HOW DO SINGAPOREAN STUDENTS RESPOND TO DAILY PHENOMENA AND SCIENTIFIC PROBLEMS?

Dr Goh Ngoh-Khang
Dr Chia Lian-Sai

Paper presented at the
4th Asian Chemical Congress
held in Beijing, China, from August 26-30, 1991

HOW DO SINGAPOREAN STUDENTS RESPOND TO DAILY PHENOMENA AND SCIENTIFIC PROBLEMS?

Dr Ngoh-Khang Goh
Dr Lian-Sai Chia
Division of Chemistry, School of Science
National Institute of Education
Nanyang Technological University
469 Bukit Timah Road, Singapore 1025

1 Introduction

One of the objectives in teaching science is to equip students with the scientific knowledge which enables them to explain natural phenomena. It is commonly believed that students acquisition of Chemistry knowledge in science classes may be attributed to their views concerning (i) how and why everyday things behaved as they do, and (ii) how they relate these views to what they learnt in theory. In their study of how well students acquire Chemistry knowledge, Haider and Abraham (1) reported that students respond differently to daily life phenomena problems (described by everyday language) and scientific problems (described by scientific terms) though both are the same in nature. They try not to mix the two situations. They tend to avoid using words like 'atom' and/or 'molecule' in describing everyday phenomena such as dissolution of sugar, diffusion, effusion and states of matter when the test items were phrased in everyday language.

When concepts introduced to students are not convincing enough, students only acquire knowledge superficially and internalization and application of knowledge outside science classes would be impossible. This has important implications for teaching. Teachers would need to teach Chemistry concepts so that students will be able to apply them, not only in classroom and examination situations, but also to everyday life situation. In other words teachers would need to bridge the two situations, if necessary, for their students.

The sample used by Haider and Abraham was drawn from 11^{th} and 12^{th} grade Chemistry students. This study is an across level study along the same lines of research as that of Haider and Abraham in order to gain a deeper understanding of the problem.

2. <u>Objective of Study</u>

(i) To investigate how Chemistry students of different levels, explain some daily phenomena pertaining to diffusion, dissolution, effusion and states of matter, as well as the extent of students' ability to use particulate theory to explain these concepts.

(ii) To get a better insight into the students' conceptual changes where there is an increasing exposure to relevant information with respect to the Particulate Theory Model.

(iii) To find out whether there is any significant correlation between students' convergent thinking, divergent thinking, divergent feeling and students' ability to apply what they have learned in Chemistry to account for some everyday phenomena.

3. <u>The Instruments</u>

Three different instruments are used for this study:

(i) A two-form ('A' & 'T') instrument called the Physical Changes Concept Test (PCCT), developed by Haider and Abraham (1), was used as test instrument.

It consists of an 'A' form whereby the questions regarding the Chemistry concepts on diffusion, dissolution, effusion and states of matters were asked using everyday language. The purpose of this form is thus to measure students' ability to use particulate terms, for example, atoms and molecules, to explain these concepts when they are not cued to use such terms. The 'T' form contains the same questions but is rephrased so as to cue students to the use of particulate terms. In this manner, students' use of particulate terms to explain chemical phenomena when cued, and when asked using everyday terms, could be evaluated.

In all there are six questions. The first three questions were aimed to test students' knowledge about dissolution. Question 1 asks students to explain why sugar dissolves in water. Question 2 asks students to explain why chalk does not dissolve in water, and Question 3 asks them to explain why an excess of sugar does not dissolve in water. Question 4 tests students' knowledge about diffusion. It asks students to explain how food colouring disperses in water. Question 5 tests students' knowledge about effusion. It asks students to explain why a balloon filled with hydrogen deflates in days. Finally, Question 6 tests students' knowledge about states of matter. It asks students to explain the differences between the states of water. A set of the test forms are attached in the Appendix. In the PCCT, only Question 5 demands extrapolation of students' particulate knowledge as effusion was not formally taught in school, but students should be able to apply if they have grasped the microscopic model.

(ii) The second instrument used is "How do I think?" developed by Lee and Pulvino (2). This instrument, which comprises 18 items, intends to assess students' convergent thinking and divergent thinking.

(iii) The third instrument used is the "Test of Divergent Feeling" developed by Williams (3). This instrument consists of 50 items. It measures all four affective factors as divergent feeling traits that are strongly correlated with a creative person. These factors include curiosity, imagination, complexity, and risk-taking. Hence this test is used indirectly to measure students' creativity in terms of their divergent feeling.

4. <u>The Sample</u>

The sample was made up of a pool of Chemistry students of various age groups and abilities. The following are descriptions of the samples, arranged in increasing years of exposure to Chemistry.

(i) For the lower end of the continuum, where students received least instruction in Chemistry, a class of 20 Normal Stream Secondary Three (Sec 3N) students was picked. Their average age is 15 years. The students had almost one full year of experience with Chemistry when the tests were administered. They should have sufficient knowledge on states of matter, atomic structure and bonding between atoms, the three salient topics associated with Particulate Theory.

(ii) 51 Secondary Three students from the Special Stream (Sec 3S), of average age 15, were also involved in this research. They too should have at least acquired the knowledge of the topics mentioned above.

(iii) The 17-year age group was represented by a class of 20 first year Junior College students (JC1) from a Junior College.

(iv) The 4th group was made up of 26 pre-service students who have joined the Institute of Education after their 'A' levels for their teacher training. They too have received formal education in Chemistry. Their performance in Chemistry is above average.

(v) The 5th group, which was made up of 50 University graduates, was trained specifically as Chemistry teachers for Secondary Schools and Junior Colleges. They are cognitively the most competent subjects in the entire sample.

5. Implementation of the Instruments

The tests of divergent feeling, "How do I think?" and 'A' form were administered during the first meeting. Time limit was not imposed to allow students to ponder over the questions. The 'T' form was administered at least four weeks after the initial meeting so as to prevent students' impression of the 'A' form from influencing their answers to the 'T' form. In this study it is very important that the 'T' form be administered last as it may serve as a hint and hence enhance students' use of Particulate Theory.

6. Data Analysis

(i) The 'A' form and 'T' form were analyzed independently. Each form was subjected to two markings. In the first marking, students' use of Particulate Theory was investigated and the marking is in accordance with Haider and Abraham's system of grading. The students' answers were classified into five categories: No Response (NR), General (G), Particulate General (PG), Particulate Specific (PS) and Particulate Specific Correct (PSC). A scoring scheme from 0 to 5 points with respect to students' increasing understanding was used. A sample of the marking scheme is given in Table 1.

(ii) In the second marking, students' conceptions were analyzed. Their responses were broadly classified under four main categories of No Understanding (NU), Alternative Concepts (AC) which is a major category that summed up all the common perceptions that students have, Partial Understanding (PU) especially in classes where students are able to state the technical terms for the processes but did not show full understanding in terms of Particulate Theory and Sound Understanding (SU). The grading scheme is shown in Tabie 2. From this second marking, valuable implications for teaching can be drawn.

(iii) Separate analyses of the tests of divergent feeling and "How do I think?" were carried out. The scores for convergent thinking, divergent thinking, divergent feeling and those of the 'A' form were correlated using Spearman-Brown (Rank-Difference) Method. Similarly, the relationship between the scores for convergent thinking, divergent thinking, divergent feeling and those of the 'T' form was also investigated using the same correlational method.

Table 1: A Scheme of Categorization of Students' Use of the Particulate Theory

Degree of Understanding Criteria for Scoring	Students' Typical Answers
No Response (NR)	Blank/No response to question. I do not know, or statement to that effect. I do not understand, or statement to that effect.
General (G)	Responses that do not use the terms atoms and/or molecules.
Particulate General (PG)	Incorrect responses using particulate terms other than atoms and/or molecules, for example, grains and particles.
Particulate Specific (PS)	Responses that use the terms atoms and/or molecules but do not match the scientific conceptions.
Particulate Specific Correct (PSC)	Responses that use the terms atoms and/or molecules and match the scientific conceptions.

Table 2: A Scheme for Categorization of Students' Conceptions

Classification	Students' Typical Answers
No Understanding (NU)	Blank/No response to question. I do not know, or statements to that effect. I do not understand, or statements to that effect. Repeating of the question by the student. Irrelevant or unclear response.
Alternative Conceptions (AC)	Responses that attempt to describe the phenomenon, but do not necessarily match the scientific conception.
Partial Understanding (PU)	Responses that include at least one of the components of the scientific conceptions but not all of the conceptions.
Sound Understanding (SU)	Responses that include all components of the scientific conceptions.

7. Results and Discussions

7.1 Students' use of Particulate Theory in responding to the 'A' and 'T' forms.

Table 3 to Table 7 show the percentages of the respective level of students' use of particulate theory

Table 8 gives a summary of the results on students' use of particulate theory, pooling together the data from Tables 3 to 7 to obtain the percentage of students who are able to explain Chemistry concepts using particulate specific and particulate specific correct terms.

Table 3: Percentage of Sec 3N Students' Use of Particulate Theory

Concept	Form	NR	G	PG	PS	PSC
Dissolution	A	35.00	65.00	0.00	0.00	0.00
	T	65.00	20.00	10.00	5.00	0.00
Diffusion	A	50.00	40.00	0.00	10.00	0.00
	T	85.00	5.00	10.00	0.00	0.00
Effusion	A	50.00	50.00	0.00	0.00	0.00
	T	85.00	0.00	0.00	15.00	0.00
States of Matter	A	40.00	50.00	5.00	5.00	0.00
	T	80.00	5.00	0.00	15.00	0.00
Average	A	43.75	51.25	1.25	3.75	0.00
	T	78.75	7.50	5.00	8.75	0.00

Table 4: Percentage of Sec 3S Students' Use of Particulate Theory

Concept	Form	NR	G	PG	PS	PSC
Dissolution	A	0.00	4.50	25.16	69.67	0.67
	T	0.00	0.00	0.64	99.36	0.00
Diffusion	A	0.00	17.65	17.65	21.57	43.13
	T	1.96	7.84	1.96	54.90	33.34
Effusion	A	0.00	35.29	3.92	56.87	3.92
	T	0.00	3.92	0.00	90.20	5.88
States of Matter	A	0.00	11.76	1.97	80.39	5.88
	T	0.00	0.00	0.00	96.08	3.92
Average	A	0.00	17.30	12.18	57.12	13.40
	T	0.49	2.94	0.65	85.14	10.78

Table 5: Percentage of JC1 Students' Use of Particulate Theory

Concept	Form	NR	G	PG	PS	PSC
Dissolution	A	0.00	46.15	17.95	30.77	5.13
	T	2.56	19.24	3.84	66.66	7.70
Diffusion	A	0.00	57.96	15.38	11.54	15.39
	T	7.96	26.92	0.00	53.85	11.54
Effusion	A	3.85	73.08	7.69	7.69	7.69
	T	11.54	11.54	0.00	65.38	11.54
States of Matter	A	0.00	53.85	3.85	42.30	0.00
	T	0.00	7.69	0.00	88.46	3.85
Average	A	0.96	57.69	11.22	23.08	7.05
	T	5.45	16.35	0.96	68.59	8.65

Table 6: Percentage of 'A' Level Holders' Use of Particulate Theory

Concept	Form	NR	G	PG	PS	PSC
Dissolution	A	0.00	25.50	15.00	60.00	0.00
	T	0.00	0.00	0.00	100.00	0.00
Diffusion	A	0.00	35.00	10.00	40.00	15.00
	T	5.00	10.00	0.00	50.00	35.00
Effusion	A	20.00	40.00	0.00	25.00	15.00
	T	5.00	15.00	0.00	60.00	25.00
States of Matter	A	0.00	30.00	5.00	50.00	15.00
	T	0.00	15.00	0.00	60.00	25.00
Average	A	5.00	32.50	7.50	43.75	11.25
	T	2.50	10.00	0.00	67.50	20.00

Table 7: Percentage of University Graduates' Use of Particulate Theory

Concept	Form	NR	G	PG	PS	PSC
Dissolution	A	0.00	4.34	31.08	55.55	9.03
	T	0.00	0.00	7.46	71.18	21.36
Diffusion	A	0.00	22.05	13.02	44.45	20.48
	T	0.00	11.46	0.00	63.37	25.17
Effusion	A	1.56	60.59	0.00	25.18	12.67
	T	1.56	9.90	0.00	54.69	33.85
States of Matter	A	0.00	12.67	9.37	24.83	53.13
	T	0.00	7.12	0.00	57.12	33.76
Average	A	0.39	24.91	13.37	37.50	23.83
	T	0.39	7.12	1.87	61.52	29.10

Table 8: Percentage of Students' Use of Particulate Specific and Particulate Specific Correct Terms in PCCT

Percentage of Students' Use of Particulate Specific and Particulate Specific Correct Terms in PCCT		
Level	'A' Form	'T' Form
Sec 3N	3.75	8.75
Sec 3S	70.52	95.92
JC 1	30.13	77.24
'A' Level	55.00	87.50
University	61.33	90.62

As shown by the graph in Figure 1, a significant percentage of students (5.00% in Sec 3N, 25.40% in Sec 3S, 47.11% in JC1, 32.50% in 'A' level and 29.29% in 'U' graduates) used particulate theory to explain the same concepts on the 'T' form as compared to the 'A' form of the PCCT. These results are in agreement with Haider and Abraham's findings (1).

ACROSS LEVEL STUDY

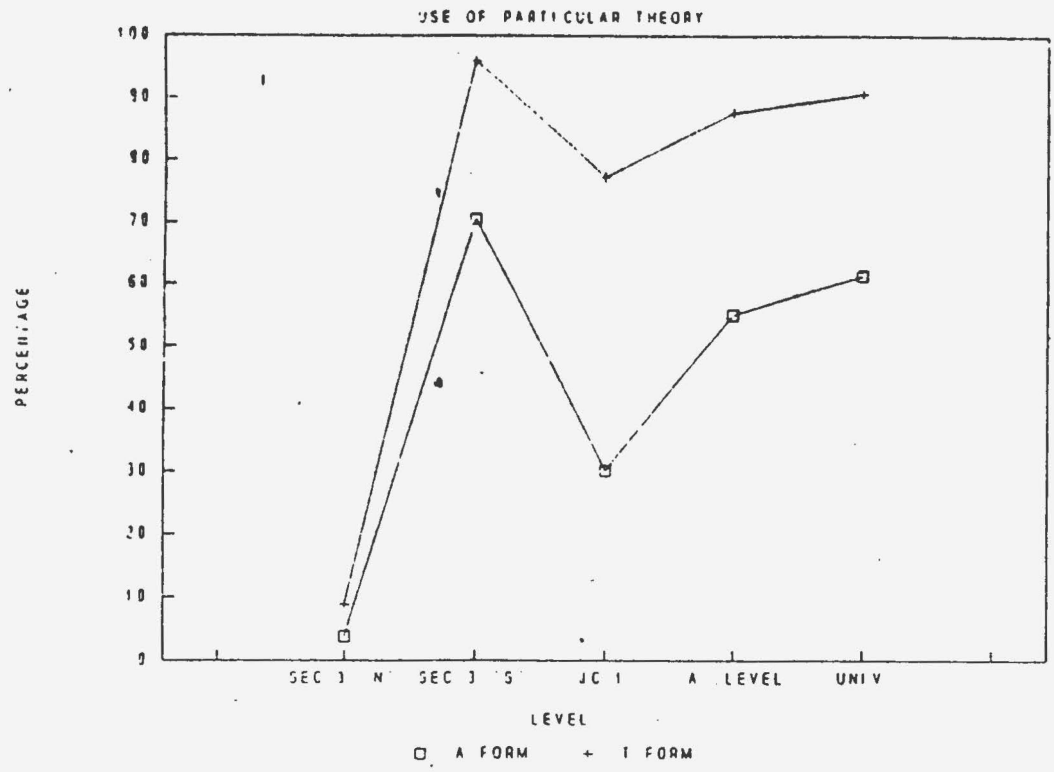


Figure 1. Students' Use of Particulate Specific and Particulate Specific Correct Terms in PCCT

More students used general terms on the 'A' form (where everyday language was used to ask the question) as compared to the 'T' form. In the use of the latter form more students used particulate theory to explain the same concepts, no doubt prompted by the questions asked using particulate terms, like atoms and molecules. This implies that students' response to questions depended on how the question are asked. Students tend to only use microscopic terms when they are cued to the use of scientific language.

However, 91.25% of the Sec 3N students, still persisted in using macroscopic terms to explain the Chemistry concepts despite the questions cues given in the 'T' form. This could possibly be due to students' lack of understanding of some particulate terms (for example, atoms and molecules) and hence their inability to apply these terms when asked to explain the Chemistry concepts.

When doing an across level study, it is intuitive to expect that the percentage of students' use of Particulate Theory will increase proportionally with level as students become more exposed to these particulate terms for a longer period of time with greater exposure to Chemistry. This is true when a comparison is made of students across JC1, 'A' level and 'U' level. However, a discrepancy is noted for students in the Sec 3S classes which may appear counter intuitive. However students in this Special Stream are of high ability (students scoring the top 10% in the Primary School Leaving Examination) and due to this, they are usually exposed to more knowledge than is required by the Secondary 3 syllabus. Additionally the topic on use of Particulate Theory was introduced to students when they were in Secondary 3 and when this test was conducted, the particulate terms were still fresh in their minds and this could have contributed to such a high percentage of students (95.92%) being able to use particulate terms to explain the concepts of Chemistry.

Thus, despite the discrepancy caused by the Sec 3S students, it could be concluded that the length of exposure to particulate theory during formal instruction (that is, teaching of Chemistry) has reinforced in students their ability to explain everyday phenomena in terms of particulate theory.

7.2 Students' conceptions

Table 9 to Table 13 show the percentages of the respective level of students' conceptions about the concepts covered in the PCCT. Table 14 is obtained by summing the percentage of students, at each level, who showed partial understanding or sound understanding to the Chemistry concepts probed in the 'A' and 'T' forms.

Table 9: Percentage of Sec 3N Students' Conception

Concept	Test	NU	AC	PU	SU
Dissolution	A	88.33	10.00	1.67	0.00
	T	81.67	16.67	1.66	0.00
Diffusion	A	55.00	40.00	5.00	0.00
	T	85.00	15.00	0.00	0.00
Effusion	A	65.00	20.00	5.00	0.00
	T	90.00	10.00	0.00	0.00
States of Matter	A	80.00	15.00	5.00	0.00
	T	90.00	10.00	0.00	0.00
Average	A	72.08	21.25	5.00	0.00
	T	86.66	12.92	0.42	0.00

Table 10: Percentage of Sec 3S Students' Conception

Concept	Test	NU	AC	PU	SU
Dissolution	A	3.92	87.58	7.84	0.65
	T	7.19	89.54	3.27	0.00
Diffusion	A	0.00	13.73	47.06	39.21
	T	3.92	37.25	21.58	37.25
Effusion	A	3.92	41.18	52.94	1.96
	T	1.96	47.06	45.10	5.88
States of Matter	A	15.69	7.84	70.59	5.88
	T	0.00	9.80	86.28	3.92
Average	A	5.88	37.58	44.61	11.93
	T	3.27	45.91	39.06	11.76

Table 11: Percentage of JC1 Students' Conception

Concept	Test	NU	AC	PU	SU
Dissolution	A	25.00	26.70	48.30	0.00
	T	11.70	30.00	50.00	8.30
Diffusion	A	15.00	10.00	50.00	25.00
	T	10.50	10.60	42.10	36.80
Effusion	A	52.90	0.00	29.50	17.60
	T	47.40	0.00	31.60	21.00
States of Matter	A	25.00	0.00	60.00	15.00
	T	10.00	0.00	65.00	25.00
Average	A	29.48	9.18	46.95	14.40
	T	19.90	10.14	47.18	22.78

Table 12: Percentage of 'A' Level Holders' Conception

Concept	Test	NU	AC	PU	SU
Dissolution	A	10.26	38.46	25.64	25.64
	T	12.82	46.16	33.33	7.69
Diffusion	A	23.08	19.23	42.31	15.38
	T	19.23	15.38	53.85	11.54
Effusion	A	15.38	11.54	69.23	3.85
	T	26.92	34.62	26.92	11.54
States of Matter	A	50.00	7.69	42.31	0.00
	T	11.54	26.92	57.69	3.85
Average	A	24.68	19.23	44.87	11.22
	T	17.62	30.77	42.95	8.66

Table 13: Percentage of University Graduates' Conception

Concept	Test	NU	AC	PU	SU
Dissolution	A	16.30	26.50	43.95	13.25
	T	6.10	20.55	45.90	27.45
Diffusion	A	5.80	17.90	50.20	26.10
	T	0.00	8.90	66.55	24.55
Effusion	A	53.80	0.00	28.30	17.90
	T	14.35	8.45	43.60	33.60
States of Matter	A	0.00	0.00	41.95	58.05
	T	0.00	0.00	59.75	40.25
Average	A	18.98	11.00	41.10	28.83
	T	5.11	9.48	53.95	31.46

Table 14

Across Level Study of % of Students' Conception about the Concepts covered in PCCT										
Concepts	Dissolution		Diffusion		Effusion		SOM		Average	
	A	T	A	T	A	T	A	T	A	T
Sec 3N	1.67	1.67	5.00	0	5.00	0	5.00	0	4.17	0.42
Sec 3S	8.50	3.27	86.27	58.83	54.90	50.98	76.47	90.20	56.54	48.82
JC 1	48.30	58.30	75.00	78.90	47.10	52.60	75.00	90.00	61.35	69.95
'A' Level	51.28	41.02	57.69	65.39	73.08	38.46	42.31	61.54	56.09	51.60
'U'	57.20	73.35	76.30	76.30	46.20	77.20	100.00	100.00	69.93	85.41

ACROSS LEVEL STUDY

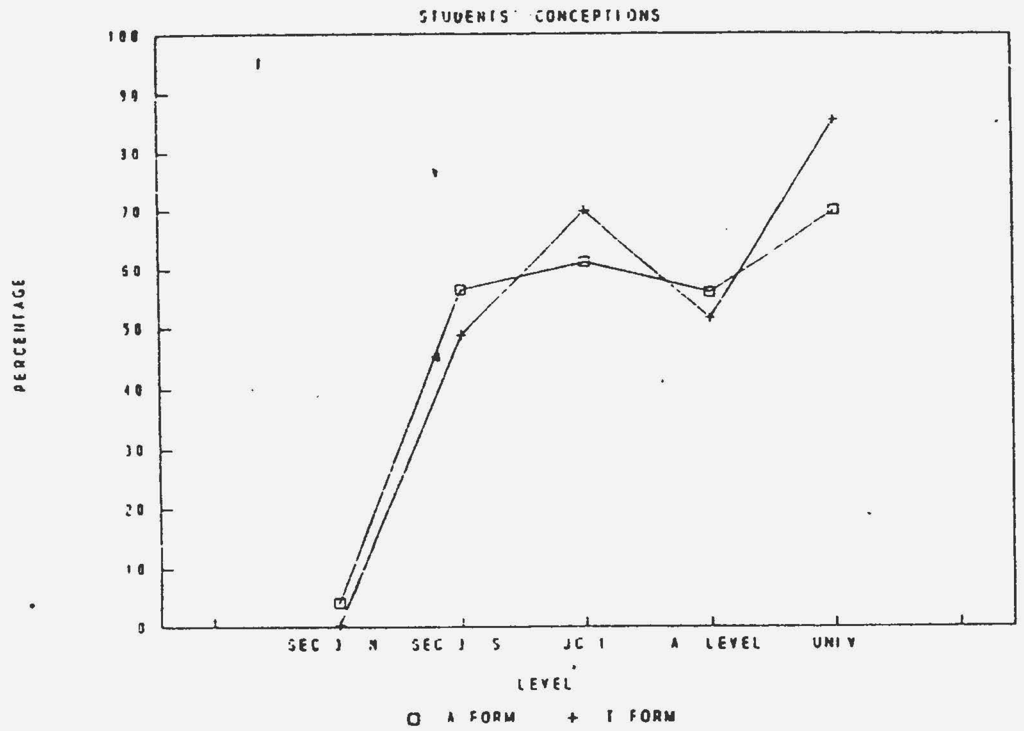


Figure 2. Students' Conception about Concepts Across Level

Comparing the results on the students' understanding across different levels there is a generally higher percentage of partial and sound understanding as the students' educational level increases. This can be attributed to students being exposed to more formal instruction in Chemistry, and consequently better able to explain concepts in Chemistry. Additionally Singapore has a spiral education system whereby the amount of knowledge taught pertaining to a particular topic is built upon in succeeding years.

From the graph in Figure 2, it was noted that the difference in students' ability to explain the concepts tested in the PCCT is not significant. That is, generally, students' understanding and ability to explain these processes is consistent in both the 'A' form and 'T' form though more students used particulate terms (see previous section) to account for these phenomena in the 'T' form. In other words, students understanding is not hampered by the use of particulate terms.

7.3 Correlation between the scores of Convergent Thinking, Divergent Thinking, Divergent Feeling and 'A' Form/'T' Form

Table 15: Correlation Coefficients Between the scores of Convergent Thinking, Divergent Thinking, Divergent Feeling and those in 'A' Form/'T' Form

Level	Sec 3N1	Sec 3N2	JC1	'A' Level	'U'
r_1	+0.17	+0.06	+0.09	-0.10	+0.18
r_2	-0.13	+0.20	-0.15	+0.17	+0.03
r_3	+0.04	+0.14	-0.11	+0.07	-0.08
r_4	-0.15	-0.03	+0.21	+0.09	-0.13
r_5	+0.20	+0.34*	+0.02	+0.16	-0.21
r_6	+0.21	+0.12	+0.07	-0.19	+0.31*

r_1 : correlation coefficient between the scores of convergent thinking and those in 'A' form.

r_2 : correlation coefficient between the scores of divergent thinking and those in 'A' form.

r_3 : correlation coefficient between the scores of divergent feeling and those in 'A' form.

r_4 : correlation coefficient between the scores of convergent thinking and those in 'T' form.

r_5 : correlation coefficient between the scores of divergent thinking and those in 'T' form.

r_6 : correlation coefficient between the scores of divergent feeling and those in 'T' form.

* : statistically significant ($p < 0.01$)

From Table 15, the evidence with regards to correlations between the students' scores of convergent thinking, divergent thinking and divergent feeling and those in 'A' form/'T' form are inconclusive. In the test of students' creativity in terms of their thinking and feeling, questions in the tests are pertaining to very general areas, but the 'A' and 'T' forms tested on students' Chemistry concepts. Thus, a student may be very creative in other areas (e.g. Arts) but he may not have the aptitude or motivation to study Chemistry, and hence accounting for the irregular correlation coefficients given in Table 15.

8. <u>Implications for Science Teaching</u>

(i) Science teachers should be aware that students' response to question depends on how the question is asked. Hence not only the 'T' form, which can test students ability to apply scientific concepts, 'A' form is an equally essential part of the assessment.

The results of this cross level study show similar pattern to that reported by Haider and Abraham. This further provides an additional evidence to confirm the usefulness of the PCCT instrument for both diagnostic and evaluative purposes.

(ii) This cross level study shows an increase in the usage of the Particulate Theory from students in Sec 3 to University as expected, despite the discrepancy caused by Sec 3S students. This ability to explain everyday phenomena in terms of particulate theory could be the result of more exposure to the respective scientific concepts as well as the maturity of the students. An interesting finding is that some of the University graduates still share the same alternative concepts as their younger counterparts.

On the other hand, the facts that (i) there are in general insignificant correlations between the scores of convergent thinking, divergent thinking, divergent feeling and those in the 'A' form/'T' form, found by this study, and (ii) there is significant correlation of students' reasoning ability and their use of the particulate theory in their conceptions of the PCCT concepts, found by Haider and Abraham study (1), may provide the following signal:

> Irrespective of the students' level as well as background, the students' behaviour in responding could still be modified if proper instruction is organized.

"What constitutes the proper instruction" needs further investigation. Definitely it is more than just to confront and change students pre-existing knowledge.

Promotion of connections between students' macroscopic experiences obtained through hands-on activities and their scientific microscopic explanations, should also be included, as indicated in Haider and Abraham's report (1).

(iii) The keenness of the Secondary 3S students to use particulate terms is surprisingly high (see Figure 1). Though students in this Special Stream are of high calibre (students scoring the top 10% in the Primary School Leaving Examination), their period of exposure to the terms is rather short and their understanding of the terms is lower than those students with more years of exposure to the terms (see Figure 2). However, the topic on use of Particulate Theory was introduced to students when they were in Secondary 3 and when this test was conducted.

Hence the particulate terms are still fresh in their minds immediately after the instruction and the short term memory here could have contributed to their strong association to the topic in hand. The implication for science teachers here is how to turn this short term memory into the long term memory. The students have taken the initial step to begin using the terms learnt. Any reinforcement along the way would help the long term memory. Do teachers provide sufficient opportunity for students to reinforce/clarify the particulate terms throughout the whole curriculum. Or do the reinforcement cease when the particulate theory topic is no longer taught? Do teachers constantly use the relevant terms to think and to solve problems to provide students with the necessary exposure?

(iv) One of the findings of this study is the mismatch of students, across the levels, thinking at the macroscopic level on one hand and the nature of the subject Chemistry at the microscopic level on the other hand. Haider and Abraham described such dichotomy as the reality/model relationship(1). They advocated that such an abstract relationship between model and reality requires science educators to help in the development of students' reasoning abilities in order to be able to make the link between model and reality.

In principle, we agree with Haider and Abraham's argument. However we would asset that it is insufficient to just develop the reasoning abilities. The reasoning abilities should be identified with the situation; in other words bring the model to the reality of the situation. Such links need to be made explicit to the students and opportunity should be provided to students to practice (3, 4).

9. Suggestions for Future Research

(i) The sample size could be enlarged.

(ii) Random samples for interview could be implemented to elicit from the respondents who have not made clear their initial responses on paper.

(iii) With regard to instruction, the assessment questions which appear in the textbook could be analysed and classified to examine whether they have any contribution to the problem.

(iii) Furthermore, we can look into how and in what way teachers emphasize a point during instruction. This calls for careful observation of science teaching.

10. <u>Conclusion</u>

By doing a cross level study of the explanations offered by students to the various Chemistry concepts, students understandings (or misunderstandings) of these concepts were discovered. This helps to pinpoint the level where the problem lies. This is essential as teaching of Chemistry in Singapore is through a spiral system whereby the knowledge acquired by students is accumulated across the years. Through such study, an insight could be gained into the root cause of students' misunderstanding or difficulties encountered and hence, provide the starting point for teachers to eradicate students' misconceptions and alternative concepts.

It is obvious that student's misconceptions as well as alternative concepts could be only uncovered as widely as possible if more assessment forms are employed.

It is also obvious that the link between the responses to the daily life phenomena and to the scientific questions, does not come naturally. The crucial problem here lies with the process of instruction and learning. It also requires the transfer of skills conscientiously to make such links obvious. Some of the implications and suggestions for science teaching have been discussed and we hope that they are useful for classroom science teachers.

<u>Acknowledgement</u>

The authors would like to thank:

(i) Dr A.H. Haider and Dr M.R. Abraham for sending us their articles;

(ii) Dr Toh Kok Aun for sharing with us his views and ideas; and

(iii) Mr Chen Lai Keat for preparing the Overhead Express Transparencies.

References

1. Haider, A.H. and Abraham, M.R. "A comparison of applied and theoretical knowledge of concepts based on the particulate nature of matter." To be published in Journal of Research in Science Teaching.

2. Lee, J.L. and Pulvino, C.J. (1981). "How Do I Think?" Minneapolis: Educational Media Corporation.

3. Williams, F. (1980). "Creativity Assessment Packet." New York: D.O.K. Publishers, Inc.

4. Maple, J.A. (1986). "A study of the teaching of certain higher practical skills and their transferability to new context". University of Oxford: Unpublished M.Sc. Thesis.

5. Wellington, J. (1989). "Skills and Process in Science Education: An Introduction. In Wellington, J. (Ed.) Skills and Processes in Science Education: A Critical Analysis. London: Routledge.

D5579 DPSP

APPENDIX

The Application Form Test

Question 1

A spoonful of sugar is added to a clear plastic cup half filled with water. The sugar and the water are stirred with a spoon. The sugar dissolves in water.

Write a paragraph to explain what happens when sugar dissolves in water.

Question 2

A spoonful of chalk is added to a clear plastic cup half filled with water. The chalk and the water are stirred with a spoon. The chalk does not dissolve in the water, where the water turns turbid (cloudy) and the chalk settles to the bottom of the cup.

Write a paragraph to explain why the chalk does not dissolve in water.

Question 3

A spoonful of sugar is added to a clear plastic cup half filled with water. The sugar and the water are stirred with a spoon . The sugar dissolves in water. A few more spoons of sugar are added to the previous sugar solution with continuous stirring until some sugar remains undissolved and settles to the bottom of the cup.

Write a paragraph to explain why water cannot dissolve all of the sugar in this example.

Question 4

A clear plastic cup is half filled with water. The cup is set on a table where it will not be moved. After the water is still, a few drops of blue food coloring are carefully added to it. After a period of time it is observed that the water is uniformly colored blue.

Write a paragraph to explain how the food coloring mixes in the water.

Question 5

A rubber balloon is filled with hydrogen gas and the opening is tightly tied. (see Figure #1.) The balloon gradually deflates. Figure #2 shows the balloon few days later.

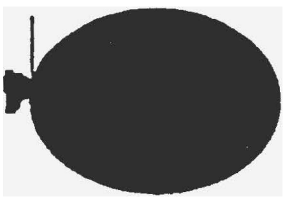


Figure #1

Filled balloon

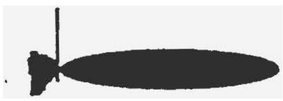


Figure #2

Deflated balloon

Write a paragraph to explain why the balloon deflates.

Question 6

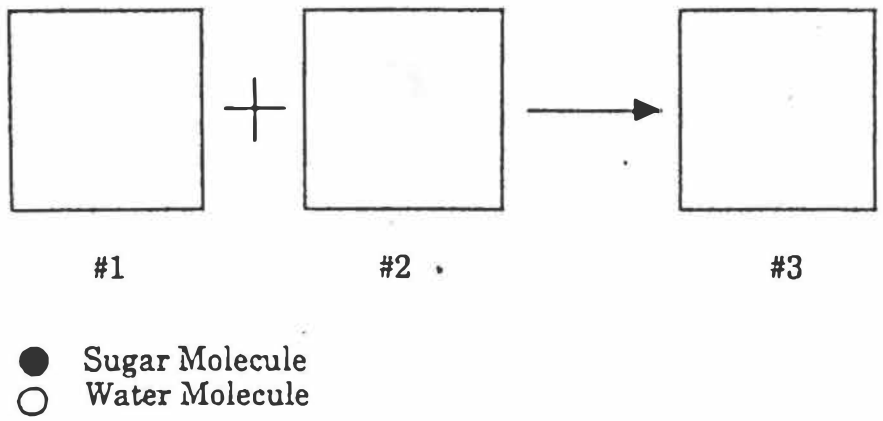
Water exists in three forms (phases): gas (water vapor), liquid, and solid (ice).

Write a paragraph or more to explain the similarities and the differences among the three phases of water.

The Theoretical Form Test

Question 1

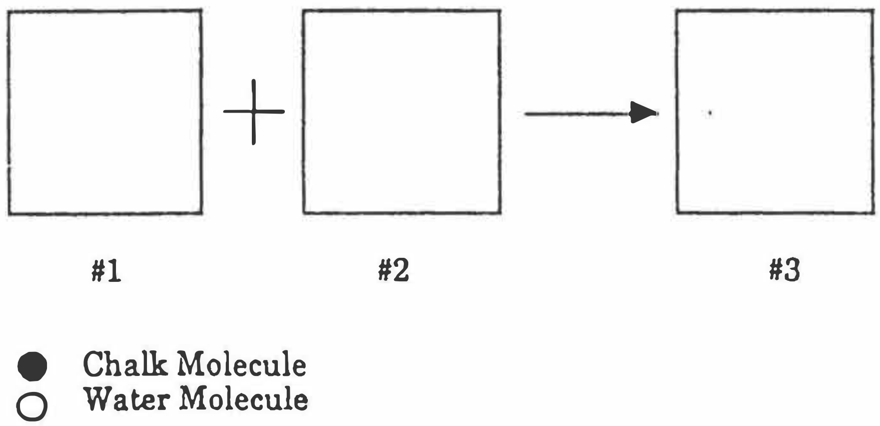
The following models will represent the process of dissolving sugar in water. Use **solid** circles to represent sugar molecules and open circles to represent water molecules. Put 4 molecules of sugar (solid state) in Box #1 and 12 molecules of water (liquid state) in Box #2. Draw the product of this process in Box #3.



Explain your drawings by discussing the relationship between the molecules in each of the three boxes. **The explanation is as important as the drawing.**

Question 2

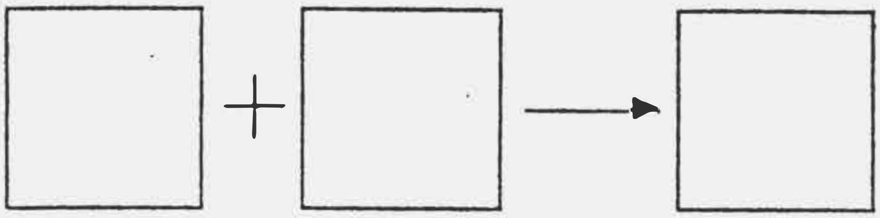
The following models will represent the process of mixing chalk and water. Chalk does not dissolve in water. Use **solid** circles to represent chalk molecules and open circles to represent water molecules. Put 4 molecules of chalk (solid state) in Box #1 and 12 molecules of water (liquid state) in Box #2. Draw the product of this process in Box #3.



Explain your drawings by discussing the relationship between the molecules in each of the three boxes. **The explanation is as important as the drawing.**

Question 3

To a clear sugar solution, more sugar is added. The excess sugar does not dissolve and settles to the bottom of the glass. Use solid circles to represent sugar molecules and open circles to represent water molecules. Put 4 molecules of sugar (solid state) in Box #1 and a clear solution of sugar containing 4 molecules of sugar and 12 molecules of water in Box #2. Draw the product of this process in Box #3.



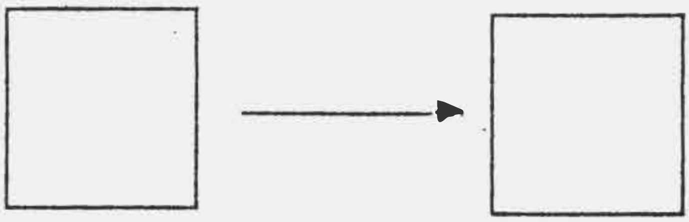
#1 #2 #3

● Sugar Molecule
○ Water Molecule

Explain your drawings by discussing why the excess sugar does <u>not</u> dissolve. **The explanation is as important as the drawing.**

Question 4

Twelve molecules of liquid water are placed in Box #1, four molecules of food coloring are added to them. Use solid circles to represent food coloring molecules and open circles to represent water molecules. In Box #1, draw the system when the food coloring molecules are just added to the water molecules and in Box #2 draw the system after a period of time.



#1 #2

Just add food coloring After a period of time

● Food coloring molecule
○ Water molecule

Explain your drawings by discussing how the molecules get from their positions in Box #1 to their positions in Box #2. **The explanation is as important as the drawing.**

Question 5

A glass box can be divided in the middle by a thin piece of rubber. On the left side of the box hydrogen gas molecules are placed and on the right side only air molecules are present. The pressure in the left side of the box is relatively higher than that in the right side. Using **solid** circles to represent air molecules and open circles to represent hydrogen gas molecules, draw in Figure #1 a model representing the arrangement of the molecules when first placed in the box. In Figure #2, draw the arrangement of the molecules few days later. Also show the rub r in your drawing.

Figure #1

Figure #2

O Hydrogen Molecule

● Air Molecule

Explain your drawings by discussing how the molecules get from their positions in Figure #1 to their positions in Figure #2. **The explanation is as important as the drawing .**

Question 6

Water exists in three forms (phases): gas (water vapor), liquid, and solid (ice). Use circles to represent water molecules and suppose you have 12 water molecules. In Box #1, draw the water molecules in the gas phase. In Box #2, draw the water molecules in the liquid phase. In Box #3, draw the water molecules in the solid phase.

#1	#2	#3
Water vapor	Liquid water	Iced water
(Gas)	(liquid)	(Solid)

Explain your drawings by discussing the arrangements of the molecules in each of the three boxes. **The explanation is as important as the drawings.**