JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

ENHANCING STUDENTS' HIGH-ORDER COGNITIVE SKILLS FOR HIERARCHICAL DESIGNS IN MICRO AND SYMBOLIC PARTICULATE NATURE OF MATTER

King-Dow Su

Abstract. *To be familiar with micro and symbolic performances, students could work out more effective approaches of innovated techniques known as five hierarchical designs in chemistry equilibrium. However, the most frequently reported problem in students' assessment of chemistry study is attributed to their poor skill recognizing basic concepts. The aim of this research was to construct the 6 test items to help undergraduate students assess their high-order and low-order cognitive skills as a deeper framework of particle representations. It takes a dynamic appeal for students to identify their profound understanding of cognitive skills in accordance with their potential performances of particle representations. In this research, students activate the test instrument to sustain their development of content validity and inter-rater reliability. The research results mark a different responsive engagement of both high-order and low-order cognitive skills in students' total performances with the skill ratio score of 1:6 for conceptual recognition and analyses of micro and symbolic performances. All students' micro and symbolic performances offer an indication for understanding their advanced cognitive skills in the particulate nature of matter. It is beneficial to improve new perspectives in the discussions and activity hierarchical designs in their chemistry equilibrium classrooms.*

Keywords: *high-order cognitive skills, hierarchical designs, micro, symbolic performances, particulate nature of matter*

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

Introduction

As a tactic skill to improve cognitive understanding, students' micro and symbolic performances play a dynamic role for their assessments of hierarchical designs in chemistry equilibrium. It is important to explore students' micro and symbolic performances with the science, technology, engineering and mathematics (STEM) curricula corresponding to their profound understanding of cognitive skills. In order to facilitate students' cognitive skills with critical thinking and self-reflective understanding, instructors should develop a two-fold hierarchical design for keeping up their micro and symbolic performances with creativity and potentialities (Barak, 2013; Lazakidou & Retalis, 2010; Zoller, et al., 2002).

Students are not only expected to know the different meanings of macro, micro and symbolic performances, but also be equipped with hierarchical designs to foster the conceptualized performance of the cognitive skills. Further discussions would clarify students' cognitive understanding for more chemistry innovative representations. Due to the abstract and complicated nature of chemistry equilibrium, the suitability of micro and symbolic performances corresponds to students' hierarchical understanding levels to distinguish their contextual operations for further identification and engagements in science classrooms. The observation by scholars (Fernandez et al., 2013) reveals students' active engagements to regurgitate and pass examinations as a problem-solving for reducing their dependent facts in memorizing chemistry.

Challenging of Micro and Symbolic Performances

The setting of hierarchical design conveys a special composite for students to distinguish their innovative understanding skills starting from ineffable impressions to ending achievements of distinct perceptions. According to explanations of Sim and Daniel (2014), a new way of determining chemical ideas can be developed by students' combining necessary skills in their cognitive skills of chemistry equilibrium. The word "micro" in scholars' explanations refers to students' component performances of atoms, ions, and

https://doi.org/10.33225/jbse/20.19.842

molecules, etc., while "symbolic" refers to their equations, formulae, mathematical and stoichiometric manipulation, and graphs (Johnstone, 2000). After ascertainments of implications with micro and symbolic performances, students should not confuse their initial word "macro" with the conceptions "observable, sensory and tangible phenomena." Since students meet trouble by learning obstacles or confronting barriers without the authentic representations of cognitive skills, they cannot build upon more and more micro and symbolic performances to relate complicated concepts into appropriate science understanding (Walker, et al., 2012).

It presents more new challenges for students to employ micro and symbolic performances in conducting their hierarchical designs in the chemistry classroom. In cases of students' encountering and creating a suitable understanding environment via the possible choice items, it provides a major learning pathway to guide students' different cognitive skills (Neumann, et al., 2013). Since many students' confrontation with chemistry equilibrium and Le Chatelier's principle up to now has met a number of difficult scientific conceptual cases (Cheung, 2009), researchers (Litzinger et al., 2010) propose effective systematic problem-solving strategies for constructing cognitive domain and procedural understanding. For example, scholars have adopted cognitive understanding levels as a logical reasoning instrument of learners' approach, such as order multiple-choice (OMC, Hadenfeldt et al., 2013; Su, 2019) and chemical symbolic representations abilities (CSRA, Wang et al., 2017). Students' cognitive skills of OMC respond to their individual conceptual developments in hierarchical designs (Briggs & Alonzo, 2012; Briggs et al., 2006). Yet scholars have noticed students' learning dilemma in different cognitive skills that impedes students to enact and reconstruct mental potentiality in chemistry equilibrium (Yakmaci-Guzel, 2013).

Research Purposes

This research put a special focus on hierarchical designs in constructing an assessed instrument of six test items (see appendix 1) for students' performances of high-order and low-order cognitive skills in chemistry equilibrium. The requirements to establish students' cognitive skills were observed in several innovative research studies for extensive conceptualized understanding in particulate nature of matter (PNM, Özmen, 2013). Students' encountering cognitive development has expected a cohesive and potential participation in the hierarchical design of micro and symbolic performances (Wang et al., 2017). Taber (2013) argued that the objective of chemistry knowledge should not be limited to purely symbolic knowledge or micro representations as a discrete knowledge level. He maintained that students' conceptual understanding could be consistent with the contextual understanding of micro and symbol elements. Accordingly, the research aim was micro and symbolic performances as substantial factors in investigating students' in-depth knowledge and understanding of hierarchical designs in order to enhance their development of high-order cognitive skills in chemistry equilibrium teaching.

Research Questions

In order to enact and reconstruct students' micro and symbolic performances with their understanding distributions of hierarchical designs, this research has built up three research questions as follows:

(1) What diagnostic assessment can be applied for developing students' constructive understanding levels of validity and reliability?
(2) What implements of students' hierarchical designs can give corresponsive interests to their micro and symbolic performances?
(3) What objectives and criteria can be made to promote students' substantial cognitive skills in chemistry equilibrium?

Research Methodology

General Background

For activating students' assessment high-order and low-order cognitive skills, this research marked a different approach in their total diagnostic performances of six test items. Students conducted their participation step by step through hierarchical cognitive skills of micro and symbolic performances. Most students' micro and symbolic performances and conceptual results of PNM chemistry equilibrium were developed during the process of 2017 academic year.

https://doi.org/10.33225/jbse/20.19.842

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

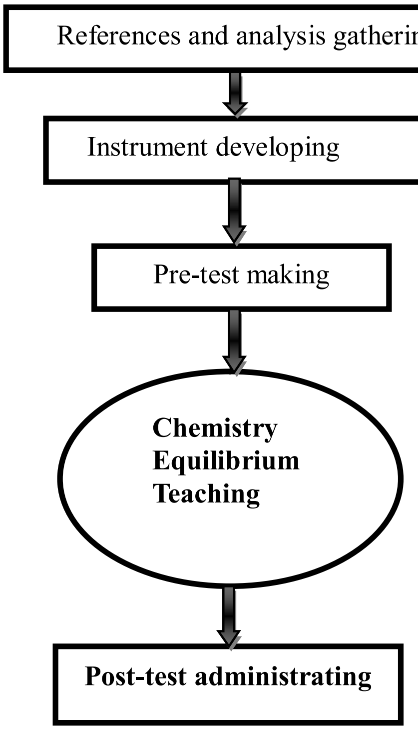
Participants of Research

All participants demonstrate their cognitive skills during two stages of the test instrument. Through the assessment of the test instrument, 548 participants could gradually manifold their substantial cognitive skills with micro and symbolic performances for chemical knowledge. There were two functional tasks to confirm their accumulated cognitive skills in general chemistry for all students. At the first stage, 173 students (age distributions from 19 to 21) attended the pilot test to gather validity and reliability data of the evaluative test instrument. At the second stage, 375 participants (including 136 males, 239 females; aged distribution from 18 to 21) took the Nature Science course in Chung Yuan Christian University, Taiwan, who were divided into 25 groups with 15 participants in each group. Participants had to take the post-test of evaluative test instrument after they had joined the experimental teaching of chemistry equilibrium.

Research Procedures

The research procedures consisted of five stages in the workflow of Figure 1.

Figure 1
Workflow of this research



The workflow includes references and analysis gathering, instrument developing, pre-test making, chemistry equilibrium teaching and post-test administrating. In this research, to design an evaluative instrument of six test items as pre-tests and post-tests, becomes the major assessment of cognitive skills. During the assessments of hierarchical designs, the researcher develops the evaluative test instrument with the validity and reliability for students' micro and symbolic performances. It is necessary in the subsequent assessments that students were required to make critical thinking and post-test administrations for conducting their cumulated cognitive skills before and after their participations.

For 25 groups with 375 participants, each group was assigned brain storming activities and group discussions in class. In order to facilitate their implementation of micro and symbolic performances, students were required

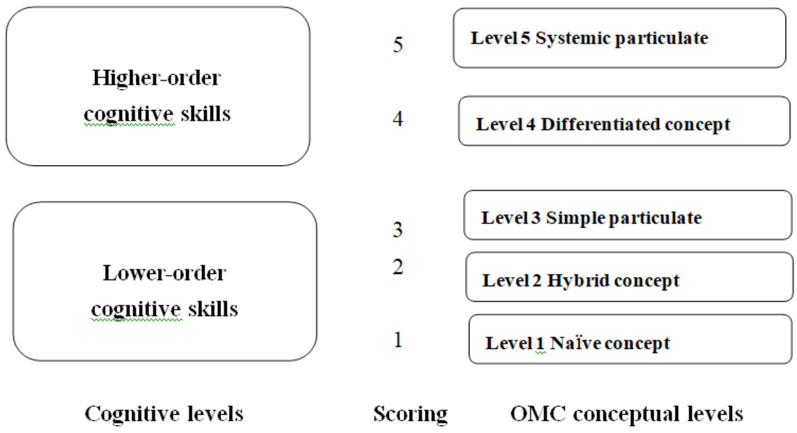
https://doi.org/10.33225/jbse/20.19.842

to do a surf test using cell phones in the OMC innovative framework for the assessment of gathering basic data. After their formulated knowledge of chemistry equilibrium, students were required to pay attention to ethical precautions and to follow consent reports without violating local legal agreements and information (Taber, 2014).

Instrument Design

The alignment of this research follows the framework of students' corresponding hierarchical designs with respect to both the quantitative and qualitative analyses. After students have achieved the cognitive skills in Figure 2, their graphical representation of cognitive skills is different from those of OMC conceptual levels (Hadenfeldt et al., 2013).

Figure 2
Students' responsive representations of cognitive skills in five hierarchical levels



The framework of this research includes two corresponding major cognitive skills: (1) three basic concepts (Naïve, Hybrid, and Simple particulate concept) as low-order cognitive skills and (2) two advanced concepts (Differentiated and Systemic particulate concept) as high-order cognitive skills indicated in Figure 2. Students' conceptual cognitive levels could be explored through a different assessment of conceptualization correlated with the five components of their mental framework. In each aspect of five hierarchical OMC conceptual levels (adopted from Hadenfeldt et al., 2013), students could respond accordingly and spontaneously to their mental conceptualization of chemical knowledge in both low-order and high-order cognitive skills as in Figure 2.

All results indicate those students' cognitive skills of micro and symbolic performances increase with the score items to be indications of the different OMC hierarchical designs in Figure 2. Students develop their cognitive skills as responsive indications with their test items of micro and symbolic performances in 5 separate scoring systems (Hadenfeldt et al., 2013). OMC could elicit individual cognitive skills of students' responsive performances to appropriate conceptual hierarchical levels and analyze their developmental elaborate insights with a learning progression in science (Briggs & Alonzo, 2012; Briggs et al., 2006). Therefore, this research deals with the systematic context and OMC integration for students' development of hierarchical designs in chemistry equilibrium.

The analysis of five hierarchical OMC conceptual levels provides an important diagrammatic designation in giving 5 separate scoring systems from score 1 to score 5 for students' test item levels in chemistry equilibrium. At the lowest level, students get their test item as score 1 for naïve concept (L1). For the next second level, students get test item as score 2 for hybrid concept (L2). Students get test item as score 3 for simple particulate concept (L3), and students get test item as score 4 for differentiated concept (L4). Finally, students get test item as score 5 for systemic particulate concept (L5, Hadenfeldt et al., 2013).

Other instrument designs in this research correspond to an innovative framework illustrated in six test items to guide students' micro and symbolic performances of chemical equilibrium. A detailed designation of micro and symbolic performances incorporates students' individual cognitive skills into their composite set of assessment perception in particle chemistry. Prior to their final assessment of five hierarchical designs of OMC levels, students

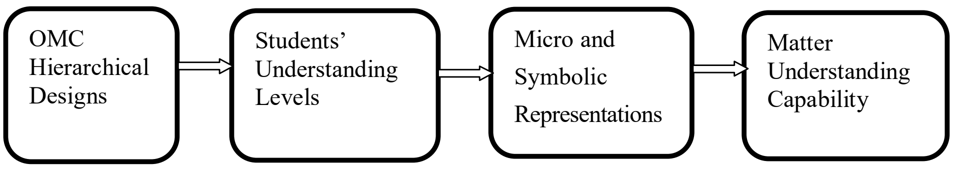
https://doi.org/10.33225/jbse/20.19.842

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

have developed more conceptual understanding of micro and symbolic performances, including structure, properties and changing particles of chemical matter.

Gradually, all students follow the guide of 4-step process to develop their micro and symbolic performances in Figure 3. With this innovative framework, students are able to go through OMC hierarchical designs and set up to matter-understanding capability.

Figure 3
The guide of 4-step process for students' matter-understanding capability



Validity and Reliability

For the functional hierarchical designs, 21 draft test items with micro and symbolic performances of chemical equilibrium were constructed by the author. In order to construct the rational difficulty index of test items and promote Kendall's coefficient of concordance (ω), the test items were scrutinized, deleted and revised by six renown and respected chemistry and science researchers. They provided expert evaluation for content validity and the revision of draft test items. An evaluative instrument of six test items was extracted by the specialists after deleting difficult and unreasonable test items. All target concepts for choice items of evaluative instrument were indicated and stated in Table 1. Students can identify and explain PNM scientific phenomena with simple or differentiated particle model to arrive their target concepts in chemistry equilibrium.

There were 173 students to engage the pilot test and gather validity data of six test items. Students' answering rate indicated that the distribution of difficulty index (p value) for the evaluative instrument was determined and shown in Table 2.

Table 1
The target concepts with responsive levels of all choice items of evaluative instrument

Level Corresponding	Target concept	Choice item
Naïve concept	To identify fundamental PNM	1A 1C 3C 3D 3E 4A 4D 5A
Hybrid concept	To explain scientific phenomena	2A 2B 2C 2D 3B 5C
Simple particulate	To explain PNM with model	1B 3A 4B 4C 4E 5B 6A 6B 6C 6D
Differentiated concept	To understand sub-atoms with model	1D 1E 5E 6E
Systemic particulate	To explain properties of matter with model	5D

In addition, three senior chemistry researchers were asked to make answer and understand authentic logic reasoning with more exact analyses of inter-rater reliability. The evaluative instrument with the coefficient of consistent agreement ($.6 < \omega < .8$) was constructed to guide students' micro and symbolic performances of chemical equilibrium (Marozzi, 2014).

https://doi.org/10.33225/jbse/20.19.842

Table 2
The difficulty index (p value) of evaluate instrument

No	p value	Statement	Test Item
1	*p < 30%*	The difficulty test item	3
2	*30%≦ p < 50%*	The difficulty towards easy test item	1, 2, 4
3	*50%≦ p < 70%*	The easy towards difficulty test item	5
4	*70%≦ p*	The easy test item	6

Quantitative Data Analysis

In response to university students' assessment of micro and symbolic performances, this research offers both comparative and analytical discussions of test instrument (see appendix 1) for students' conceptual development. With the same background study and instructive assessment, all participants were scored with the total 96 points of OMC score for the test instrument within the 30-minute test span in class. Students' assessments for each test score provide an exploratory analysis conducted in Excel.

Ethical Approval

In order to facilitate students' implementation of micro and symbolic performances, they were required to do a surf test using cell phones in the OMC innovative framework for the assessment of gathering basic data to conduct this study. During their formulated knowledge of chemistry equilibrium, all students were required to pay attention to ethical precautions and consent reports without violating local legal agreement and information (Taber, 2014).

Research Results

Quality of Evaluative Instrument

As the research question 1 for the main support of hierarchical designs, this research proposes the responsive answers with the innovated framework in the evaluative instrument of six test items that illustrate students' micro and symbolic performances. A suggestive framework for students' response on high-order and low-order cognitive skills needs a dynamic instrument design in discovering their cognitive distribution levels of particle representations. With the help of three senior chemistry professors, the substantial agreements of OMC options for the test instrument examined the relevant reliability through Kendall's coefficient of concordance (ω=.61, χ^2=33.11, p<.05, N=375) in chemistry equilibrium. It took a unified consistent agreement for the instrument design of 6 test items to set up students' responsive analyses of content validity and inter-rater reliability in accordance with their conceptual understanding competence.

To explore the research question 2 on students' figured proportion of OMC hierarchical designs, this research manifests a detailed investigation of the evaluative instrument together with each corresponding performances of micro and symbolic performances. Students' enactment of the evaluative instrument elicited individual responses to appropriate performances and facilitated their corresponding development of hierarchical designs for conceptual representation of cognitive skills. As a substantial factor in chemistry learning, the formulation of the test instrument served as an effective configuration to explain separately students' 5 choice items corresponding cognitive skills (5 choice items A, B, C, D and E) from Level 1 to Level 5.

Students' Responsive Result

The following cases are 375 students' cognitive response levels of test instrument on 5 choice items -- A, B, C, D, and E, show in Table 3 below. Since test item 1 has given the fundamental conceptions of chemical equilibrium, it occurs when opposing reactant molecules are proceeding at the same rates, in which each reactant, activated

https://doi.org/10.33225/jbse/20.19.842

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

complex and product can exert its potential energy and behave independently before and after collision. In test item 1, 62 students who took choice A item were correlated to Level 1, 225 students (took B choice item) correlated to Level 3, 42 students (C choice item) correlated to Level 1, 25 students (D choice item) correlated to Level 4, and 21 students (E choice item) correlated to Level 4. The whole test item analysis of particle understanding percentage (%) was indicated in Table 3 for students' micro and symbolic performances.

Table 3

Students' responsive distribution numbers (N=375) for each test item in 5 A, B, C, D, E choice items

Test item	Choice items				
	A	B	C	D	E
1	62/L1	225/L3	42/L1	25/L4	21/L4
2	19/L1	115/L1	129/L1	20/L1	92/L4
3	78/L3	139/L2	72/L1	62/L1	24/L1
4	69/L1	47/L3	209/L3	27/L1	27/L3
5	22/L1	87/L3	147/L2	88/L5	31/L4
6	22/L3	72/L3	96/L3	91/L3	83/L4

Likewise, to answer test item 2, students found that the affected factors of chemical reaction would disturb the balance and shift the equilibrium position. Students would examine how each of these variables (such as, activated energy, kinetic and potential energy, temperature, catalyst, concentration) affected a reacting system at equilibrium. In test item 2, 19 students (A choice item) are corresponded to Level 1, 115 students (B choice item) corresponded to Level 1. 129 students (C choice item) corresponded to Level 3, 20 students (D choice item) corresponded to Level 1. 92 students (E choice item) corresponded to Level 4. Students understood the applications of Le Châtelier's principle (Brown, et al., 2000, p576) could help to answer test item 3. In students' cognitive response for test item 3, 78 students took A choice item as the corresponding Level 3, 139 students (B choice item) as the corresponding Level 2, 72 students (C choice item) as the corresponding Level 1. 62 students (D choice item) as the corresponding Level 1. 24 students (E choice item) as the corresponding Level 1.

According to Haber process in test item 4, the system put together N_2 and H_2 in several hundred atmospheres, in the presence of catalyst, and at several hundred degrees Celsius to product ammonia in chemical equilibrium. To search for students' cognitive response for test item 4, 69 students provided an account of A choice item as the corresponding Level 1, 47 students (B choice item) as the corresponding Level 3, 209 students (C choice item) as Level 3, 23 students (D choice item) as Level 1and 27 students (E choice item) as Level 3. A correct response to test item 5 students would understand the reaction quotient (Q) and equilibrium constant (K). When Q=K, only at equilibrium, Q<k, the reaction would achieve equilibrium by forming more products, and Q>K, the reaction would approach equilibrium by forming more reactants. To reply for students' cognitive response for test item 5, 22 students were given A choice item as the corresponding Level 1, 87 students (B choice item) as the corresponding Level 3, 147 students (C choice item) as Level 2, 88 students (D choice item) as Level 5, and 31 students (E choice item) as Level 4.

All students gave the optimization answer for test item 6, they could clearly understand the expression of equilibrium constant for the changes of initial and final equilibrium concentrations. The stoichiometry of this reaction presented the relationship of molecule particulates between the changes of all reactant and product concentrations. In answer for students' cognitive response of test item 6, 22 students took A choice item as the corresponding Level 3, 72 students (B choice item) as the corresponding Level 3, 96 students (C choice item) as Level 3, 91 students (D choice item) as Level 3, and 83 students (E choice item) as Level 4. The completely detailed item tests were supplied with students' micro and symbolic performances in Table 4.

All the aforementioned investigations of the evaluative instrument for students' cognitive response in research question 2 made a different distribution of five hierarchical designs in this research. Students' cognitive response for test items 1, 3, 4 gave a mediated distribution from Level 1 to Level 3. Their cognitive response for test items 2, 5, and 6 displayed a high indication up to Level 4. Of all response for the test instrument, only their cognitive response

https://doi.org/10.33225/jbse/20.19.842

for test items 5 reached a higher indication to Level 5 as the micro and symbolic performances. Judged from major distributions of five hierarchical understanding levels, we could discern that Level 3 performed an outstanding diagrammatic figure for students' cognitive response in Table 4. Most students' hierarchical understanding levels built up the formulation of Level 3 in accordance with their simple particulate concept cognitive skills.

Table 4
Students' test item percentage (%) for five conceptual levels

Conceptual level	Test item					
	1	2	3	4	5	6
1	34.4	41.1	42.1	24.5	5.9	0
2	0	0	37.1	0	39.2	0
3	65.6	34.4	20.8	75.5	23.2	77.9
4	0	24.5	0	0	8.2	22.1
5	0	0	0	0	23.5	0

Students' Responses of Cognitive Skills

According to students' self-initiated responses for question 3, this study revered an analysis of high-order and low-order cognitive skills in Table 5.

Table 5
Two fundamental categories of cognitive skills for 375 students' responses: percentage (%) within test instrument

Test item	Cognitive skills	
	Low-order	High-order
1	94.4	5.6
2	75.5	24.5
3	100	0
4	100	0
5	68.3	31.7
6	77.9	22.1
Average	86	14

Fundamentally, students could identify their developments of chemistry equilibrium into two basic categories of cognitive skills: (1) the low-order cognitive skills including three basic concepts – Naïve, Hybrid, and Simple particulate concept; and (2) the high-order cognitive skills including two advanced concepts – Differentiated and Systemic particulate concept. Students scored their micro and symbolic representations as percentage (%) of particle understanding in Table 5. Only 14% of students achieved a better performance of higher-order cognitive skills within the evaluative instrument, and 86% of students had their development of low-order cognitive skills within the same items. Furthermore, students fulfilled their self-initiated score ratio between high-order cognitive skills and low-order cognitive skills up to 1:6, and the ratio also proved to be an important indication for chemistry instructors to make substantial improvements in students' micro and symbolic performances as the previous article (Su, 2019).

https://doi.org/10.33225/jbse/20.19.842

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Discussion

It has been advantageous for researchers to note students' recognition of hierarchical designs in setting up the postulation of their results of content validity and inter-rater reliability. For the justification of micro and symbolic performances, this research contributed a design of the evaluative instrument linked to students' five hierarchical understanding levels. To obtain students' total assessment of the test instrument, two fundamental categories of their responsive levels were designed as high-order and low-order cognitive skills in chemistry equilibrium. The assessed instrument of six test items was administered to all participating students for OMC response of both aspects of cognitive skills. In comparison with other implemented chemical learning instruments, this research demonstrated a design of the test instrument that would be consistent with scholars' examination (Marozzi, 2014; Su, 2019) for content validity and inter-rater reliability. The employment of the test instrument had more consistent agreement with three senior chemistry professors' critical responses in students' cognitive skills.

Students' five hierarchical designs with distributed percentage (%) can be categorized as exemplars of both low-order and high-order cognitive skills. Because of students' response for the design in Figure 2, we found that all students' performances of the test instrument in this research were identified as either high-order or low-order cognitive skills in Table 5. Students' performances of the test instrument manifested different indications of distributed percentages. In cases of test items 1, 2, 5 and 6, students' performance went up to the high-order cognitive skills in the following way: test item 1 as high-order distributed percentage 5.6%, test item 2 as percentage 24.5%, test item 5 as percentage 31.7% and test item 6 as percentage 22.1%. Yet in the cases of test items 3 and 4, students' performance gave the same indication of low-order distributed percentage as 100 %.

It is a crucial finding for scholars to make alternative agreements in their assessment of students' different responses and learning performances of cognitive skill distributions in micro and symbolic performances. As in all responsive cognitive skills, there exists an important link between critical thinking and problem-solving skills that was oriented toward the design exemplified in the discussion of five OMC levels (Taconis et al., 2001). A comparative analysis of developed distributions can be made for two respondents, namely both low-order skills students and high-order skills students. In more formulated results of statistic, low-order skills students need to adjust their cognitive distributions of micro and symbolic performances in more endeavor for bringing out deeper learning engagements (Adams, 2015; Wilson, 2005; Yakmaci-Guzel, 2013).

The assessed performances in the design had justified students' shift in responsive understanding levels for cognitive skill distributions from low-order skills to high-order skills. With distributions of low-order skills, students with lower understanding levels had to reinforce the evaluative instrument through their accumulation of critical thinking and problem-solving skills. Accordingly, students with higher understanding levels required commitments of high-order cognitive skills to develop the contextual applications of PNM and interconnected level of scientific literacy for the ultimate goal of chemistry performances (Zoller & Pushkin, 2007).

The ultimate goal for students to enact their high-order cognitive skills would be to bring about a natural manipulation in conceptual understanding and scientific literacy, which would correspond to their contextual application of interconnected levels (Zoller & Pushkin, 2007). On the other hand, it is necessary for students with low-order cognitive skills to transfer their potential accumulation with higher understanding levels through the flexible design of the evaluative instrument (Wilson, 2005; Yakmaci-Guzel, 2013). The more continuing domains of high-order cognitive skills develop; the further framework of higher understanding levels activates low-order students to make applicable fulfillment of conceptual understanding.

Conclusions and Suggestions

The innovative design of the evaluative instrument exemplifies most students' cognitive performances of hierarchical designs with more content validity and inter-rater reliability. Systematically, students' both lower and higher order cognitive skills scrutinize two major respondents on their distributed competence. For high-order skills students, they need to conduct suggestive responses in particle representations for extensive alternative learning. For low-order skills students, they are required to reinforce more cognitive accumulation with their understanding of micro and symbolic performances in the evaluative instrument.

To set up the appropriate environment for innovated design, it would be necessary to construct both high-order skills and low-order skills students' responsive performances. Through the conceptual recognition and ad-

https://doi.org/10.33225/jbse/20.19.842

justed understanding of hierarchical analyses of micro and symbolic representations, students gradually acquire their learning exploration from the unknown chemistry concepts to the known development of low-order and high-order skills. The suggestive proposal for low-order skills students is to organize a selective feedback and coherent distribution with mediating responses over the nature and extent of PNM. It also posits a new challenge to reinforce students' conjectural performances of individual problem undertaking with in-depth responses for high-order cognitive skills students.

This research offers a collaborative perspective for exploring college students' micro and symbolic performances with an innovated design of cognitive skills. It suggests more mediated design for both low-order and high-order skills students in search of higher correlation of conceptual understanding levels. Up to the aim of this study, their performances will become an increasing target understanding for the formulated contribution of original, creative and alternative teaching methods with students' cognitive understanding in particulate chemistry. In the future, to explore students' more potentiality should be influential in creating their dominant identification of the self-improvement area.

More suggestive instructions for students' conceptual understanding will be responsive to future teaching programs, such as identification factors and mechanisms that might guide or hinder students' cognitive skills and improving development to be collected as alternative assessments.

Acknowledgements

A short but sincere thank must also be given to the patronage of the Ministry of Science and Technology, MOST in Taiwan (under Grant No. MOST 105-2511-S-237-002-MY2 and MOST 107-2511-H-237-001). Without their help and financial support, this research could not have been completed in the present form.

References

Adams, N. E. (2015). Bloom's taxonomy of cognitive learning objectives. *Journal of the Medical Library Association, 103*(3), 152–153. http://doi.org/10.3163/1536-5050.103.3.010

Barak, M. (2013). Impacts of learning inventive problem-solving principles: Students' transition from systematic searching to heuristic problem solving. *Instructional Science, 41*(4), 657-679. https://doi.org/10.1007/s11251-012-9250-5

Briggs, D. C., & Alonzo, A. C. (2012). The psychometric modeling of ordered multiple-choice item responses for diagnostic assessment with a learning progression. *Learning Progressions in Science*. Sense Publishers, Rotterdam. https://doi.org/10.1007/978-94-6091-824-7_13

Briggs, D. C., Alonzo, A. C., Schwab, C., & Wilson, M. (2006). Diagnostic assessment with ordered multiple-choice items. *Educational Assessment*, *11*(1), 33-63. https://doi.org/10.1207/s15326977ea1101_2

Cheung, D. (2009). The adverse effects of Le Châtelier's principle on teacher understanding of chemical equilibrium. *Journal of Chemical Education*, *86*, 514-518. https://doi.org/10.1021/ed086p514

Fernandez, C., Holbrook, J., Mamlok-Naaman, R., & Coll, R. K. (2013). How to teach science in emerging and developing environments? In *Teaching chemistry – A study book* (pp. 299-326). Sense Publishers. https://doi.org/10.1007/978-94-6209-140-5_11

Hadenfeldt, J. C., Bernholt, S., Liu, X., Neumann, K., & Parchmann, I. (2013). Using ordered multiple-choice items to assess students' understanding of the structure and composition of matter. *Journal of Chemical Education*, *90*, 1602-1608. https://doi.org/10.1021/ed3006192

Johnstone, A. H. (2000). Teaching of chemistry — Logical or psychological? *Chemistry Education Research and Practice in Europe, 1*, 9–15. https://doi.org/10.1039/A9RP90001B

Lazakidou, G., & Retalis, S. (2010). Using computer supported collaborative learning strategies for helping students acquire self-regulated problem-solving skills in mathematics. *Computers & Education, 54*, 3–13. http://dx.doi.org/10.1016/j.compedu.2009.02.020

Litzinger, T. A., Van Meter, P., Firetto, C. M., Passmore, L. J., Masters, C. B., Turns, S. R., Gray, G. L., Costanzo, F., & Zappe, S. E. (2010). A cognitive study of problem solving in statics. *Journal of Engineering Education, 99*(4), 337–353. https://doi.org/10.1002/j.2168-9830.2010.tb01067.x

Marozzi, M. (2014). Testing for concordance between several criteria. *Journal of Statistical Computation and Simulation*, *84* (9), 1843-1850. https://doi.org/10.1080/00949655.2013.766189

Neumann, K., Viering, T., Boone, W. J., & Fischer, H. E. (2013). Towards a learning progression of energy. *Journal of Research in Science Teaching*, *50*, 162–188. https://doi.org/10.1002/tea.21061

Özmen, H. (2013). A cross-national review of the studies on the particulate nature of matter and related concepts. *Eurasian Journal of Physic and Chemistry Education, 5*(2), 81-110.

Sim, J. H., & Daniel, E. G. S. (2014). Representational competence in chemistry: A comparison between students with different levels of understanding of basic chemical concepts and chemical representations. *Cogent Education, 1*, 2-17. https://doi.org/10.1080/2331186X.2014.991180

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Su, K. D. (2019). A feasible guidance for ordered multiple-choice items in students' hierarchical understanding levels. *Journal of Baltic Science Education*, *18*(1), 77-89. https://doi.org/10.33225/jbse/19.18.77

Taber, K. S. (2013). Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chemical Education Research and Practice, 14*(2), 156–168. https://doi.org/10.1039/C3RP00012E

Taber, K. S. (2014). Ethical considerations of chemistry education research involving 'human subjects.' *Chemistry Education Research and Practice, 15*, 109-113. https://doi.org/10.1039/C4RP90003K

Taconis, R., Ferguson-Hessler, M. G. M., & Broekkamp, H. (2001). Teaching science problem solving: An overview of experimental work. *Journal of Research in Science Teaching, 38*(4), 442-468. https://doi.org/10.1002/tea.1013

Walker, R., Voce, J., & Ahmed, J. (2012). *2012 Survey of technology enhanced learning for higher education in the* UK. Universities and Colleges Information Systems Association. http://www.ucisa.ac.uk/groups/ssg/surveys.aspx

Wang, Z., Chi, S., Luo, M., Yanga, Y., & Huanga, M. (2017). Development of an instrument to evaluate high school students' chemical symbol representation abilities. *Chemical Education Research and Practice, 18,* 875-892. https://doi.org/10.1039/C7RP00079K

Wilson, M. (2005). Constructing measures: An item response modeling approach. Lawrence Erlbaum. https://doi.org/10.4324/9781410611697

Yakmaci-Guzel, B. (2013). Preservice chemistry teachers in action: An evaluation attempts for changing high school students' chemistry misconceptions into more scientific conceptions. *Chemistry Education Research and Practice*, *14,* 95-104. https://doi.org/10.1039/C2RP20109G

Zoller, U., Dori, Y. J., & Lubezky, A. (2002). Algorithmic, LCOS and HOCS (chemistry) exam question: Performance and attitudes of college students. *International Journal of Science Education*, *24*(2), 185–203. https://doi.org/10.1080/09500690110049060

Zoller, U., & Pushkin, D. (2007). Matching higher-order cognitive skills (HOCS) promotion goals with problem-based laboratory practice in a freshman organic chemistry course. *Chemistry Education Research and Practice, 8*(2), 153-171. https://doi.org/10.1039/B6RP90028C

Appendix 1 Six items test instrument

Test item 1

Which statement is correct for the following choice item?

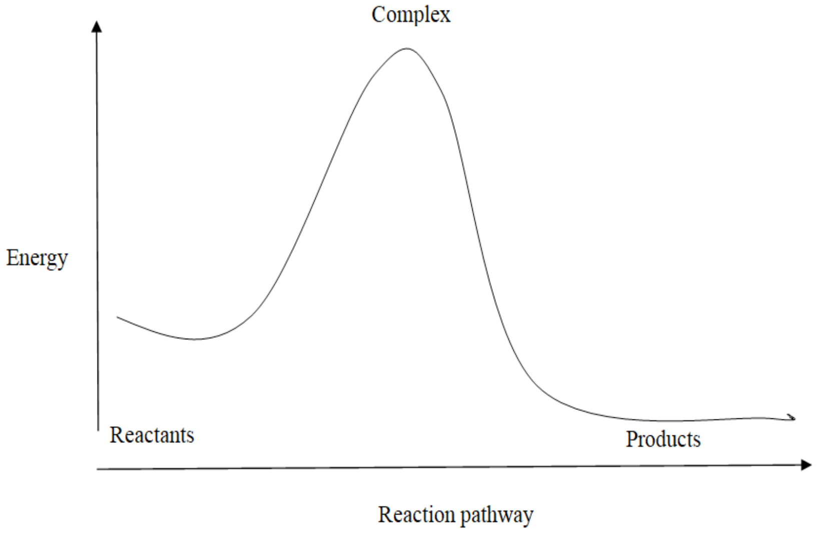
Choice item A: Some equilibrium must have enough reactants to support their stable situations. (L1)

Choice item B: When they are reached up to the equilibrium, both reactions of forward and reverse are continuously still in action. (L3)

Choice item C: As reactant molecules collide, they can immediately generate chemical reactions. (L1)

Choice item D: During the collision, the potential energy is higher than those energies both before and after collisions. (L1)

Choice item E: The activated complex is indicated in a mediated state between reactants and products. (L4)



https://doi.org/10.33225/jbse/20.19.842

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Test item 2

Which statement is correct for the following choice item?

Choice item A: Both activated energies of forward and reverse reaction are all positive. (L1)

Choice item B: During the collision, kinetic energy and potential energy will go hand in hand for transference. (L1)

Choice item C: As the temperature rises up, it will accelerate the speed and vise visa. (L3)

Choice item D: The catalyst will make the transformation steps of reactions. (L1)

Choice item E: In the process of chemical equation, the increased concentration on the right side will accelerate the rate of reverse reactions. (L4)

Test item 3

Which statement is correct for the following choice item?

Choice item A: During the chemistry reaction is in the equilibrium state, to add up the concentration of products will accelerate the rate of reactions. (L3)

Choice item B: During the chemistry reaction is in the gas equilibrium state, reducing the volume of a gaseous equilibrium mixture causes the system to shift in the direction that reduces the number of moles of gas. (L2)

Choice item C: When the temperature rises up, it will make the shift in the direction that exothermic reaction. (L1)

Choice item D: The value of equilibrium constant is in relation with the temperature rate. (L1)

Choice item E: The more equilibrium constant gets, the more it becomes the static tendency for forward reactions. (L1)

Test item 4

During the Haber process, it combines elements to make ammonia in the following equation: $N_2(g)+3H_2(g) \rightleftharpoons 2NH_3(g)+92kJ$. What is the best condition for optimization if the factory has to produce the ultimate yield in the shortest time span?

Choice item A: Low temperature and high pressure will have long time and high yield rates. (L1)

Choice item B: Low temperature and low pressure will have long time and low yield rates, due to the short of the collision energy of nitrogen and hydrogen? (L3)

Choice item C: High temperature and high pressure will have short time and high yield rates, because of increased collisions of effective frequency between intermolecular? (L3)

Choice item D: High temperature and low pressure will have long time and low yield rates. (L1)

Choice item E: Both normal temperature and pressures do not get the reaction easily, because of the collision direction and both low energies of nitrogen and hydrogen. (L3)

Test item 5

The initiate program indicates 5 states in the following figures: (a) Pure reactants, (b) Left of equilibrium, (c) Equilibrium state, (d) Right of equilibrium, (e) Pure products, and Q also is presented as the reaction quotient. Please predict which choice item is the best condition for the optimization reaction: $2HI(g) \rightleftharpoons H_2(g)+I_2(g)$, $Kc=1.84x10^{-2}$, at 698k and initiate concentration $[H_2]=[HI]=[I_2]=1.00M$?

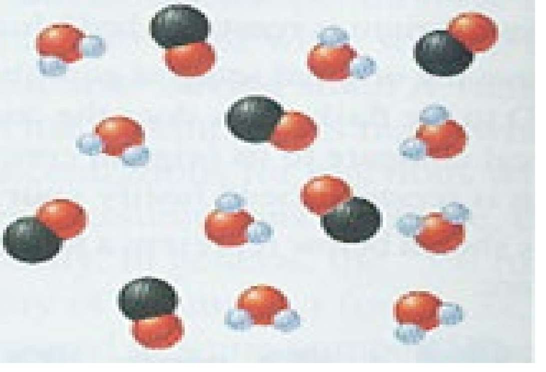
	(A)	(B)	(C)	(D)	(E)
Initial states	Pure reactants	Left of equilibrium	Equilibrium state	Right of equilibrium	Pure products
Q (Reaction Quotient)	0 →	Q< K →	Q= K	Q > K ←	∞ ←
Level	1	3	2	5	4

https://doi.org/10.33225/jbse/20.19.842

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Test item 6

Reaction equation is presented as $H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$. When it arrives at T℃, the equilibrium constant presented as Kc=2.0, and it is supposed to put some moles H_2O and CO into the container with 1 liter (the particulate distribution as the following figure). When it reaches up to the equilibrium, which statement is correct for the following choice item?



Choice item A: To reach up the equilibrium, the reactants get six moles. (L3)
Choice item B: To reach up the equilibrium, all four species get the same mole number. (L3)
Choice item C: To reach up the equilibrium, all species get the 14 moles number. (L3)
Choice item D: To reach up the equilibrium, the number of mole H_2 is equal to that of CO_2. (L3)
Choice item E: There are 8 mole H_2O and 6 mole CO in the initiate reactants. To reach up the equilibrium, the number of mole H_2O is twice as much as that of mole CO. (L4)

Received: *June 11, 2020* Accepted: *September 25, 2020*

Cite as: Su, K.-D. (2020). Enhancing students' high-order cognitive skills for hierarchical designs in micro and symbolic particulate nature of matter. *Journal of Baltic Science Education*, *19*(5), 842-854. https://doi.org/10.33225/jbse/20.19.842

King-Dow Su PhD, 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@mail. hdut.edu.tw
ORCID: https://orcid.org/0000-0001-5248-5589