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CONCEPTUAL UNDERSTANDING IN CHEMICAL EQUILIBRIUM OF SURFACE AND DEEP LEARNERS

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Abstract

This study aimed to determine and describe the conceptual understanding in chemical equilibrium among selected freshman students who were classified as surface and deep learners. Data were gathered utilizing study process questionnaire and conceptual understanding test. This study involved two intact classes of 58 engineering students enrolled in General Chemistry II and was conducted for three weeks. Using the study process questionnaire, students were classified as either surface or deep learners. After the lesson on chemical equilibrium, conceptual understanding test was given to the students. Students were then grouped into six based on their learning approaches and level of conceptual understanding.
The findings of the study revealed that majority of the class (53%) are deep learners while 47% are surface learners. Using t-test analysis, surface and deep learners differ in the scores they obtained on concepts about factors affecting equilibrium. Chi square test of independence also showed that surface and deep learners significantly differ from each other in terms of their level of conceptual understanding on factors affecting equilibrium concepts.
The results of t-test and chi-square test revealed that there could be times that differences between surface and deep learners could only be seen when tested across different concepts within a certain topic.

Keywords: Conceptual Understanding; Surface Learner; Deep Learner; Chemical Equilibrium; Learning Approach.

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1. Introduction

Conceptual understanding is the ability to apply knowledge across a variety of instances or circumstances. It differs from declarative knowledge learning in that declarative knowledge involves a memorization of an association between two or more entities (Smith, 1999 in Darmofal, Soderholm, & Brodeur, 2002). Brown (2004) stated that teaching for deep understanding emphasizes students' capacity for meaningful independent use of essential declarative knowledge

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(facts, concepts, generalizations, rules, principles and laws) and procedural knowledge (skills, procedures, and processes). Students demonstrate genuine understanding when they express their learning through one or more of the following facets of understanding: explanation, interpretation, application, perspective, empathy and self-knowledge. Biggs (1999) stated that if students 'really' understood a concept they would act differently in contexts involving that concept, and could use the concept in unfamiliar or novel contexts. He further stated that real understanding is performative, which echoes the constructivist view that learning changes students' perspectives on the world.

Posner, Strike, Hewson, and Gertzog (1982) argued that four conditions must be met for conceptual change to occur: A) The learner must be dissatisfied with a currently held concept- the student must realize that their concept does not work in all circumstances. B) The new concept must be intelligible- the student must be able to comprehend it. C) The new concept must be plausible- the student has to conclude that it is reasonable. D) The new concept must be fruitful- the student must recognize it as useful.

Conceptual understanding is considered lasting if the concept represents a "big idea" having lasting value beyond the classroom, resides at the heart of the discipline, requires uncoverage of misconceptions, and offers the potential to engage students (Wiggins, 1998 in Darmofal, Soderholm, & Brodeur, 2002). Brown (2004) stated that students develop deep conceptual understanding when they can cue into the enduring understandings and essential questions at the heart of their curriculum. Enduring understandings are statements that clearly articulate big ideas that have lasting value beyond the classroom and that students can revisit throughout their lives.
In an ideal system, all students would be expected to engage the highest level learning activities and thus to handle the task, or to solve the problem appropriately. This is in fact the generic definition of a deep approach while a student using a surface approach would use lower order verbs in lieu of the higher order (Biggs, Kember & Leung, 2001). Biggs, Kember and Leung (2001) further stated that deep and surface approaches are the indicators which are most pertinent to its intended use by teachers in their classrooms.

Biggs (1987) identified three approaches to learning: surface, deep and achieving. Achieving approach is a learning approach that involves using a strategy to maximize one's grades. Each of these approaches was also further classified into motive and strategy. Biggs (1999) stated that learning is not imposed or transmitted by direct instruction, but is created by students' learning activities, their approaches to learning. The low cognitive level of engagement deriving from the surface approach yields fragmented outcomes that do not convey the meaning intended by the encounter, whereas the deep approach is more likely to help the student construe the meaning.

Marton and Saljo (1976) stated that the surface approach was characteristics of students who oriented their learning towards memorization and reproduction and who viewed learning as acquiring knowledge merely for passing examinations, with little or no focus on the processes. Learning of this type of student is externalized. On the other hand, learners who adopt a deep approach are those who internalize learning, relate the parts to each other and derive a wider picture for understanding how knowledge fits together and represents reality.

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In the study of Bernardo (2003), students' approach to learning had been shown to be an important predictor of academic achievement among Filipino students. The study also indicated that the Learning Process Questionnaire (LPQ) is a viable instrument for describing the approaches to learning of average- and high-achieving Filipino students, but not of low-achieving Filipino students.

Hackling and Garnett (1985), stated that there are four topics within the domain of chemistry that give learners most difficulty: chemical equilibrium, the mole, reaction stoichiometry and oxidation-reduction. From among this list, chemical equilibrium was rated as the most difficult for students to comprehend. Wheeler and Kass (1978) stated that in addition to acquiring certain prerequisite concepts and skills in chemistry, treatments of chemical equilibrium, tend to call for considerable abstraction and propositional thinking by students. They further stated that their review of literature revealed two major reasons for students having difficulties in these areas; firstly, the topics are very abstract, and secondly, words from everyday language are used but with different meanings. Harrison and De Jong (2005) stated that chemical equilibrium is one of the central organizing topics in chemistry education, and includes several important subtopics, such as reversible reaction, reaction rate, energy effects, chemical kinetics and dynamic equilibrium.

Boujaoude (1992) investigated the relationship between high school students' learning approaches, prior knowledge and attitudes toward chemistry, and their performance in a misunderstanding test. The author also described and analyzed the difference between the responses of students with different learning approaches on the same test. Results revealed that students' performance on a misunderstanding pretest and the students' learning approach both accounted for a statistically significant proportion of the variance on their performance on the misunderstanding posttest. Additionally, the results showed that the relatively meaningful learners performed significantly better than the relatively rote learners on the misunderstandings posttest.
Dimagiba (2004) in her study on facilitating conceptual change on matter through constructivistic teaching revealed that there were more meaningful learners in the class than the rote learners. Further no significant difference existed on the conceptual understanding between meaningful learners and rote learners across topics prior to instruction, after instruction, and prior and after instruction. Meaningful learners performed equally as well as the rote learners in the tests, although meaningful learners have higher gain scores than the rote learners.

Chin and Brown (2000) explored in greater depth a comparison of deep versus surface approach to learning science. Analysis of the students' discourse and actions during the activities and their interview responses revealed several differences in learning approaches. These differences fell into five emergent categories: generative thinking, nature of explanations, asking questions, metacognitive activity, and approach to tasks. When students used a deep approach, they ventured their ideas more spontaneously; gave more elaborate explanations which described mechanisms and cause-effect relationships or referred to personal experiences; asked questions which focused on explanations and causes, predictions, or resolving discrepancies in knowledge; and engaged in "on-line theorizing." Students using a surface approach gave explanations that were reformulations of the questions, a "black box" variety which did not refer to a mechanism, or macroscopic descriptions which referred only to what was visible. Their questions also referred to more basic factual or procedural information. The findings also suggest that to encourage a deep

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learning approach, teachers could provide prompts and contextualized scaffolding and encourage students to ask questions, predict, and explain.

In teaching, it is important for the chemistry teachers to become aware of the learning approaches adapted by students to prepare well-planned and well-defined lessons that will enhance the development of students. Awareness of conceptual understanding and difficulties in chemical equilibrium will also help teachers design more effective teaching strategies and monitor student work. Along this perspective, this study intended to describe and classify students' level of conceptual understanding in chemical equilibrium and compare and contrast them among surface and deep learners.

2. Materials and Methods

The study was conducted in two phases: Preparation and validation of the research instruments and administration of the Study Process Questionnaire (R-SPQ-2F) and conceptual understanding test.

Phase I: Preparation and Validation of the Research Instruments

The learning approach of students was assessed using the Revised Study Process Questionnaire (R-SPQ-2F) by Biggs, Kember and Leung (2001). R-SPQ-2F is designed to evaluate the learning approaches of tertiary students. It assesses deep and surface approaches and contains 20 items and 4 subscales: deep motive, deep strategy, surface motive and surface strategy. In the original instrument, the reliability of the two constructs was reported by Biggs, Kember and Leung (2001) as 0.73 for Deep Approach and 0.64 for surface approach. The internal consistencies of the sub-scales were reported to range from 0.57 to 0.72.

However, the presentation of the instrument was slightly modified by the researcher for ease of answering on the part of the students and scoring on the part of the researcher. The term chemistry was also added to some part of the test to focus students' attention on learning chemistry. A 5-point likert scale was used for responding (1= "never or only rarely true of me" to 5= "always or almost always true of me"). The instrument was shown to three evaluators for assessment of the form and appropriateness of the language used to the subjects under study. It was pilot tested on a different group of engineering students to make sure that subjects will not have any difficulty with the presentation and language. Participants in the pilot study were asked to encircle unclear word(s), phrase(s) or sentence(s). Results of the pilot testing as well as the comments and recommendations of evaluators were the basis of further revisions. A sample of this questionnaire is shown in Appendix A.

The conceptual test consists of 20 items. The items were developed by the researcher based from the misconceptions identified in the literature. The concepts included in the conceptual understanding test focused on the following sub-topics:

- as the system approaches equilibrium
- characteristics of a system when equilibrium has been attained
- changing equilibrium conditions
- use of equilibrium constants

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This test was given at the end of the regular equilibrium lesson. The exam is a multiple choice test with four options and an open ended portion for students to write their explanation for their choice. The exam assessed students' conceptual understanding and further categorizes the level of conceptual understanding of students as; sound conceptual understanding (SCU), partial conceptual understanding (PCU), & no conceptual understanding (NCU) based from the concept-evaluation scheme by Boujaoude and Barakat (2003) adopted from Abraham, Grzybowski, Renner and Marek (1992).

The conceptual understanding test was first shown to two chemistry consultants and was then validated by three evaluators from the field of chemistry to determine their adequacy on concepts and appropriateness for the subjects under study. Reliability coefficient of the CUT was 0.859 using KR20 formula and 0.855 using SPSS Cronbach alpha. Sample items of the final form of the conceptual understanding test are shown in Appendix B.

Phase II: Administration of the R-SPQ, Conceptual and Problem Solving Test
Study Process Questionnaire (R-SPQ-2F) was given before the start of chemical equilibrium lesson. Proper instructions were given before the start of the test. Questions and other clarifications were also answered. Based on the results, students were grouped into: deep learners or surface learners.

After the conduct of the lesson on equilibrium in their General Chemistry class, a conceptual understanding test was given to the students. This test assessed students' conceptual understanding. From their test scores, students were grouped into three: sound conceptual understanding, partial conceptual understanding, and no conceptual understanding.

The researcher personally administered the R-SPQ-2F and conceptual understanding test to facilitate retrieval of the necessary data.

Analysis of Data
After administration of R-SPQ-2F, the score on each sub-scale and the total score on each scale was computed for each student. The scores were determined by summing up the scores on each item as follows:

	Learning Approach	Item Nos.
Subscales:	Deep Motive (DM):	1, 5, 9, 13, 17
	Deep Strategy (DS):	2, 6, 10, 14, 18
	Surface Motive (SM):	3, 7, 11, 15, 19
	Surface Strategy (SS):	4, 8, 12, 16, 20
Main Scales:	Deep Approach (DA):	1, 2, 5, 6, 9, 10, 13, 14, 17, 18
	Surface Approach (SA):	3, 4, 7, 8, 11, 12,15,16, 19, 20

Each student has scores on surface approach (SA) items and deep approach (DA) items. Based on their scores on surface and deep items, students were divided into 2 groups. Students having higher SA scores than their DA scores are classified as Surface learners. Students having higher DA scores than their SA scores are classified as Deep learners.

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The conceptual understanding test was scored. The t-test was used to determine significant differences on the scores of students in conceptual understanding test among surface and deep learners. Students were also identified into three categories: Students with sound conceptual understanding (SCU), partial conceptual understanding (PCU) and no conceptual understanding (NCU) (lowest scores). The responses of each student on the conceptual understanding test were analyzed using the criteria shown in Appendix C to find out the level of their understanding of each of the four sub concepts and principles. Then, a total score on each concept for each student was calculated and the scores on all the concepts and principles were summed up to a total score. Students were categorized into three according to their total scores. To further determine any significant relationship between students' level of conceptual understanding and learning approach, chi-square test of independence was done.

3. Results and Discussions

At the start of the data gathering procedure, Study Process Questionnaire (R-SPQ-2F) was given to the two sections composed of 58 civil engineering students. From the scores of the test obtained by the participants, 27 students (47%), composed of 16 male and 11 female, were identified as surface learners while 31 students (53%), composed of 23 male and 8 female, were identified to be deep learners. Majority of the students are deep learners. Also majority of the male students were deep learners while majority of the female students were categorized as surface learners.

The Conceptual Understanding Test (CUT) given to 58 students was scored based on the criteria for categorizing student's conceptions (Appendix C). From the scores on each subtopic and from the total score obtained, student's levels of conceptual understanding were categorized as: Sound Conceptual Understanding (SCU), Partial Conceptual Understanding (PCU) and No Conceptual Understanding (NCU). The results obtained are shown in Tables 1 and 2.

Table 1: Students' Level of Conceptual Understanding in Chemical Equilibrium

	Sound Conceptual Understanding	**Partial Conceptual Understanding**	**No Conceptual Understanding**	**Total**
Surface Learners	2 7 %	11 41 %	14 52 %	27 100 %
Deep Learners	3 10 %	18 58 %	10 32 %	31 100 %
Total	5 9 %	29 50 %	24 41 %	58

Table 1 reveals that only 5 students or 9 % of the class belongs to SCU level. Forty one percent of the class belongs to NCU level while majority (50 %) is in PCU category. Of the 5 students belonging to the SCU category, 3 (60 %) are Deep Learners. While majority of the students, 14 or 50 %, belonging to the NCU category are Surface Learners. It could also be seen that of the 27 Surface Learners majority (52 %) belong to NCU level while Deep Learners are mostly (58 %) in the PCU level. Although most of the Deep learners are in PCU category, still 10 are in NCU level.

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This indicates that even among those who consider themselves deep learners, many were not able to comprehend the concepts of chemical equilibrium.

Students' levels of conceptual understanding were further analyzed using the values shown in Table 2. Levels of conceptual understanding of the learners in each of the four subtopics included in the test are separately determined.

Table 2: Surface and Deep Learners' Level of Conceptual Understanding in the Four Sub Topics

Subtopic		**SCU**	**PCU**	**NCU**	**Total**
I Characteristics of the system as it approaches	Surface Learners	3 (11 %)	14 (52 %)	10 (37 %)	27
Equilibrium	Deep Learners	3 (10 %)	21 (68 %)	7 (22 %)	31
	Total	**6 (10 %)**	**35 (60 %)**	**17 (29 %)**	**58**
II Characteristics of the system when	Surface Learners	1 (4 %)	18 (67 %)	8 (29 %)	27
equilibrium has been attained	Deep Learners	0	24 (77 %)	7 (23 %)	31
	Total	**1 (2 %)**	**42 (72 %)**	**15 (26 %)**	**58**
III Use of equilibrium constants	Surface Learners	0	10 (37 %)	17 (63 %)	27
	Deep Learners	2 (6 %)	16 (52 %)	13 (42 %)	31
	Total	**2 (3 %)**	**26 (45 %)**	**30 (52 %)**	**58**
IV Factors affecting chemical equilibrium	Surface Learners	3 (11 %)	14 (52 %)	10 (37 %)	27
	Deep Learners	8 (26 %)	19 (61 %)	4 (13 %)	31
	Total	**11 (19 %)**	**33 (57 %)**	**14 (24 %)**	**58**

It can be seen that majority of the students, both surface and deep learners, belong to PCU level except in Subtopic III, which is on the Use of Equilibrium Constants. In this subtopic, more percentage of Surface Learners (63 %) are in NCU level. In all subtopics, the greatest percentages of students belonging to NCU category are Surface Learners.

Also, majority of students in the SCU level are Deep Learners except in Subtopic II, which is on characteristics of the system as it approaches equilibrium, wherein 1 Surface Learner belongs to SCU while none in the Deep Learner category. Students at the PCU level in all subtopics are mostly deep learners. It can also be noted that in the SCU level there are more deep learners than surface learners in the III and IV subtopics. These are subtopics on the Use of Equilibrium Constants and Factors affecting Equilibrium. These subtopics involve concepts that require deeper understanding compared to Subtopics I and II. It is likely that Deep learners are more able to comprehend the difficult concepts as compared to surface learners. As a whole, Tables 1 and 2 showed a similar pattern of student distribution. It also shows that more Surface Learners obtain lower scores than Deep Learners.

To determine if there is a significant difference between the level of conceptual understanding of surface and deep learners, both independent-samples t-test and chi square test were employed in the analysis. Raw scores in the CUT of both surface and deep learners were used in the t-test

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analysis. This test analyzes if there would be a significant difference between the scores obtained by surface and deep learners. Analysis was first done on the overall scores of students in the conceptual understanding test. SPSS result yield p= .06. This value reveals that scores obtained by surface and deep learners are significantly different only at .06 level of significance. However, since the test is set at .05 level of significance, the result reveals no significant difference between the two learners in terms of the scores they obtained in the CUT.

To further analyze the difference between Surface and Deep learners, t-test analysis was done on each subtopic separately. SPSS result on each test is shown in Table 3.

Table 3: Independent-samples t-test Results on Chemical Equilibrium Subtopics

Subtopic	**P**
I. Characteristics of the system as it approaches equilibrium	.507
II. Characteristics of the system when equilibrium has been attained	.341
III. Use of equilibrium constants	.405
IV. Factors affecting chemical equilibrium	.028

From the table, it can be clearly viewed that p values of Subtopics I, II and III are all greater than .05. It reveals that scores obtained by Surface and Deep Learners are not significantly different in the three subtopics. Subtopic IV however, revealed a significant result ($p<.05$). Surface and Deep Learners significantly differ in the scores they obtain in Subtopic IV test items.

It could further be stated that Surface Learners could more likely obtain lower scores and Deep Learners could more likely obtain higher scores in concepts about factors affecting chemical equilibrium. This difference may be due to the fact that concepts on factors affecting chemical equilibrium require a deeper analysis and often needs a comprehension of several prerequisite concepts in answering. It shows that Deep Learners are more successful than surface learners in the analysis of such concepts.

Chi square test of independence was also done after collapsing scores into level categories. This test will further determine if the two groups are significantly different in their levels of conceptual understandings. The computed chi-squares are shown in Table 4. This values were compared to the critical chi-square value of 5.99 at df = 2 and $\alpha = .05$.

Table 4: Chi- Square test Results on Level of CU of Surface and Deep Learners

	Computed Chi-square Value	**p**
Overall test	2.291	.318
I. Characteristics of the system as it approaches equilibrium	1.661	.436
II. Characteristics of the system when equilibrium has been attained	1.656	.437
III. Use of equilibrium constants	3.659	.160
IV. Factors affecting chemical equilibrium	5.351	.069

The table showed that all values are lesser than critical value of 5.99. Levels of conceptual understanding of Surface Learners are not significantly different with that of Deep Learners. This

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only shows that level of conceptual understanding is not significantly associated with learning approach of students. However, it is good to note that at Subtopic IV, value (5.35) almost reach critical value of 5.99 with p=.069. This means that levels of conceptual understanding of Surface and Deep Learners in Subtopics IV concepts are significantly associated at .069 level of significance. This result also shows that learning approach of students could almost be associated with level of conceptual understanding of students in Factors Affecting Chemical Equilibrium concepts. The result is similar to that obtained using t-test analysis.

The results of t-test and chi-square test revealed that there could be times that differences between surface and deep learners could only be seen when tested across different concepts within a certain topic. This relationship between conceptual understanding and learning approach of students were also tested by Dimagiba (2004) and Boujaoude (1992). Dimagiba (2004) found no significant differences that exist between conceptual understanding among meaningful and rote learners while Boujaoude (1992) found out that meaningful learners performed significantly better than rote learners.

4. Conclusions and Recommendations

Within the scope and limits of this study and based on the findings, the researcher has concluded that learning approach of students is only associated to the conceptual understanding of students in more complex concepts of chemical equilibrium.

Based on the findings and conclusions drawn, the following recommendations are offered:

1) The results of this study can be made available to teachers and curriculum developers to serve as basis for improved instructional design in teaching chemical equilibrium and suitable ways in developing students' meaningful learning approaches.
2) On further studies, the complex relationships between students' learning approaches and conceptual understanding should be investigated making use of diverse questions that could reveal further the conceptual difficulties of the students.
3) Further enhancement of this study can be done involving greater number of samples and wider research locale to strengthen the generalizability of the results of this study.

5. Acknowledgements

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6. Appendices

Appendix A
Study Process Questionnaire (Sample Items)

Name: ____ Course: __________________________

This questionnaire has a number of questions about your attitude towards your studies and your usual way of studying chemistry.

There is no right way of studying. It depends on what suits your own style and the course you are studying. It is accordingly important that you answer each question as honestly as you can.

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Please **encircle** the **number** beside the question. The numbers stand for the following response:

1) this item is ***never*** or ***only rarely true*** of me
2) this item is ***sometimes true*** of me
3) this item is ***true*** of me about ***half the time***
4) this item is ***frequently true*** of me
5) this item is ***always*** or ***almost always true*** of me

Example: I study best with the radio on.

If this is **almost always true** of you, encircle 5.	1	2	3	4	(5)
If you only **sometimes** studied well with the radio on, encircle 2.	1	(2)	3	4	5

Please choose the one most appropriate response for each question. Encircle the number that best fit your immediate reaction. Do not spend a long time on each item.

Your first reaction is probably the best one.
Do not worry about projecting a good image. Your answer is **CONFIDENTIAL**.
Thank you for your cooperation.

Items	**never or only rarely true of me**	**Some-times true of me**	**true of me about half the time**	**Frequent-ly true of me**	**always or almost always true of me**
I find that at times studying chemistry gives me a feeling of deep personal satisfaction.	1	2	3	4	5
I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied.	1	2	3	4	5
My aim is to pass the chemistry course while doing as little work as possible.	1	2	3	4	5
I only study seriously what's given out in class or in the course outlines.	1	2	3	4	5
I find most new topics interesting and often spend extra time trying to obtain more information about them.	1	2	3	4	5

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Appendix B
Conceptual Understanding Test (Sample Items)

Name: ____ Score: ____________
Course & Yr. __________________________
Instructions:
Below are 20 questions on chemical equilibrium. Each question is followed by four options from which you will choose your answer by encircling the letter of your choice and a space where you will write the explanation for your answer.
Read each question carefully and take time to think for the correct answer.
Do not leave any question unanswered. You are given 1 hour to answer this test.

1. **Consider the following statements:**

I.	The concentrations of reactants and products are equal.
II.	The rate constants of the forward and reverse reactions are equal.
III.	The rates of the forward and reverse reactions are equal.
IV.	The concentrations of reactants and products do not change.

At equilibrium, the correct statements are
1) I and II.
2) III and IV.
3) I, II, and IV.
4) All of these are correct.

Reason:
____
____
____

2. **Consider the Reaction Between Steam and Carbon Monoxide in A Closed Vessel**

$$H2O(g) + CO(g) \rightleftharpoons H2(g) + CO2(g)$$

During the approach to equilibrium
1) the rate of formation of H2O and CO is greater than its rate of decomposition.
2) the rate of formation of H2O and CO is less than its rate of decomposition.
3) the rate of formation of H2O and CO is equal to its rate of decomposition.
4) Not enough evidence is available to judge the relative rates of formation and decomposition of H2O and CO.

Reason:
____
____
____

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Appendix C
Criteria for Categorizing Students' Conception on Conceptual Understanding Test

Category	Part I Multiple Choice	Part II Explanation	Total Point
Sound Conceptual Understanding (SCU)	correct (1pt)	correct (1pt)	2
Partial Conceptual Understanding (PCU)	correct (1pt) wrong (0)	wrong (0) correct (1pt)	1 1
No Conceptual Understanding (NCU)	wrong (0)	wrong (0)	0

References

[1] Abraham, M.R., Grzybowski, E.B., Renner, J.W. & Marek, E.A. (1992). Understandings and misunderstandings of eight graders of five chemistry concepts found in textbooks. Journal of Research in Science Teaching, 29(2), 105-120.

[2] Alvarez, M.L. (1998). Difficulties in solving chemical equilibrium problems. Unpublished Masteral Theses. University of San Carlos, Cebu City.

[3] Bernardo, A.B.I. (2003). Approaches to learning and academic achievement of Filipino students. The Journal of Genetic Psychology, 164(1), 101-114.

[4] Biggs, J. (1987). Student approaches to learning and studying. Melbourne, Australia.

[5] Biggs, J. (1999). Teaching for quality learning at university. Buckingham: Society for Research into Higher Learning and Open University Press.

[6] Biggs, J., Kember, D., & Leung, D. (2001). The revised two-factor study process questionnaire: R-SPQ-2F. British Journal of Educational Psychology, 71, 133-149.

[7] Boujaoude, S. (1992). The relationship between students' learning strategies and the change in their misunderstandings during a high school chemistry course. Journal of Research in Science Teaching, 29(7), 687-699.

[8] Boujaode, S. (1993). Students' systematic errors when solving kinetic and chemical equilibrium problems. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. Atlanta, GA, April 16-19.

[9] Boujaoude, S. & Barakat, H. (2003). Students' problem solving strategies in stoichiometry and their relationships to conceptual understanding and learning approaches. Electronic Journal of Chemical Education, 7(3). Retreived October 15, 2005 from http://unr.edu/homepage/crowther/ejse/ boujaoude.pdf

[10] Boujaoude, S., Salloum, S., & Abd-El-Khalick, F. (2004). Relationship between selective cognitive variables and students problem solving ability. International Journal of Science Education, 26(1), 63-84.

[11] Brown, J. (2004). Making the most of understanding by design. USA: Association for Supervision and Curriculum Development.

[12] Chin, C. & Brown, D. (2000). Learning in Science: a comparison of deep and surface approaches. Journal of Research in Science Education, 37(2), 109-138.

[13] Darmofal, D., Soderholm, D., & Brodeur, D. (2002). Using concept maps and concept questions to enhance conceptual understanding. 32nd ASEE/IEEE Frontiers in Education Conference. Boston, MA.

[14] Dimagiba, E. (2004). Facilitating conceptual change on matter through constructivistic teaching. Unpublished Doctoral Dissertation. De La Salle University, Manila.

ISSN- 2350-0530(O), ISSN- 2394-3629(P)
DOI: 10.5281/zenodo.3262203

[15] Hackling, M. & Garnett, P.J. (1985). Misconceptions of chemical equilibrium. International Journal of Science Education, 7(2), 205-214.
[16] Harrison, A. & De Jong, O. (2005). Exploring the use of multiple analogical models when teaching and learning chemical equilibrium. Journal of Research in Science Teaching, 42(10), 1135-1159.
[17] Marton, F. & Saljo, R. (1997). Approaches to learning (2^{nd} ed.). Edinburg: Scottish Academic Press.
[18] Marton, F. & Saljo, R. (1976). On qualitative differences in learning. The outcome as a function of the learners' conception of the task. British Journal of Psychology, 46, 4-11.
[19] Mortimer, C. (1986). Chemistry (6^{th} ed.). California: Wadsworth, Inc.
[20] Posner, G., Strike, K., Hewson, P. & Gertzog,W.(1982). Accomodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66(2), 211-227.
[21] Wheeler, A. & Kass, H. (1978). Student misconceptions in chemical equilibrium. Science Education, 62(2), 223-232.
[22] Zumdahl, S. (1992). Chemical principles. USA: D.C. Heath and Company.

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