The findings in this research justified that the more positive students' learning attitude got, the better learning achievement they attained.

Not surprisingly, there also appeared a number of limitations in this study. Students' samplings of involvement were only limited in the experimental group students, not including all students, but these samples were representatives of case studies, to conduct the number of samplings through two stages of intermediate qualification tests. In spite of the above research results, readers were reminded that they should not be over generalized beyond the context and limitations of this study. Continuing efforts would be needed to confirm further approaches to fulfill and solve complex, open-ended problems with longitudinal academic developments of strategic PSS applications in the future.

Conclusions

Based on the above research findings and discussions, it could be concluded that the strategic PSS applications encouraged students had more effective learning performances and active participation of learning attitude. With the emphasis on step-by-step encounters of individual conceptual understanding and algorithmic proficiency, students attained more positive learning attitude and better learning achievement. Students' learning performances, in turn, played a contributory role in scrutinizing and formulating their cognitive understanding which served as the beneficial assessment of strategic PSS applications for problem-solving maps and six functional learning activities. Affiliated with implements of the substantial environment, students manifested a new advancement of self-performed modules in their feedback and intelligent analyses. The positive implications of these finding had a direct bearing for both teaching and learning because the developments of strategic PSS applications contributed to be increasingly popular pedagogies in undergraduate chemistry education. To sum up, strategic PSS applications marked a significant improvement of students' learning performance to build their deductive abilities, and at the same time to construct useful learning basis in gas chemistry. Aided by multi-functional skills and practical modules, students could not only foster individual creativity but also promote more positive learning performances in their fulfillment of problem-solving skills. For the limitation of the main subject, further studies will be consistent with extending students' different learning performances of chemistry understanding in the future.

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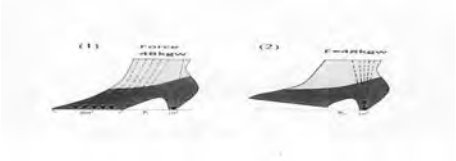
Appendix 1--The algorithmic and conceptual pair questions

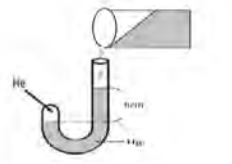
1. In the following two figures, the 48 kg woman put on her shoes with the heel area of 30cm^2 and the spike area of 1cm^2 to perform different assessments of two pressures. We use the formula P=F/A, and the words Pressure (P) to signify the amount of force (F) for the given area (A). If the 48 kg woman put all her weight on the spike area instead of both heel area and spike area, she would get two different pressures-- the pressure P_2 ((figure (2), on the spike area) and the pressure P_1(figure (1),on both heel area and spike area). What is the correct measurement for the pressure of the 48 kg woman?
   a) Which is correct answer for the pressures on her shoes between P_1 and P_2 in the following two figures?
      (A) P_1=1.80 Kgw/cm^2 (B)* P_2=48 Kgw/cm^2 (C) $P_1 = P_2$ (D) None of above is correct
   b) What reason is your choice for answering the above question a?
      (A) Both the area and pressure for the same force did not have any effects (B) When the area got greater, the pressure for the same force became much larger (C)* When the area got greater, the pressure for the same force became much smaller (D) None of these reasons



2. According to Boyle's law, there appeared an inverse relationship between the pressure exerted on a quantity of gas and its volume if the temperature would held constant. The addition of giving more mercury into the apparatus J tube as the following figure, would cause the trapped gas He to be compressed. When additional mercury got added to the J tube at 25 and h (mercury height) was38cm, the volume for gas He became 8.0 mL.

a) What volume of the trapped gas He would be at the same atmospheric pressure?
    (A) 4 (B) 6 (C) 8 (D)* 12 mL

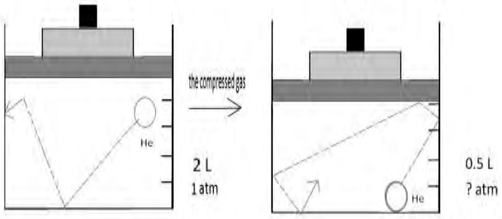
b) Which statement of the following reasons would be correct about the above question a? (A)*****The increase in pressure would cause a reduced volume (B) The pressure was proportional to the volume (C) The increase in pressure would cause a small increase in volume (D) None of these reasons



3. In the following two figures, the atoms He bounced off the container walls with a certain frequency to create a particular pressure. According to the kinetic molecular theory, the atoms or molecules became ideal gases to be attributed in motion continuously, totally random and perfectly for elastic collision. When the volume of the atoms He was decreased from 2L to 0.5 L at 25°C, the pressure would frequently increase in the atoms He collision with the container walls.

    a) Which of the following choice would be the correct pressure of the compressed atoms He?
        (A) *4 (B) 3 (C) 2 (D) 1 atm

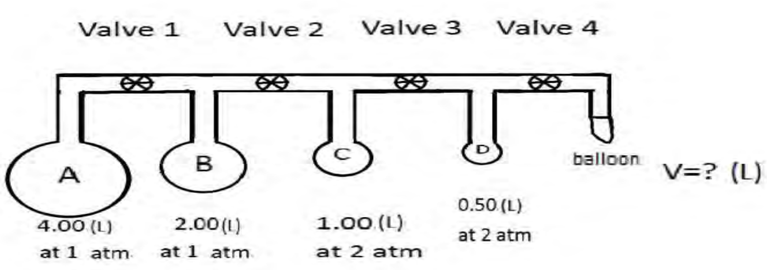
    b) Which statement of the following reason would be correct answer for the above question a?
        (A) Gas volume would became the function of temperature (B)* Gas molecules underwent elastic collisions with each other and with the container walls (C) The numbers of the atoms He would increase in the process of collisions (D) The atoms He would not be moved at random and in the straight-line motion.



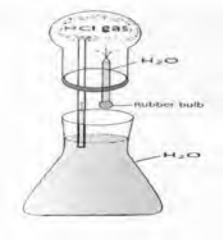
4. According to Dalton's law of partial pressures, each gas would expand to fill the container and exert its own pressure in a mixture of independent gas, and the individual gas pressure would be called a partial pressure. In the following apparatus, gas A tank (He), gas B tank (N_2), gas C tank (O_2), gas D tank (CO_2) and balloon were initially separated as shown below. When four valves were open, four gases – He, N_2, O_2 and CO_2 – quickly mixed in complete condition. Assumed that the temperature would remain at constant 25°C.

    a) Which of the following would be correct answer for the gas volume to be remained in the balloon at 1.0 atm of the gas mixture system?
        (A) 4.5 (B) 3.5 (C) 2.5 (D)* 1.5 L

    b) b. Which statement of the following reason would be correct answer for the above question a?
        (A)* The partial pressure of He would be larger than N_2 (B) The partial pressure of N_2 would be larger thanO_2 (C) The partial pressure of CO_2 would be larger than N_2 (D) The partial pressure of He would be smaller than CO_2



5. According to Charles' Law, the volume of a fixed amount of a gas at a constant pressure would be directly proportional to its absolute temperature. The balloon had the volume of 2.0L at 0°C. When the balloon got warmed up through the temperature interval from 0°C to 80°C, there existed not any changes in the gas presure. The balloon volume continued to increase in the linear function as the temperature got heightened.
   c) Which of the following would be the approximate volume of the balloon at 80°C?
      (A) 4.6 (B)* 2.6 (C) 1.3 (D) 0.7 L
   d) Which statement of the following reason would be correct answer for the above question a?
      (A)* When the balloon was given more heat, the gas molecules gained kinetic energy and began to move faster than when they were at the low temperature (B) When the balloon was given more heat, the gas molecules gained potential energy and began to move faster than when they were at low temperature (C) When the balloon was given more heat, the gas molecules lost kinetic energy and began to move slower than when there were at low temperature (D) When the balloon was given more heat, the gas molecules gained potential energy and began to move slower than when there were at low temperature.
6. Consider the apparatus shown below; the round-bottom flask is filled with hydrogen chloride gas. The Erlenmeyer flask is filled with water and connected to the round-bottom flask with long glass tubing. When a small amount of water is introduced into the by squeezing the rubber bulb of the dropper, water is squirted upward out of the long glass tubing and into the round-bottom flask.
   a) Which of the following would be the pressure of the round-bottom flask as a small amount of water was introduced into flask by rubber bulb (about 60% HCl gas was dissolved in the water)?
      (A) 304 (B)*456 (C) 760 (D) 1064 torr
   b) Which statement of the following reason would be correct answer for the above question a?
      (A) When the HCl gas would not be dissolved in the water, the round-bottom flask created an absolute vacuum (B) When the HCl gas would be dissolved in the water, the round-bottom flask created an absolute vacuum (C) When the HCl gas would not be dissolved in the water, the round-bottom flask created an larger pressure (D)* When the HCl gas would be dissolved in the water, the round-bottom flask created a partial vacuum.



Appendix 2-- Factor Loadings of the attitude questionnaire.

Subscale	Items	Factor Loading
Qa_1	1. Curriculum incorporation of strategic PSS applications is my ideal way of studying.	.563
	2. I can do my best in strategic PSS applications of curriculum.	.638
	3. Incorporation of strategic PSS applications into courses helps me a lot in learning.	.655
	4. Incorporation of strategic PSS applications into courses provides different fields in technology subjects.	.519
	5. I take activities related to all strategic PSS applications courses.	.470
	6. Incorporation strategic PSS applications into courses gives me full confidence in the learning process.	.790
	7. I pay attention to incorporation strategic PSS applications into texts and assessments.	.742
Qa_2	8. Teachers are satisfied with my learning attitude for strategic PSS applications.	.725
	9. Teachers always encourage me and make me able to be actively Involved in a strategic PSS applications of curriculum.	.741
	10. Teachers often care much about my learning achievements and results.	.751
	11. Teachers in charge of strategic PSS applications of courses are inspiring and full of animated power.	.650
	12. Teachers have different approaches for various levels of students.	.664
Qa_3	13. Our classmates participate in all strategic PSS applications of activities.	.482
	14. Classmates are helpful partners to solve problems in strategic PSS applications of learning.	.733
	15. Classmates develop correct learning habits for strategic PSS applications.	.582
	16. Classmates respect teachers of strategic PSS applications of courses.	.740
	17. Classmates have discussions in strategic PSS applications of learning.	.725
Qa_4	18. I can make a well-planned strategic PSS application of study.	.610
	19. I can do both a preview before and a review after strategic PSS applications of learning.	.702
	20. I can study diligently in strategic PSS applications of learning.	.694
	21. I can do my best to finish teachers strategic PSS applications of assignments.	.684
	22. I think strategic PSS applications of courses can upgrade my scores.	.674
Qa_5	23. Strategic PSS applications of learning improves my solving abilities in quantitative exercises.	.503
	24. Strategic PSS applications of learning increases my learning abilities for scientific concepts.	.602
	25. Strategic PSS applications of learning makes me have a desire to learn more relevant knowledge.	.488
	26. Strategic PSS applications of learning broaden my interests to learn more.	.827
	27. Strategic PSS applications of learning inspires me to pursue the willingness I have for new knowledge.	.565
	28. I think using strategic PSS applications in class can hold my attention.	.742
	29. I think using strategic PSS applications in class is helpful to my learning.	.523

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