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Strategic Applications of Dynamic Reaction Figures to Redox Chemistry for Improving Students' Skills in Problem-Solving

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Abstract

This research deals with strategic applications of dynamic reaction figures (DRF) in chemistry for problem-solving skills of students. It focuses on reaction equations in the unit of redox chemistry with ions and charge transmissions to clarify college-students' misconceptions in chemical learning. This experimental study takes sample models from two student groups, the experimental group and the controlling group, with the total number of 95 college students. All quasi-experimental approach and statistical analyses for students' skills in problem-solving are summarized as follows: (1) The experimental group students had better posttest achievements than those of the controlling group students because they got many skills in the unit of redox chemistry learning. (2) In the comparison between their posttest and pretest results, the same experimental group students had more significant and increasing posttest achievements than those of controlling group students. (3) In regard to different dispositions of students in chemistry, experimental group students revealed more significant satisfaction in learning of redox chemistry.

On the whole, students with applications of DRF showed more problem-solving skills which could be applicable for their learning performances of chemistry.

Keywords: dynamic reaction figures, problem-solving skills, redox chemistry, quasi-experimental approach

Introduction

In order to promote students' learning performances, science educators like Nakhleh and Malina [1] proposed that college students at all levels should endeavor their best for strategic chemistry learning, and they often felt much dispirited in abstract chemical conceptions. The dynamic reasons may be attributed to the fact that many students failed to get control of chemical conceptions at the start of their learning [2]. For the majority of college students, to raise their scientific learning efficacy and techniques was a difficult task, because they only picked out recited methods for passing exams [3].

To have techniques of algorithmic operations paved the traditional way for college students to decipher or answer similar basic chemical conceptual problems [4].Whereas the time came for students to solve intermediate or advanced chemical conceptual problems, such as Electric Chemistry [5], Stoichiometry [6], Chemical Equilibrium [7], and Stereochemistry [8], they usually became blurry with too much abstract and elaborate chemistry in their learning. Schultz [9] upheld that cognitive validity should take more skills with chemistry narrations progressively and use expressions of visual animations for increasing their curiosities and dexterities in chemistry learning. There were different teaching highlighted supported by visual advantages of molecules to enhance students' learning recognition, which some science educators adopted such as representations of computer animations [10-12], tactics of problem-solving maps [13], or dynamic reaction figures (DRF) [14, 15]. Many scientific educators [16, 17] indicated that conceptual maps had more learning efficiency for students' skills in science problem-solving.

In this study, the teaching design of this textual study of redox chemistry was following applications of Schultz's DRF approach and constructivism theories of Driver and Oldham [18], with problem-solving skills, so as to get more meaningful learning and create more substantial chemical conceptions.

Purposes

This research focuses on major applications of DRF implemented by 2D animations highlighted with chemical conceptions of ions and charge transmissions. Two fundamental prospects of college students' chemistry learning would be conducted as follows:

(1) To design dynamic DRF redox chemistry for students' skills in problem-solving learning achievements.

(2) To construct effective applications of DRF redox chemistry for students' skills in problem-solving and examine their satisfactory questionnaire.

Theoretical Perspectives

Conceptual map of DRF

DRF could be a strategic application of conceptual maps, which was full of conformity, clarity, visualization, variety, insight and expansibility, all these could help students organize, classify, analyze, assess and deduce, and promote critical thinking, not only as a kind of study tactics, but also as a useful technology of teaching and learning achievements [9, 14]. These strategies could make problem-solving skills available by drawing DRF in their brain-storming presentations, and these gradual highlighted analyses would conduct learning for ions and charge transmissions in reaction equations of redox chemistry. All above chemistry problem-solving skills would clarify students' conceptual difficulties in their classes. Four characteristics of DRF technology tools would be listed as follows:

(1) To enhance students' feedbacks for discerning and thinking analyses
(2) To substantiate students' performances of chemical reaction equations, principles, laws, and theorems
(3) To require students to compare other presentations of problem-solving skills
(4) To upgrade students' learning performances, so as to overcome difficulties, and solve encountering problems.

For a more effective DRF approach, Schultz [9] developed the advanced chemistry learning, derived from the theory of meaningful learning [19]. To take the chemistry DRF example, we divided the experimental sample into two hemispheres: the upper hemisphere to provide protons (H^+) can be called "Donor Hemisphere," and the lower hemisphere to accept protons (H^+) can be called "Acceptor Hemisphere," which is indicated in Schultz [9] and Su [15]. Put two hemispheres into a whole composition for the chemical reaction. To learn transmission mechanism of ions or charges from the upper and lower hemispheres, and to increase conceptual knowledge of chemical equations, we need cartooned animations in demonstrating students' problem-solving abilities in this study.

Problem-solving skills

Up to recent years, problem-solving skills (PSS) in chemistry researches have been one of major academic focuses [15], and this study attempts to integrate many prevalent approaches in special functions of PSS. Two chemistry questions of algorithmic and conceptual PSS were treated critically as functional assessments by Sanger and Phelps [20], Cracolice, Deming, and Ehlert [21], and Domin and Bodner [22]. Cracolice, Deming and Ehlert [21] explored different levels of reasoning conceptual skills to examine the gap between conceptual questions and algorithmic questions of problem-solving abilities. To train well-equipped scientific reasoning skills would lower the above gap phenomena, and upgrade constructions of students' conception. To integrate DRF into highlighted chemistry learning would increase conceptual reasoning skills and construct students' abilities in problem-solving.

In the modern scientific era of information technology, integrated applications of highlighted DRF with creative scientific technologies will become a dominant multi-functional approach from day to day. To develop strategic applications of DRF technologies, this study explored fundamental scientific knowledge [23, 24] in the unit of redox chemistry learning. Teaching tools would be employed in designs of the experimental chemistry process such as Flash Animations, combined with experimental apparatus, and developments of multimedia technology including sounds and graphic arts.

Methodology

Participants

In order to have a detailed data discussions and analyses, 95 junior college freshmen were selected from the same class into two groups, the experimental group (47 ps) taught by the integrated DRF technologies, and the control group (48 ps) by lecture-based teaching methods without any assistance of DRF technological tools. The characteristics of the two different student groups who completed a 6 hour program in the three-week DRF animated schedules of chemistry during the 2012 academic year were discussed below.

Research approach and procedure

To achieve effective teaching goals of redox chemistry, this study proposes several presentations of macroscopic and microscopic conception of dynamic changes with the integrated DRF technology in chemistry to facilitate students' learning performance in the following six research procedures:

(1) Set up the learning target goal
(2) Find out appropriate integrated DRF technology for learning in redox chemistry
(3) Integrate DRF with animated demonstrations
(4) Stimulate learning activities with DRF teaching models
(5) Use quasi-experimental approach in the study project
(6) Assess students' performance in chemistry learning

Brief introduction of chemistry learning

Applications of computer technologies in chemistry; for example, integrated animations, static charts, and descriptions of learning performances were constructed as DRF modules. All chemistry teaching was divided into several relevant and meaningful DRF modules. The cognitive programs of redox chemistry designs, teaching methods, teaching situations, course technologies and students' satisfaction, were included in these major DRF modules. All these DRF modules were organically combined together to create new reliable programs and applications for students' skills in chemistry learning. Demonstrations with power points were presented in the experimental group of animated DRF modules. Figure 1 summarizes parts of Flash Animations; each animation would last for almost 20 seconds. In the experimental group, students had a 5 minute practice with animations during demonstration spans.

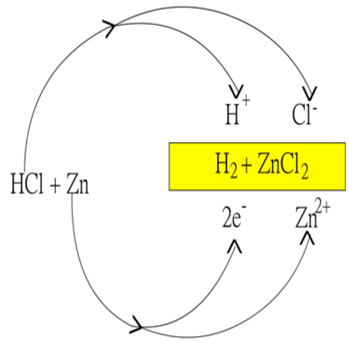

Figure 1. Selected illustrations from dynamic reaction figures to redox chemistry.

Instruments of applied methods

To achieve effective problem-solving skills, a quasi-experimental approach for questionnaire tests was used in this research, together with different criterion related to statistical analyses of students' learning efficiency and performances. This research design included pretesting, target-group teaching, posttests and questionnaire evaluation of satisfaction in chemistry learning. All research methods of pretests and posttests, experimental teaching, learning satisfaction questionnaire, and statistical analyses of achievements and students' satisfaction in chemistry learning, made students get involved in positive learning efficiency for promoting their problem-solving ability in chemistry.

Orientation of achievement tests

Cognitive knowledge was incorporated into students' achievement tests in pretests and posttests. The original draft test was designed by educators [23, 24] and approved by four senior chemistry professors. To analyze the achievement tests, the reliability of Cronbach's α coefficients was examined in statistical methods to determine the internal consistency of questionnaires. The α coefficients obtained for redox chemistry in pretests and posttests were 0.76 and 0.75. DeVellis [25] regarded the 0.70 reliability as the minimum acceptable reliability. Both pretests and posttests were employed in the same method to record changes and detect differences in students' achievements in chemistry learning.

Developments of students' satisfaction in chemistry learning

The draft 30 test items were included in the questionnaire for assessing students' satisfaction in chemistry learning. On the whole these test items corresponded to the author's revisions of the draft design [12, 15]. Likert-type scale was also employed in the questionnaire. For constructing better content validity, this study asked two science educators, two scientific philosophers and two educational psychologists to perform advisors make revisions and examine the survey. To increase the constructive validity, 296 copies of pretests were taken into considerations for factor analyses. The first results of factor analyses for the Kaiser-Meyer-Olkin (KMO) data (0.943) and χ^2 data (5621.899) of Bartlett spherical investigation (the degree of 300 freedoms) proved significantly important, so factor analyses were deemed suitable. Three aspects were considered in main component analyses of the questionnaire. The Eigenvalues obtained were above 1.0 with an accumulative explanation variation of 65.341%. These Eigenvalues of three aspects were 3.778 (9 items), 3.475 (5 items), and 3.183 (11 items). The Cronbach's α value could correspond to 0.930, 0.893, and 0.938 as shown by internal consistency inspection of the Cronbach's α. There were totally 25 items in the questionnaire (see Table 1) which could be classified into three dominant aspects: Q_1, Q_2, and Q_3.

Q_1, to integrate DRF presentations for students' satisfaction

Q_2, to investigate students' satisfaction in chemistry learning

Q_3, to inspire active participations for students' satisfaction in chemistry learning

Three dynamic aspects Q_1, Q_2, and Q_3 were focused on students' satisfaction feedback in learning from the factor analyses. Factor loadings of all items were indicated in Table 1.

Statistical analyses

SPSS 12.0 Windows software was combined with some statistical analyses for all information before and after the experimental teaching on the questionnaire.

Results and discussions

This study focused on constructing DRF modules based on educational principles of chemistry learning at a Taiwan technical college and exploring two student groups learning performances with specific implementation conditions and learners' performances of integrated DRF in chemistry.

Statistical analyses of students' learning achievements

To meet strategic applications of DRF teaching modules, this research explored whether there were any significant statistical results between the experimental group students and the control group students. Statistical analyses were treated for students' posttest learning achievements, with students' pretest data as covariate variables, and posttest data as dependent variables, and two divided groups as independent variables. Homogeneity examinations of the regression slopes showed that there were no significant statistical differences between two group students for the unit of redox chemistry learning by independent variables and dependent variables, responding to group assumptions of covariate variable analyses. Therefore, further covariance analyses were available for this research. Statistical results of covariants listed in Table 2 indicated that there were significant differences in students' posttest achievements between two groups. The result that the Cohen's experimental effect size (*f*), *f* value were .61 indicated a higher effect size in the unit of redox chemistry learning. The posttest scores of the experimental group

Table 1. Likert items for the DRF learning satisfactory attitude and subscales

Subscales	Items	Loading Factors	Cronbach α
Q1	1. Each unit of the DRF-integrated teaching program matches my need to study.	.656	**.930**
	2. I take part actively in related DRF learning.	.658	
	3. I have confidence in DRF-integrated courses which are helpful for my study.	.668	
	4. Integrated DRF can provide my necessary aids to study in every subject.	.642	
	5. The teaching style of DRF instructors is lively.	.796	
	6. The teaching method of DRF instructors is flexibility for students.	.762	
	7. The instructor of my DRF class cares my learning performances.	.760	
	8. The instructor of my DRF class often encourages me to study.	.766	
	9. I am satisfied with the teaching performances of my DRF class instructor.	.791	
Q2	10. Our classmates can actively participate in the teaching activities during DRF class.	.707	**.893**
	11. Our classmates can take part in discussions of DRF questions in the class.	.758	
	12. Our classmates can help me to sole learning difficulties in DRF class.	.727	
	13. Our classmates are imbued with learning atmosphere in DRF class.	.739	
	14. Our classmates can share and cooperate with others' opinions in DRF class.	.669	
Q3	15. I can actively set out learning schedule of the DRF class.	.687	**.938**
	16. I will take previews of our DRF texts before class.	.749	
	17. I will take reviews of our DRF texts before class.	.721	
	18. With applications of DRF effective learning, I can pay more attention to study.	.733	
	19. I can do my best to complete DRF assignments by our instructor.	.685	
	20. I think DRF teaching can upgrade my scores in the class.	.714	
	21. Our DRF-integrated teaching methods can enhance my macroscopic problem-solving abilities.	.706	
	22. Our DRF-integrated teaching methods can enhance my microscopic problem-solving abilities.	.702	
	23. Our DRF-integrated teaching methods can increase my willing to pursue new knowledge.	.721	
	24. Our DRF-integrated teaching methods can inspire my willing to pursue new knowledge.	.627	
	25. I completely agree to integrate our DRF teaching methods into chemistry learning.	.695	
KMO=0.943 Accumulative Explanation Variation (%)= 65.341 Total Cronbach's α = 0.959			

were higher than those of the control group, which confirmed the major assumption that the strategy of experimental teaching was better than that of traditional teaching.

Table 2. Summary of *F*-ratios, *p*-values, and effect sizes (*f*) for redox learning achievement in the ANOVAs of post-tests

Content	**Source**	***SS***	***df***	***MS***	***F* -ratio**	***p*-value**	***f***
Qxidation and Reduction	Between Group	72.352	1	72.312	34.506	0.000***	0.61
	Error	192.906	92	2.097			

*** p< 0.001

Posttest scores with *t*-test

This study put more emphases on pairwise comparisions with posttest mean values so that *t*-test rersults showed that students' posttest scores of the experimental group were higher than those of the control group, as shown in Figure 2. After teaching implements of posttest scores' covariance, pairwise comparisons, and learning achievement tests, all DRF statistic applications had more significant influence on students' learning achievements. More significant differences between two student groups in the unit of redox chemistry learning were detected.

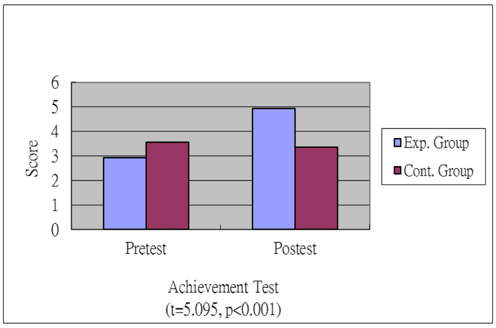

Figure 2. *t*-test analyses of students' posttests between the experimental group and control group

The result for statistic differences was attributed to the fact that highlighted DRF chemistry with systematic knowledge structure and repeated animation presentations, not only showed macroscopic differences in students learning of chemical reactions, but also presented changeable factors of microscopic conceptions of ions and charge transmissions. Presentations of highlighted DRF chemistry gave students' learning interactions to analyze, compare, criticize, feedback, link symbols and abstract conception relationships between microscopic ions and charge transmissions with accurate recognizable knowledge.

Analyses of students' satisfaction in chemistry learning

To complete the presentation of integrated DRF chemistry, this study made surveys of students' satisfaction in learning for a better statistic module of students' chemistry learning. After statistical analyses of experimental teaching, this research chose experimental group students as students' satisfaction in learning for statistical analyses. The statistic results of students' satisfaction in learning in Table 3 showed three dependent variables (Q1, Q2, and Q3) and total correspondents of mean values (*M*), standard derivation values (*SD*), and Cronbach's α values (α) in the unit of redox chemistry learning. The overall Cronbach's α values (total) was 0.989, indicating that the internal consistency of retest total scales reached a satisfactory degree [26], and their mean values were over 3.19, indicating that after a series of experiments students in the experimental group had more positive satisfaction in chemistry learning.

Statistical analyses of learning satisfaction attitudes, with the three-subscales of students' satisfaction in learning as dependent variables, this study chose students' gender, enrolment, disposition toward chemistry, and frequency of the digital-modules usage as independent variables for statistical analyses of one-way ANOVA to explore if there existed any significant changes in the multi-variables of the Wilks' Lambda parameter. All multi- variables significances in Wilks' Lambda parameter were listed in Table 3, including the *F*-ratio, *p*-value, and effect sizes (*f*).

Statistical results of students' independent variables for disposition toward chemistry in the unit of redox chemistry learning reached significant differences. For further Scheffes' post hoc comparisons, this research found out that the positive disposition in the subscale Q1 was larger than the negative disposition, the positive disposition in the subscale Q2 was larger than the negative disposition, and that the positive disposition in the subscale Q3 was larger than the neutral and negative dispositions. Results of effect sizes in three subscales were 0.87, 0.51 and 0.49 respectively, indicating larger effect sizes ($f > 0.4$) [27]. Learning attitudes for students' independent variables of disposition toward chemistry were shown in subscales Q1, Q2, and Q3. No significant differences for independent variables of gender, enrollment, and digital module frequency were detected in redox chemistry learning. Statistical results of three subscales were indicated from small (f is 0.1) to large (f is above 0.4) effect sizes [27] (in Table 3).

Table 3. Summary of F-ratios, p-values, and effect sizes (f) for each learning attitude in ANCOVAs post-tests

Teaching Unit	Blocking Variable	Analysis of Variance	Attitude Q1	Q2	Measure Q3
Redox	**Gender** (male, female)	F-ratio	0.477	0.076	0.385
		p-value	0.493	0.784	0.538
		f	**0.11**	**0.15**	**0.12**
	Enrolment (grades, recommendation, application, no test)	F-ratio	0.018	0.701	0.114
		p-value	0.997	0.557	0.951
		f	**0.28**	**0.15**	**0.26**
	Disposition toward Chemistry(positive, neutral, negative)	F-ratio	10.124	3.739	8.495
		p-value	0.000***	0.032*	0.001**
		f	**0.69**	**0.42**	**0.64**
	Use of Model (many, medium, few, no)	F-ratio	0.520	0.569	0.290
		p-value	0.671	0.639	0.833
		f	**0.19**	**0.18**	**0.23**

*p<0.05; ** p <0.01; *** p <0.001

In short, most students firmly agreed that applications of DRF chemistry technologies were helpful for clarifying the process of ions and charge transmissions and increased students' learning interests and skills in problem-solving. It was expected that learners had the strategic agreement and usefulness of DRF chemistry technologies because of the implements, demonstrations and multi-functions in problem-solving strategies.

Conclusions and Suggestions

To be a promising strategic teaching, this study incorporated computer animated presentations into DRF problem-solving abilities with suitable interviews for promoting students' chemistry performances in the following way.

Conclusions

The statistical analyses of this research explored implemented validity of DRF problem-solving skills in previous research results [15, 28-30]. While traditional lecture-based teaching could not fully meet students' learning and curiosities, this study recommended multimedia DRF problem-solving strategies to promote learners' chemistry learning performances. Statistical results showed that experimental group students' learning performances, with strategic abilities of DRF, had higher posttest scores than those of controlling group students. The same experimental group students with strategic abilities of DRF had more significant and increasing learning achievements in posttests of problem-solving skills in the chemistry learning unit than in their pretests. For different dispositions of chemistry, experimental group students also indicated more significant satisfaction in chemistry learning, and over larger effect sizes ($f > 0.4$) in the unit of redox chemistry learning. According to semi-structure interviews between students and teachers, all DRF chemistry applications had much appeal to students' curiosity and interests, which could enrich their satisfaction in learning and construct the validity of concise chemistry conceptions.

Suggestions

This research is aimed at the validity of DRF problem-solving tools in promoting students to have the macroscopic and microscopic demonstrations with symbols and to clarify students' overall conceptions in chemistry, as well as in enhancing their problem-solving skills and learning performances. Three further suggestions could be indicated below:

(1) Strengthening more highlighted DRF applications
The highlighted DRF chemistry should be designed to contain more practices and demonstrations, including textual explanations, static figures, and colorful presentations in order to attract students' learning motivation and good cognition.

(2) Building up a well-equipped e-environment in chemistry learning
Educators should set up digital multimedia equipment with projector slides and well-prepared DRF presentations.

(3) Linking macroscopic and microscopic demonstrations with chemical symbols
Students were required to link chemistry conceptions between verbal and visual inputs and to construct macroscopic and microscopic DRF abilities with chemical symbols.

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