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TACTIC FULFILLMENTS OF THREE CORRELATIONS FOR PROBLEM-SOLVING MAPS AND ANIMATED PRESENTATIONS TO ASSESS STUDENTS' STOICHIOMETRY PERFORMANCES

King-Dow Su

Abstract. *This research focuses on students' tactic assessments of 3 correlations with illustrated 2-step strategic map and animated presentations in stoichiometry. The participants were divided into 2 learning groups: the experimental and the control group by quasi-experimental approach. Most of all, experimental group participants have been contingent on critical performances of thinking capabilities in accordance with tactic fulfillments of 3 correlations helpfully. In contrast with statistic findings of post-tests, experimental group participants get more formulated goals of individual learning in answering 5 algorithmic and conceptual pairs of achievement test items than those of control group participants. Students' shift of reasoning from model-based to case-based requires them to explore an effective mental cognition and responses for full-fledged performances of problem-solving skills. After tactic fulfillments for 3 study objectives of visualized developments, experimental group participants have upgraded a distinct learning accumulation and project-based feedback at their best learning performances.*

Key words: *problem-solving, stoichiometry, three correlations, tactic fulfillments.*

King-Dow Su
Hungkuo Delin University of Technology, & Chung Yuan Christian University, Taiwan

Introduction

An elaborated constituent of three correlations is designed to integrate problem-solving skills into tactic fulfillments of learning assessments. Tactic fulfillments of three correlations, illustrated in students' mental thinking of algorithmic (ALG), lower-order cognitive skills (LOCS), and higher-order cognitive skills (HOCS) could contribute much to essential learning objectives for college students' problem-solving implements (Cracolice, Deming & Ehlert, 2008). The importance of the three correlations, an explicative mental mode from the basic algorithmic proficiency developed into in more promoting thinking and elaborated critical learning, is evident in constructing students' performances of problem-solving maps and animated presentations. As scholars' implementation of problem-solving developments will provide students with independent thinking and effective chemistry learning performances, it is critical to assess their competences for cognitive creativity and learning potentialities (Barak, 2012; Lazakidou & Retalis, 2010; Zoller, Dori & Lubezky, 2002). To develop algorithmic learning and cognitive skills for problem-solving fulfillments is urgently critical (Cooper, et al., 2008; Selvaratnam & Canagaratna, 2008) as exemplified in the following introductory developments for participants to assess their role in the tactic-based approach of the three correlations.

Up to now, many stoichiometry problems have still remained a dynamic challenge for academic studies and college students' learning performances (Sanger, 2005; Tang, Kirk & Pienta, 2014). Because students' confrontations with problem-solving often result in achieving the algorithmic understanding of chemistry more readily than the conceptual proficiency of chemistry, their acquirement of problem-solving skills would narrow the gap between interactive processes and learning objectives (Fischer et al., 2014; Nakhleh, Lowrey & Mitchell, 1996; Sanger, 2005). Instructors

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could assess students' chemistry performances through constructing the newly-designed fulfillments of the three correlations to be implemented from algorithmic proficiency to critical conceptualization for an in-depth chemical conceptual understanding. The current motivation to integrate the three correlations, ALG, LOCS, and HOCS into tactic fulfillments of major thinking skills would clarify students' concepts, principles, laws, and assessments toward problem-solving understanding in chemistry (Domin & Bodner, 2012; Sanger & Phelps, 2007; Sanger, 2005; Sanger, Campbell, Felker & Spencer, 2007).

As in many cases of students' dilemma learning, when they had done their best to finish all the exercises, yet they still confined in depression not to construct authentic chemistry knowledge (Siburt, Bissell & Macphail, 2011). For instance, stoichiometry problems are difficult for students to solve, not only in making balance for chemical equations, dimensional analysis, and conversion between moles and grams but also in building mathematical operations based upon comprehensive understanding (Wagner, 2001). Students' failed responses to abstract and complicated problems in stoichiometry (Davidowitz, Chittleborough, & Murray, 2010) might be attributed to their lack of authentic understanding for fundamental chemistry concepts and tactic assessments (Sanger, 2005; St Clair-Thompson et al., 2012; Fischer et al. 2014; Tiruneh, Verburgh, & Elen, 2014; Tiruneh et al. 2016). To search for the educational perspective of building-up cognitive skills, scholars have offered several academic researches to strengthen the importance of college students' problem-solving performances. These functional research skills include tactic assessments with integrated communication technologies (Su, 2008a, 2008b), two-step strategic map (Selvaratnam & Frazer, 1982; Selvaratnam & Canagaratna, 2008; Su, 2016), problem-solving maps (Liu, Lin & Tsai, 2009; Selvaratnam & Canagaratna, 2008), and chemical dynamic reaction figures (Schultz, 2008; Su, 2013). All propounded visual models and tactic implementation of the above researches can help build up students' constructive learning of problem-solving developments step-by-step (Cracolice, Deming & Ehlert, 2008; Overton & Potter, 2008; Siew & Mapeala, 2016).

From the review of previous main researches, students' mastery of tactic assessments imposes a coherent conduct upon the three correlations in accordance with their empirical problem-solving skills and presentations. The accumulations of two group participants' problem-solving performances are conceived as the requisition of tactic assessments related to cognitive levels of conceptual understanding. According to students' creative abilities, this research sets up to emphasize tactic assessment of the three correlations; namely, there are correlations toward algorithmic (ALG), lower-order cognitive skills (LOCS) and higher-order cognitive skills (HOCS), which serve to widen students' conceptual learning for assessing their problem-solving performances. The shift of reasoning from model-based to case-based allows students have the mental acquisition to explore their three correlations in the full-fledged performances of problem-solving skills. Among other things, most students' mind perceptions towards different visual models acquired from two-step strategic map and communicative animations will be full of individual performances in junction with tactic assessments extended to the three correlations of ALG, LOCS and HOCS. Consequently, this research aims at the guidance of student-centered assessments in stoichiometry problem-solving.

Objectives of the Research

From empirical tactic assessments, students' mastery of the three correlations strengthens their learning objective and curriculum engagement in the acquisition of cognitive knowledge. How can students' cognitive learning be guided from model-based reasoning to case-based reasoning through effective provable set-up? To adopt students' ALG, LOCS and HOCS problem-solving assessments, this research sets up three functional objectives of stoichiometry learning performances in the following way:

1) To visualize college students' mental cognition for building individual learning achievements of ALG, LOCS and HOCS;
2) To propose experimental group students' role engagement throughout detailed applications of two-step strategic map and animated presentations;
3) To coordinate experimental group students' case-based learning attitude for externalizing their mental feedback related to learning objectives.

Research Questions

The motivation of this research was guided by three major research questions: (1) What individual learning achievements could be attainable for students' best mental cognition? (2) How did students apply role engagement to upgrade tactic fulfillments after their cognitive response of the three correlations to two-step strategic map and animated presentations? (3) What case-based learning attitude was best contrived to facilitate experimental group students' feedback in their acquired knowledge of problem-solving stoichiometry? This research was credited with assessing students' mental cognition for individual learning achievements of ALG proficiency and LOCS and HOCS; in other words, after examining their cognitive response to two-step strategic map and animated presentations, students' reasoning approach has been shifted from model-based reasoning to case-based reasoning to arrive at the manipulated tactic fulfillments of both the second and the third objectives.

Methodology of Research

General Background

Students' cognitive learning could be best accentuated upon their constituents of problem-solving skills shifting from model-based reasoning to case-based reasoning. Christian & Talanquer (2012) gave an expository approach manifested for students of undergraduate program. Their research assessed different reasoning in which students solved the problems in firstly constructing models of the situations in a problem and then using their experiences and performances to solve the problem in case. Both two-step strategic map and animated presentations of stoichiometry were constructed and designed operationally as students' tactic assessments for the three correlations of ALG, LOCS and HOCS in this research. The research methodology focused on students' problem-solving performances in the inquiry of visual models and feedback attitude of individual learning. This research was mostly based on observations of students' cognitive understanding rather than the simple empirical formula assessments. It was predicated that quasi-experimental method had been planned to examine two group students' differential learning performances after the tactic assessment process.

Context and Participants

The selection of context and participants were implemented with a quasi-experimental approach to assess problem-solving performances in stoichiometry for two group students – the experimental group and the control group. The practicality of choosing with accessible participants was considered in this research as a two-stage selection; and the eligible participation was also selected out with the careful qualification test. The participation was limited due to the aim of research requirements and guided texts of the selection test. First of all, the research participants were considered of 165 engineering students from Taiwan Technology College and chosen from the pilot study for the first stage of qualification tests with the pre-knowledge of basic chemistry. From the next process of sample participants, no less than one third of students had passed the second trial in their accumulated knowledge of general chemistry. Up to the end of the final qualification, only a small number of 47 students got average grade scores from A^- to B^+ with more advanced chemistry performances for participant tests as the same required sample of previous research by Su (2016).

To fit in more detailed requirements of research visual models, this research divided qualified participants into two groups to take part in the following experimental assessment. The experimental group (24 students) was instructed with strategic applications including both the two-step strategic map (seen in Figure 1) and animated presentations of stoichiometry (seen in Figure 2). The control group (23 students) was taught with traditional text teaching methods without any assistance of visual models. All these qualified participants were clearly aware that their empirical work would conform to ethical precaution in so far as secrecy and publication code is concerned (Taber, 2014). The students from the two eligible groups, who had finished the pre-tests individually, had to take the next experimental assessments. The students of both groups were asked to complete the same syllabus in one-semester and the same stoichiometry instructor. During their whole learning process, the experimental group students were required to do post-tests and learning attitude questionnaires. There was no need for the control group students to go into the experimental teaching of visual models after doing their detailed post-tests without any questionnaires.

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Guided Learning Program of Visual Models

Two representational visual models were integrated into the main guided learning program for students to get involvements of the two-step strategic map and animated presentations. Students' performances were accessible in their constructing exercise of mind through model-based reasoning to case-based reasoning. Their resourceful mind might be applied to visualize things together for a model-based reasoning for the first stage construction of problem-solving. It worked out as a creative agency to solve the imposed case reasoning in an analytical way for the second stage construction of problem-solving. Students' ingenious mind might do wonder with the shifting from model-based reasoning to case-based reasoning as the following way:

The first representational visual model -- the two-step strategic map was based on Ausubel's constructive learning theory (2000) to set up a new approach of two-step strategic map (shown in Figure 1) for students' constructing two-fold visual learning framework. The initial procedure of the two-step strategic map was derived from the author's design of the overall step-by-step construction. To guide students follow up the whole visual models, this research started with the step one for the finding of weight product ($W_{product}$), through conversion factors to figure out the exact calculation of the rated proportion for $Mw_{product}$ x $W_{reactant}/Mw_{reactant}$ (judged from the known statement that $W_{reactant}$ is the weight of reactant, $Mw_{product}$ is the molecular weight of product and $Mw_{reactant}$

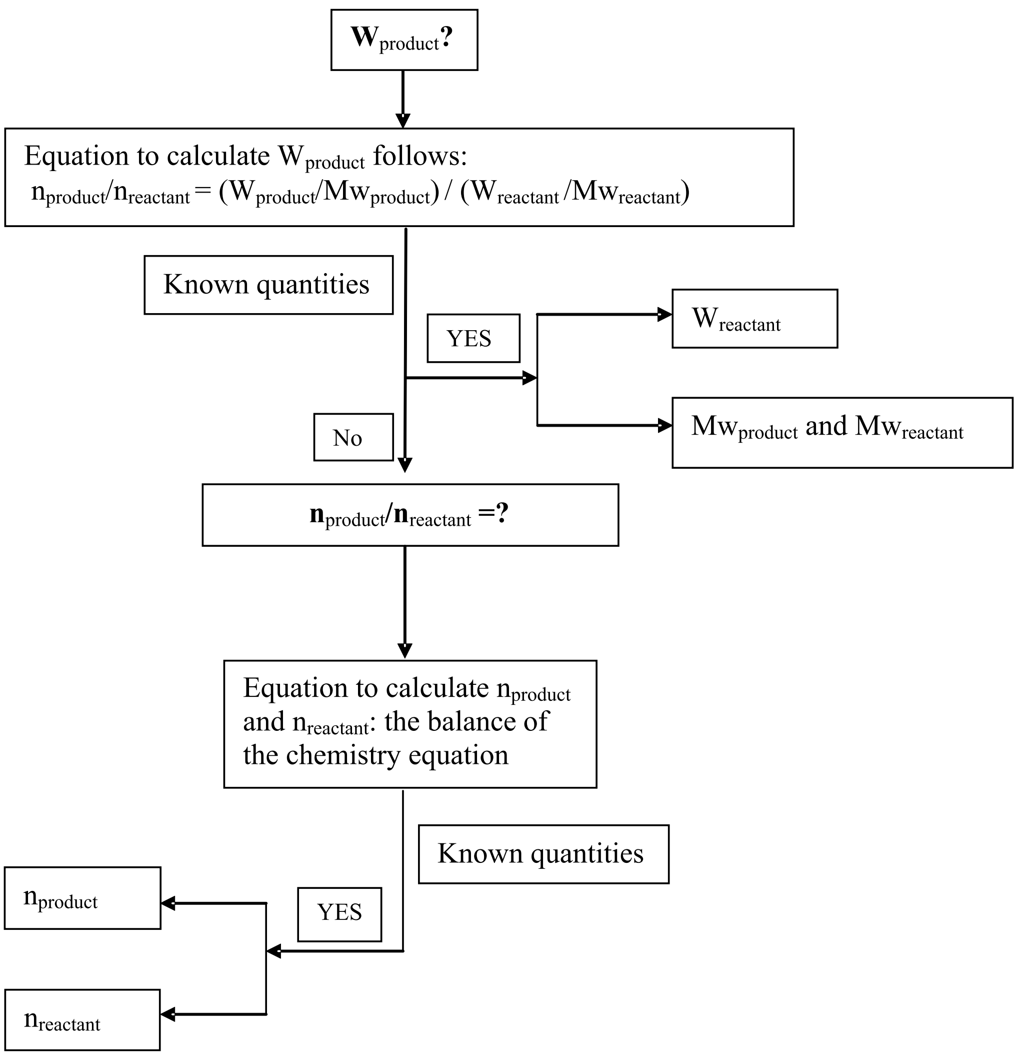

Figure 1: Two-step strategic map of constructive problem-solving in stoichiometry solutions.

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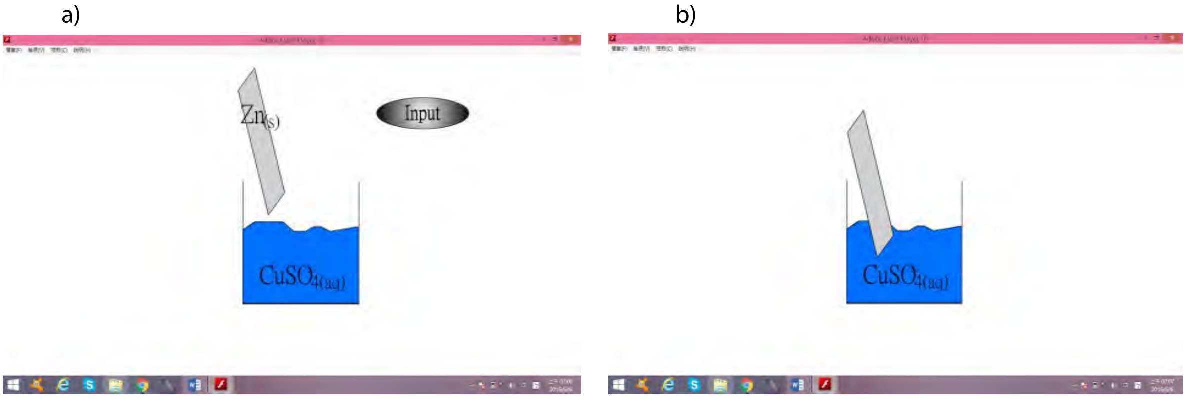
is the molecular weight of reactant). Thus, the experimental group students went on the calculation of the step two for the ratio number of mole from product over reactant ($n_{product}/n_{reactant}$) at class (shown in Figure 1). After the completion of figuring out the correct rated proportions for both $Mw_{product}$ x $W_{reactant}$ /$Mw_{reactant}$ and $n_{product}/n_{reactant}$, students could unmistakably point up the required answer of $W_{product}$ as judged from the equation of $n_{product}/n_{reactant}$ =($W_{product}/Mw_{product}$) / ($W_{reactant}$ /$Mw_{reactant}$).

There were at least two advantages for students' manipulation of the two-step strategic map for an appropriate equation in stoichiometry. First of all, students had to exert themselves to the utmost for drawing out the required strategic map associated with each unknown qualities in an equation as known qualities. Secondly, students' presentation of the two-step strategic map extended their efficient operations of acting mind to capture abstraction in the problem-solving skills of stoichiometry conceptions as claimed by scholars to reduce cognitive load (Sevian et al., 2015). To put these advantages into practice, the two-step strategic map offered an inspired way to assess students' cognitive learning of complex concepts in effective guidance for constructing problem-solving abilities as to how students organized stoichiometry information, and to what extent students' dynamic concept reasoning were imposed as the shift from model-based to case-based reasoning.

The second representational visual model -- animated presentations of stoichiometry could be best exemplified on the authoritative expositions of Paivio's Dual Coding Theory (1971, 1991) and Mayer's cognitive theory of multimedia learning (2009). These animated visual models not only promoted students' cognitive learning connected with macroscopic symbols but also provided students' visualized perception forged with the microscopic understanding of the spontaneous Zn-Cu^{2+} reaction (shown in Figure 2). In a similar executive way, college students could take the correlated stoichiometry reaction as an ever-increasing performances insomuch their animated visual models up to the above distinguished level for the conceptual attainment. The importance of these animated presentations of stoichiometry was evident in encouraging students' verbal and visual performances of designed guidance; that is to say, its tutorial goal was to make up the learning environment, to activate students' mental cognition, and to conceptualize learning components of animated stoichiometry.

The best approach to comprehend the context design of Figure 2 is for students to visualize learning environment in a series of step-by-step animated presentations of stoichiometry. Figure 2 involves a series of visual animations of stoichiometry in the following process (from Figure 2a to Figure 2e). Students' attention will be in the subsequent shifting of key module designs corresponded to problem-solving skills. All their visualized presentation gives a direct link of cognitive process in animated module deigns. It starts with the guided ongoing statement: when a piece of zinc bar was dipped into a cupric sulfate solution (Figure 2a), initially zinc atoms (Zn) were oxidized to zinc ions (Zn^{2+}) and at the same time gradually cupric ions (Cu^{2+}) were reduced to red metallic Cu, the overall kinetic reactions demonstrated in Figure 2 from (a) to (e). Furthermore, students will comprehend step-by-step the dynamic correlation of stoichiometry in the particulate nature matter through the visualized process of animated presentations. Here, students' attention will be shifting to an answering module to clarify the abstract code of stoichiometry relationship between Zn atoms and Cu^{2+} ions. The whole process of animated models became an expositive way to incorporate previous visual findings into the correctly balancing chemical equation for the product ratio numbers of moles ($n_{product}$) Zn^{2+} or Cu and the reactant numbers of moles ($n_{reactant}$) Zn or Cu^{2+}. The two half reactions of the next contextual design stimulated students to shift their conceptualized understanding from model-based reasoning to case-based reasoning.

a) b)



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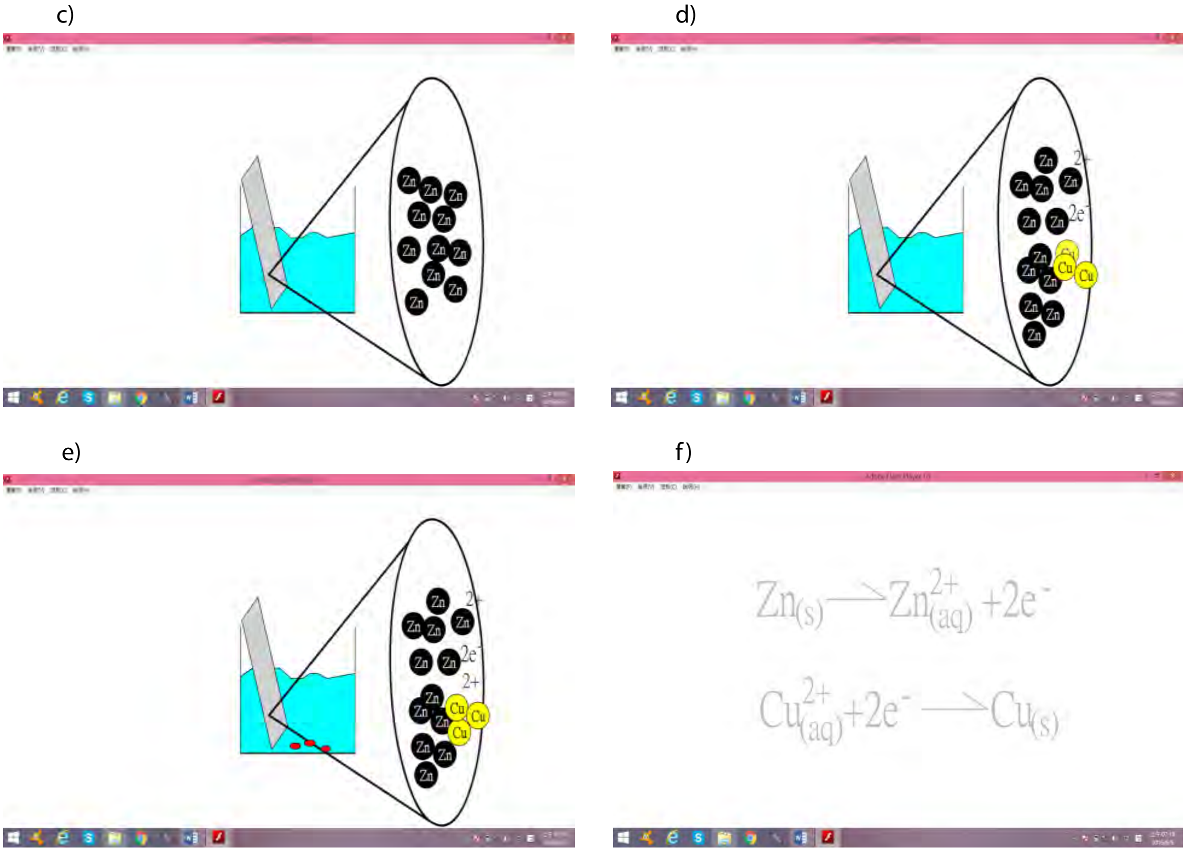

Figure 2: Animated presentations of visual mode for quantitative reactions shown in sequence from (a) animated map to (f) animated map, as treated by Flash MX (Macromedia, Inc.).

It would help students to combine their case-based reasoning with the attainable fulfillments of visual modules to engage in an innovative integration of cognitive strategic map and animated learning as shown in Figure 1 and Figure 2. For an acceptable cased-understanding of Figure 1, an account of two advantages for the two-step strategic map was needed to evaluate students' cognitive learning of complex concepts. So far as Figure 2 was concerned, these animated representational visual models required students to activate their mental cognition with conceptualized understanding and increased stoichiometry performances. With the case-based guidance, students would step by step manipulate words, pictures, images, animations, identify cognitive skills and algorithmic learning, and construct their individual response of activating the two-step strategic map as an expedient application of case involvements. Obviously, students could simultaneously reduce cognitive load of stoichiometry equation in their link of macroscopic, particulate nature and symbol, which all related to constructive and expressive changes in their learning performances (Treagust, Chittleborough & Mamiala, 2003; Jaber & BouJaoude, 2012). Judged from the above case-based reasoning, three levels of students' ALG proficiency, LOCS and HOCS could be an important assessment for learners' response of 5 algorithmic and conceptual pair questions to indicate a promising perspective in understanding stoichiometry.

Instruments

Students' achievement pre-tests and post-tests were assessed and scored in accordance with 5 algorithmic and conceptual pair questions for their ALG proficiency, LOCS and HOCS conceptual understanding of stoichiometry. The draft achievement tests were developed with research resources of Sawrey (1990), Nakhleh (1993) and general chemistry textbooks. The draft tests were scrutinized and revised by five renowned chemistry professors for the validity of final achievement tests. Students' reliability of achievement tests was analyzed by the Cronbach's α statistical methods. The final scores for the Cronbach's α coefficient were given as 0.790 and 0.800 in both pre-tests and post-tests respectively. DeVellis (1991) regarded the 0.70 reliability as the minimum acceptable reliability. The same reliability was carried out between two time span of the pre-tests and post-tests so as to detect differences in students' learning performances.

Students' attitude questionnaire was assembled for developing experimental group students' strategic feedback in their process of learning stoichiometry. The whole framework of students' attitude questionnaire involved several factors, such as content validity, constructive validity, and internal consistency reliability, which had been elaborated in the previous publication (Su, 2016) and briefly described in the following way. Firstly, this research asked advice from six senior chemistry educators to preview the survey draft and revised the final versions for the content validity of pilot tests. As for students' second factor of constructive validity, which was based on the significant assessment of Bartlett spherical investigation, this study proposed that five aspects of the Eigenvalue were all above 1.0 by factor analyses. All these five aspects could be defined as students' dependent variables of learning attitude; there were S_1 (toward representational design technologies courses), S_2 (toward science technologies instructors), S_3 (toward students' interests of participation), S_4 (toward self-evaluation), and S_5 (toward statistical results). From the results of internal consistency reliability, it was clear that the total scale score of the Cronbach's α 0.92 reached the satisfactory degree in accordance to students' learning attitude (Gay, 1992).

Data Analysis

Aspects of data analysis were categorized by students' acquisition in their tactic fulfillments of the three correlations. In their answering to 5 algorithmic and conceptual pairs of achievement test items, students were allotted with 20 points for the correct answer to each paired test item, with 10 points for the correct answer to each half paired test item, with totally 100 points for the correct answer to total 5 paired test items. For this research with a solid emphasis on students' guided learning programs of visual and case models, it was important to perform the related data and statistical analysis on SPSS 22.0 Windows software. The statistical findings would be of interest for our discussion such as students' achievement covariance and t-tests of both pre-tests and post-tests, answering rate for the three correlations, students' learning attitude, and one-way ANOVAs.

Results of Research

With the assumed approach of quantitative analysis, this research dealt with students' tactic fulfillments to interpret their shifting performance from model-based reasoning to case-based reasoning. All students' data performances in both visual and textual presentations included students' achievement covariance and t-tests of both pre-tests and post-tests, answering rate for the three correlations of ALG, LOCS and HOCS, students' learning attitude, and one-way ANOVAs.

Analyses of Achievement Tests

In response to research question 1, what individual learning achievements could be attainable for students' best mental cognition? The most appropriate stimulus was to conduct students' pre-knowledge in conforming to accepted statistical assessments for the research question 1. Students' learning achievements were documented and analyzed by means of pre-tests and post-tests; the means and standard deviations were calculated by descriptive statistics brought about by stoichiometry. The descriptive results of students' learning achievement showed pre-test mean values (25.42 and 26.09), post-test mean values (43.33 and 36.13), pre-test standard derivation values (4.76, and 4.16), and post-test standard derivation values (10.90 and 11.16) in both group students' stoichiometry learning. In the present analyses of quantitative tests, it was applied to regard pre-test data as covariate variables, post-test data as dependent variables, and divided student groups as independent variables. This research considered that no significant differences (p= .052) existed between two group students by the homogeneity examination of regression slope. Thus, when used in the context of covariate variables analyses, an existing result of Table 1 indicated that there were significant differences in post-test achievements between the control group and experimental group students.

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Table 1. Stoichiometry comparison of mental cognition for students' individual learning achievement in ANOVAs of post-tests.

Source	SS	df	MS	F –ratio	p-value	f
Group	1689.656	1	1689.656	23.000	< .001	0.722
Error	3232.416	44	73.7464			

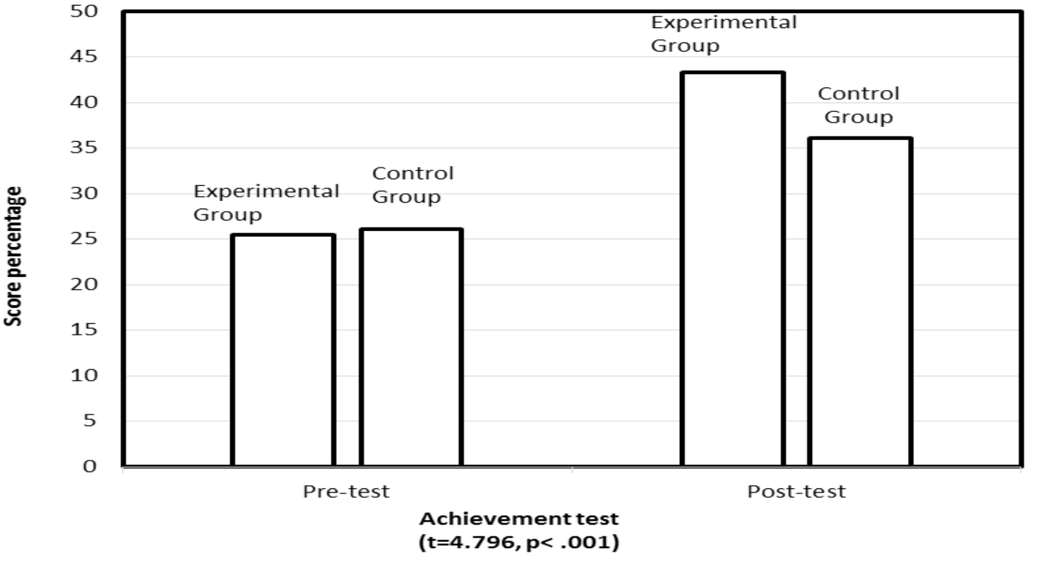

Figure 3: Students' achievement t-tests of both pre-tests and post-tests between the experimental group and the control group students.

To inspire more students to get involvements in active mental cognition, this research scrutinized an exemplified indication of superior scores for experimental group students who got beyond the scores of the control group students as indicated by adjusted post-test mean scores. The experimental effect size, *f* value .722, served to examine the inquiry research of above indication in a larger above Cohen's (1988) effect size ($f > .4$). Compared to students' directly or indirectly testing figures, all students' achievement t-tests (see Figure 3) turned out to be more significant differences (t=4.796, $p<.001$) between the experimental and the control group students. Students' individual mental learning achievements underwent a compared shift from model-based reasoning to case-based reasoning in their answering test items of 5 algorithmic and conceptual pairs. Accordingly, all the three above research programs of adjusted post-test mean, experimental effect size and students' achievement t-tests were verified with experimental group students' tactic fulfillments of problem-solving maps and animated presentations.

Students' Answering Rate for the Three Correlations

In response to research question 2, how did students apply role engagement to upgrade tactic fulfillments after their cognitive response of the three correlations to problem-solving maps and animated presentations?

Since students' cognitive response was essential to their role engagement for more prevailing performances, this research made a full discussion of students' answering rates in relation to the three correlations – ALG, LOCS, and HOCS. As indicated in the above discussion, the experimental group students got more superior learning achievements than those of the control group. Insomuch the present answering rates (%) and item numbers (ns) in Table 2 would be limited to statistical analyses of the experimental group students. It was observed that the experimental group students had more accurate answering rates and item numbers (23.4% corresponding to 28ns, 12.3% to 12ns, and 16.0% to 16ns respectively) in post-tests based on their ALG, LOCS and HOCS three correlations than those set of the pre-tests.

It was highlighted in this research that statistical analyses of students' answering rates provided the necessary research-based support in their fulfillment of the three correlations. In contrast to their pre-tests, the experimental group students assumed higher scores of answering rates 23.4% ALG, 12.3% LOCS and 16.0% HOCS in their three correlations of post-tests. With an emphasis on the algorithmic questions, the highest scores indicated students' involvements of high proficiency to solve stoichiometry questions. Another post-test conducted on the HOCS questions was correlated with the lowest scores of students' response for higher-order thinking in their inquiry-oriented skills (Barak, Ben-Chaim & Zoller, 2007). Thus, the experimental group students performed consistently on each post-test of the three correlations in the following order: ALG> LOCS> HOCS with a consequent development of critical thinking capabilities in Table 2. The target programs of the three correlations were accredited with an important impetus for instructors to observe the significant differences between pre-tests and post-tests in stoichiometry.

The experimental group students were required to develop overall capabilities of self-reflective assessment, utilizing tactic fulfillments of stoichiometry texts with systematic knowledge structure and repeated animation presentations in class. Presentations of tactic fulfillments stoichiometry text not only accumulated students' macroscopic learning understanding of chemical reactions, but also strengthened their case-based reasoning in microscopic particulate conceptions. All students' answering rates for the three correlations, ALG, LOCS, and HOCS statistical analyses of post-test scores' covariance proved to have more effective influence on students' learning achievements.

Table 2. Experimental group students' average percentages of correct answering rate (%) and test items (ns) between pre-tests and post-tests.

Correct pairwise comparisons	Pre-test			Post-test		
	ALG	LOCS	HOCS	ALG	LOCS	HOCS
Rate (%)	30.8	14.7	10.5	50.2	22.0	14.5
Items (ns)	74	35	25	120	53	35

Students' Feedback and ANOVAs

In response to research question 3, what case-based learning feedback would be the most appropriate attitude for experimental group students' acquired problem-solving fulfillment in stoichiometry? There were three comparative case dispositions of tactic fulfillments indicated by students' five attitude subscales in Table 3. Since experimental group students had to carry out the same learning attitude survey, the blocking variable was confined to tactic case samples conducted with a series of ANOVAs. The design of variance factors, *F*-ratio, *p*-value, *f* and Schěffè in Table 3 was listed in different variants to determine students' learning attitude. All significant effects were tested to determine students' case dispositions toward stoichiometry learning. The required effect sizes ranging between .44 and .65 demonstrated a larger than large level (f >.4, Cohen, 1988). To some extent, the effect sizes conducted within experimental group students' case samples suggested a configured index to detect students' different variants in learning attitude.

Another noticeable feature for students' dependent variables marked a set of survey to conduct comparative analysis of individual learning attitude in ANOVAs. The acquisition of dependent variables was designed and constructed in the following three comparative case dispositions. Initially, the first comparative case disposition for students' dependent variables S_1 to S_5 illustrated more "positive" attitudes than those reporting "negative" in Schěffè's post hoc. Next to be discussed, the second comparative case disposition for students' dependent variables S_1 to S_3 reflected more "neutral" attitudes than those reporting "negative" in Schěffè's post hoc. And subsequently the third comparative case disposition for students' dependent variables S_4 displayed more "positive" attitudes than those reporting "neutral" in Schěffè's post hoc. The above three comparative case dispositions assisted students to acquire more individual feedbacks of learning attitude in stoichiometry.

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Table 3. Three comparative case dispositions of individual learning attitude in ANOVAs.

Experimental Course	Blocking Variable	Analysis of Variance	Attitude S_1	S_2	S_3	S_4	Measure S_5
Stoichiometry	Disposition toward Chemistry (positive, neutral, negative)	*F*-ratio	7.498	3.553	6.476	4.652	6.243
		p-value	.002**	.039*	.004**	.016*	.005**
		f	0.65	0.44	0.60	0.51	0.59
		Schěffè	1>3, 2>3	1>3, 2>3	1>3, 2>3	1>2, 1>3	1>3

**p*< .05; ***p*< .01*

Synoptically, the above results of quantitative analysis elevated students' case encountering of conceptual understanding and algorithmic proficiency in 5 paired items to develop learning performance. By contrast, it was not restricted that experimental group students would limit their individual learning achievements for an effective tactic fulfillment of the three correlations as those of control group students in answering achievement test items.

A close look at experimental group students' answering rate with a consequent development of critical thinking capabilities (ALG > LOCS > HOCS in Table 2) evoked their cognitive response from model-based to case-based reasoning which reflected more effective influence on their role engagement of tactic learning achievements. After having taken up three comparative case dispositions of learning attitude through the learning application, experimental group students could create an environment in facilitating their tactic fulfillments and upgrade case-based feedback for accumulating learning performance on a whole.

Discussion

The premise in this research to set a priority on students' engagement of learning achievements requires an integrated module for effective tactic fulfillments of the three correlations. As in earlier researches of effective problem-solving approach (Barak, 2012; Lazakidou & Retalis, 2010), instructors not only needed to design problem-solving maps of mental cognition knowledge, but also inspired new knowledge by model-based reasoning for college students' tactic fulfillments. Students could make potential implementations of constructive thinking and independent learning based on effective tactic fulfillments for various cognitive competences of problem-solving skills in stoichiometry. Accordingly, improving students' engagement of tactic fulfillments in previous research about macroscopic, particulate nature and symbol (Treagust, Chittleborough & Mamiala, 2003; Jaber & BouJaoude, 2012), would be available for students' encounter of cognitive case learning and achievements of constructive stoichiometry.

This research highlights the new assessment of the three correlations for students' tactic fulfillments of model-based reasoning. It justified an important impetus for instructors to notice students' significant different achievements between pre-tests and post-tests in stoichiometry. Since experimental group students were expected to develop self-reflective capabilities, the agglomerated results of processes through which model-based reasoning was gathering to utilize systematic knowledge structure and repeated animation presentations with the cognitive assessment embedded in ALG, LOCS, and HOCS. Serial presentations of tactic fulfillments enabled students to accomplish cognitive achievements for macroscopic contexts of chemical reactions, in accordance with microscopic particulate conceptions for conceptual visualized instructions at class. Among many recipients, students' answering rate for the three correlations, ALG, LOCS, and HOCS, testified by many pedagogic chemical researchers (Domin & Bodner, 2012; Sanger & Phelps, 2007), together with statistical analyses of post-test scores' covariance, and the tactic fulfillments of learning applications witnessed an influential reasoning on students' case-based learning.

Students' feedback served as a prevailing intensification of case-based reasoning for their admirable learning attitude in the field of cognitive developments. After their cognitive encounter with learning environment, experimental group students had to participate in the survey of individual learning attitude illustrated in their three case dispositions towards stoichiometry. On their account of dimensional analysis of stoichiometry, most experimental group students would figure out the conversion factors for a turning point to describe their learning attitude with positive disposition. Followed by conversion factors, they would be aware of other relevant factors involved in their case-based illustration of stoichiometry. Without the employment of conversion factors, the control group students had only fragmented encounter in their dilemma of stoichiometry cognitive developments. In fostering more affiliated learning attitude with positive cased-disposition, students would construct multiple learning competences in the ultimate goal to reduce their learning cognitive load as suggested by researchers (Sevian *et al*., 2015).

To search for students' tactic fulfillments, the incorporated alignment of the three correlations and self-performed feedback awakened experimental group students' cognitive need in attentive co-work relationship. The goal of tactic fulfillments in this research was not restricted to group students' individual adjustment of stoichiometry knowledge from model-based conception to case-based perception. Aided by three correlations ALG, LOCS, and HOCS, students could develop different talents, which lead to eminence in their construction of learning performances. After their acquisition of extensive problem-solving skills, students set upon measuring voluntary feedback prescribed with positive evaluation behaviors befitting singly or collectively. Despite limitations of the sample size in the first draft, this research was supplemented by students' group qualification of two-tier item tests. Common to more longitudinal academic developments, students' independent variants conveyed the scrutinized tactic fulfillments of learning attitude to evaluate strategic problem-solving contexts. It was crucial to bringing about both a positive result and significant contributions that group students' accomplishments corroborate their step-by-step development of reasoning skill, visual presentations and critical thinking in their learning process.

It would be not an easy task to transfer all specific domains of problem-solving abilities into students' tactic application during a limited time span; therefore, this study took an eclectic measurement exemplified from model-based to case-based reasoning for them to explore their mental cognition through two-step strategic map and animated presentations with ALG, LOCS, and HOCS. Students' commitments from model-based to case-based reasoning have put up tactic fulfillments of the three correlations for many pedagogic chemical researchers under a substantial critical thinking (Domin & Bodner, 2012; Sanger, 2005; Sanger, Campbell, Felker, & Spencer, 2007; Sanger & Phelps, 2007). The findings within this research would offer a new perspective and be of interest to both school and college teaching instructors.

Conclusions

The perspective of this research promises a new insight into enhancing students' stoichiometry performances up to the accomplished levels of tactic fulfillments and the cognitive context of the three correlations. Visualized developments of problem-solving maps and animated presentations can get into students' thoroughly learning activities for their inquiry of tactic fulfillments. The prevailing three correlations involved students' responsiveness of critical mental thinking with forcible tactic fulfillment in ALG, LOCS, and HOCS. An ideal research for investigating the meaningful engagement of students' learning performances enabled the recipients to accomplish a specific mental adjustment which went beyond traditional abstract and difficult stoichiometry learning. With an aid of visualized presentations in this research, students demonstrated greater immediacy for conceptual delineations and problem-solving competency. More motivations were attributed to students' corresponding results to paired-test items as well as students' engagements on the entire learning progress. Also students' positive learning feedback was explored consistently to different thinking levels set in similar contexts of learning performances.

The guidance for students' tactic fulfillments was not a one-way destination, but a joint effort between instructors and students in discovering and conducting effective operations through thinking skills of problem-solving performances. This research made an important implementation to detect students' different cognitive understanding as a compatible fulfillment with students' validity of the three correlations represented in their core stoichiometry achievements. Illustrated fulfillments of students' ALG, LOCS and HOCS's mental thinking served to widen the horizon of their cognition to take more participation of problem-solving. The participants in the survey selected from the two-stage qualification test reached up to a valid indication examined continuously before, during, and after the feedback. A limited assumption was given to the experimental group students for the regular curriculum after one year span of the intervention. Although all findings and results presented a sound base for further researches on how to assess students' cognitive learning and visual models into problem-solving performances, some extended and longitudinal studies still remained to be addressed in the future refinements. Thus, the further explorations of students' problem-solving skills observed in the present research will be suggested to conduct and analyze through more tactic development of students' participation and assessments.

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King-Dow Su Chemistry Ph. Dr., Professor, Department of Hospitality Management and Center for General Education, Hungkuo Delin University of Technology;
NO.1, Lane 380, Ching-Yun Road, Tu-Cheng District., New Taipei City, Taiwan 23646, R.O.C. & Center for General Education, Chung Yuan Christian University, 200 Chung Pei Road, Chung Li District, Taoyuan City, Taiwan 32023, R.O.C.
E-mail: su-87168@dlit.edu.tw, su-87168@mail.hdut.edu.tw