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TEACHING CHEMISTRY IN THREE-HOUR TIME BLOCKS
(Toward a more student-centred General Chemistry classroom)

THE CONTEXT

At Caribbean Union College classes are normally one hour in length and, with the exception of practical classes, are held in the afternoons, Mondays to Thursdays. The effect of this time constraint is to reduce the options one has for making variations in the course schedule. However, this past school year I succeeded in having General Chemistry scheduled from 8 to 11 a.m. (Labs were already scheduled in that time slot for Tuesdays and Wednesdays.)

THE RATIONALE

Over the years of teaching introductory college chemistry, I have become even more convinced that student effort, far more than teacher effort, is the determining factor for success -- or failure -- in Chemistry. I therefore needed a way to increase the proportion of scheduled class time that the student would be actively involved in interfacing with the concepts. It was hoped that this adjustment, together with incorporating current thinking on learning styles and multiple intelligences[1], would lead to improved learning and interest.

THE EXPERIMENT

Each student would attend lecture on Mondays, at which time the topic would be fully presented. In addition, he/she would choose a Tuesday or Wednesday lab day and one tutorial session (Tuesday, Wednesday or Thursday). The effect was to keep the weekly lecture time at no more than three hours while increasing the tutorial time by one to two hours. Mondays would start out with a quiz covering the relevant chapter, and after a short break I would present the lecture, using colour transparencies and the chalkboard (and structural models where relevant). During the lecture I would provide answers to the questions on the quiz or to any other questions that students asked. The students would get a second break about midway during the lecture.

The main focus of the three-hour tutorial session was problem-solving by individual students in a setting where help was readily available: students could work singly, in pairs, or in groups; they were called on at times to answer questions verbally or on the chalkboard while explaining the steps leading to the solution.
Having a three-hour block of time allowed for several variations such as discussions, practical activities, role playing and games, thus extending the range of intelligences catered to.

THE METHODOLOGY

The students were told at the beginning that feedback from them about this new arrangement would form the basis of a presentation to be given at a chemical education conference. Near the end of the year each student, including some who had dropped out along the way, was given a short questionnaire on which to record his/her assessment of the effectiveness of, interest generated by and helpfulness of the various teaching approaches. Subsequently, I shared with them the overall report and invited them to comment on, explain or elaborate on the report or on any other aspect of the class, as they wished.

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[1] Gardner identifies the following eight types of intelligences: verbal/linguistic, logical/mathematical, natural, bodily/kinaesthetic, visual/spatial, musical/rhythmic, interpersonal, intrapersonal.

THE EXPERIMENT

COMPARISON OF TRADITIONAL AND EXPERIMENTAL TIMETABLES

	TRADITIONAL	EXPERIMENTAL
1	Four 1-hour lectures Monday to Thursday	One 3-hour lecture period on Mondays
2	Quiz twice per week (Monday, Tuesday)	Quiz one per week (Monday)
3	One 1-hour tutorial session weekly	One 3-hour tutorial session weekly
Total Hours	5	6

THE ORIGINAL TIMETABLE

TIME	**MONDAY**	**TUESDAY**	**WEDNESDAY**	**THURSDAY**
8:00 to 11:00 am		LAB GROUP A	LAB GROUP B	
11:00 to 12:00 am		Tutorial Group #1	Tutorial Group #2	Tutorial Group #3
12:00 to 1:00 am	*Lecture	*Lecture	*Lecture	*Lecture

* With limited opportunities for problem-solving by students.

THE EXPERIMENTAL TIME TABLE

<table>
<tr><th colspan="2">MONDAY
(LECTURE DAY)</th><th>TUES/WED/THURS
(TUTORIAL DAYS)</th></tr>
<tr><td>***8:00 to 8:10 a.m.**</td><td>Devotion,

Roll call</td><td rowspan="6">TYPES OF ACTIVITIES

A. Summary problems (singly, pairs, groups)
o Covers highlights of chapter in a few questions.

B. Sharing of responses (verbally/on chalkboard)
O Students provide step-by-step solutions and answer questions posed by other students.

C. Games/Role-playing/ Practicals/Discussions on contemporary issues.

(Usually at least one)</td></tr>
<tr><td>***8:10 to 8:40 a.m.**</td><td>Pre-lecture quiz</td></tr>
<tr><td>***8:40 to 8:50 a.m.**</td><td>Break #1</td></tr>
<tr><td>***8:50 to 9:50 a.m.**</td><td>Lecture Part 1</td></tr>
<tr><td>***9:50 to 10:00 a.m.**</td><td>Break #2</td></tr>
<tr><td>***10:00 to 11:00 a.m.**</td><td>Lecture Part 2</td></tr>
</table>

*** Approximate times**

**** Order may vary**

EXAMPLES OF PRE-LECTURE QUIZ

[The emphasis is on definitions and concepts which are presented in the text in a fairly straightforward manner.]

Quiz 1 on Chemical Equilibrium

1.The symbol K is called ___________________.

2.The equation $K = \frac{[A]^a}{[B]^b}$ is called _____________.

3.The symbol Q is called _____________________.

4.The relationship between Q and K is _________

5.True or False:

___ Only reversible reactions can be described as equilibrium systems.

___ Only reactions involving gases and/or solutions can be considered as equilibrium systems.

___ Only balanced equations can be used to define an equilibrium system.

___ When a system achieves equilibrium reaction ceases.

___ A system at equilibrium can have only one possible value for reactant and product concentrations.

___ At equilibrium reactant and product concentrations are equal.

___ Increasing temperature could decrease the value of K.

___ Increasing volume of one reactant in a system at equilibrium causes the volume of the other reactant to increase.

6. Three industrial processes whose yield is dependent on principles of chemical equilibrium are:

a. _________________ which produces _______________

b. _________________ which produces _______________

c. _________________ which produces _______________

Increased temperature is used because it favors the forward reaction in the reaction(s) _____________________________above.

Quiz 2 on Acid-Base theory

1. The acid-base model introduced in this chapter

is________________________________in which an acid is defined

as ____

An equation to illustrate this is [label acid(s) + base(s)]:

2. An amphiprotic species, e.g. ______________

is one which_____________________________________

3. K_w = ___________ and is called __________________

4. An acidic solution is one in which ________________________

A basic solution is one in which ____________________________

A neutral solution is one in which ____________________________

5. pH is defined as ________________________________

It can be measured in two DIFFERENT ways,

using ____

or using ____.

pOH is defined as________________________________.

pK_a is defined as________________________________

pH and pOH are related as _______________________

6. Complete the table, choosing one word from each group of classification terms.

For the acid H_2S, write the expressions for K_{a1}, and K_{a2}. How are they related?

For the base NH_3, write the expression for K_b.

AN EXAMPLE OF A SUMMARY PROBLEM[2]
(on atoms, molecules, ions)

[Since the answers are given, the emphasis is on using appropriate steps to arrive at the answers.]

Chlorine is a yellow-green toxic gas. It is most commonly used as bleach and as a bactericide for drinking water. Chlorine was also used as a poison gas in World War I.

a. What is its molecular formula?
b. How many protons and electrons are there in a molecule of chlorine gas? in a chloride ion?
c. What is the atomic number of chlorine?
d. Write the nuclear symbol for the chlorine atom with 17 proton and 18 neutrons.
e. In what group and period does chlorine belong in the periodic table? Is it a metal nonmetal, or metalloid?
f. A compound is made up of two atoms of tellurium and two atoms of chlorine. What is the simplest formula? What is the name of this compound?
g. When chlorine and aluminum combine, an ionic compound is formed, Give its name and formula.
h. Chlorine and oxygen combine to form oxoanions. Give the name and formula of the oxoanion of chlorine made up of two atoms of oxygen and one atom of chlorine. Give the name and formula of the corresponding oxoacid.

Answers

a. Cl_2 b. 34 protons, 34 protons; 17 electrons, 18 electrons c. 17 d. $^{35}_{17}Cl$ e. period 3, group 17; nonmetal

f. Te_2Cl_2; ditellerium dichloride g. $AlCl_3$; aluminum chloride
h. ClO_2^-, chlorine ion; $HClO_2$, chlorous acid

[2] Masterton and Hurley, Chapter 2

AN EXAMPLE OF A PRACTICAL ACTIVITY
(Electrochemistry)

No. 1: Introductory observational exercise

[If you need to handle the metal pieces, use tweezers rather than your hand.]

Place 2 drops of 1 M $CuSO_4$ onto the top of a piece of copper metal and onto the top of a piece of zinc metal. Place 2 drops of 1 M $ZnSO_4$ onto the top of the other pieces of copper zinc.
Using hand lens, study each solution-metal interface.
Going in a clockwise direction, describe in turn to each other what you see, and identify the reactions which take place.
Explain the chemistry of the reactions, using as aids the following questions.

[Each member of the group should choose a colour. The other members of the group should assess the response given.]

Green: To what is the discolouration of the zinc due?
Red: Which is the spontaneous reaction?
Yellow: Does the reaction involve sharing or transfer of electrons? How many?
Blue: What name is given to such types of reactions?
Write the equation for each-half reaction and balance them. Combine the half reactions to get the overall reaction.
Red: In which direction are the electrons being transferred?
Yellow: Which is the reducing agent? Which is the oxidizing agent?
Blue: Is this redox reaction homogeneous or heterogeneous?
Green: How does the copper produced in the redox reaction compare in appearance with the copper pieces you were given? (You may use a cotton swab to remove the solution.) Give an explanation.
Yellow: What can you say about the size of the equilibrium constant of the redox reaction that took place, and of its reverse reaction? Justify your answer.
Blue: What simple tests could you do to show that the Cu^{2-} ions disappear in the reaction and are replaced by Zn^{2-} in solution?
Green: Why did the other reactions not take place?
Red: What are the oxidation numbers for each element in the reaction? (Go back to the overall equation.

No. 2: Electrolysis

Place the Al foil into the petri dish and place the filter paper onto the

foil.
Add 2 or 3 drops of 1 M KNO_3 to the paper.
Place a clean coin onto the paper.
Clip an electrical lead to the foil and clip the other end of it to the negative end of the battery.
Clip the other lead to the positive terminal of the battery and then touch the other end to the coin for no longer than 3 seconds. Remove the coin, lift up the paper, and place it on a small piece of microtowel. Place 1 or 2 drops of dimethylglyoxime reagent onto the paper.
Observe the results with your hand lens and use the following questions to help you explain the chemistry.

Blue: Which metal is the anode? The cathode?
Green: What half-reaction is occurring at the coin? Write the equation.
Red: What kind of electrochemical reaction is this?
Yellow: Could this reaction be carried out with a standard 1.5 V battery?

No. 3: Batteries

Half-fill a well of a 24-well tray with 1 M H_2SO_4 solution and place 2 small strips of lead metal into the solution so that they do NOT touch.

Clip electrical leads to the 9-V battery and clip an electrical lead to each strip of metal. DO NOT ALLOW THE LEAD STRIPS TO TOUCH. WHY?

Unclip the battery and examine the strips of lead.

Green: Initially, "electrolysis of sulphuric acid" took place.
What was essentially electrolysed? Write the equation.
Red: What compound* accounts for the different colour of one of the lead strips? Give its formula.
Yellow: How was this compound* formed?
Blue: Which lead strip is the cathode? The anode?
Red: Write the oxidation half-equation.
Yellow: Write the reduction half-equation.
Blue: Write the overall charge reaction.
Green: Write the overall discharge reaction.

[Other practical activities included topics such as Equilibrium Systems, pH of Salts in Aqueous Solution, Chemical Kinetics, Spontaneity of Reactions -- enthalpy, entropy, free energy.]

Discussion topics were based on a chemistry-related issue of current/societal interest, such as nuclear phenomena or a newspaper article that ranked Trinidad and Tobago second in world production of ammonia.

THE QUESTIONNAIRE

Students were asked to record their assessment of the 12 teaching approaches, with "1" being the highest in each case, as follows:

In Column 1: Rate each (1 to 12) in order of its effectiveness.
In Column 2: Rate each (1 to 5) by level of interest it generated.
In Column 3: Rate each (1 to 5) for its helpfulness in `learning' the concept(s).
The student could write 13 in column 1 and 6 in columns 2 and 3 if he/she did not have sufficient information.

THE RESULTS

The mean of the scores given by all the students to a particular teaching approach was determined. The results are as follows:

RANK IN EFFECTIVENESS OF TEACHING APPROACH		MEAN
1	Teaching with chalk and talk	4.15
2	Problem-solving summary questions	4.30
3	Problem-solving on blackboard	5.35
4	Problem-solving end-of chapter problems	5.75
5	Practical activity	5.80
6	Teaching with colour transparencies	6.55
7	Games	6.77
8	Problem-solving in groups of 2/3 persons	7.35
9	Role playing	7.70
10	Problem-solving on paper, singly	8.85
11	Problem-solving in groups of more than 3 persons	9.60
12	Problem-solving verbally from seat	9.85

RANK IN INTEREST LEVEL GENERATED BY TEACHING APPROACH		MEAN
1	Practical activity	1.85
2	Games	1.95
3	Problem-solving summary questions	2.05
4	Role playing	2.40
5	Problem-solving on blackboard	2.50
6	Teaching with chalk and talk	2.60
7	Problem-solving end-of-chapter problems	2.65

8	Problem-solving in groups of 2/3 persons	2.80
9	Problem-solving on paper, singly	2.95
10	Teaching with colour transparencies	3.05
11	Problem-solving verbally from seat	3.45
12	Problem-solving in groups of more than 3 persons	3.60

RANK	IN HELPFULNESS OF TEACHING APPROACH	MEAN
1	Problem-solving summary questions	1.45
2	Problem-solving end-of-chapter problems	1.90
3	Problem-solving on blackboard	2.15
4	Games	2.20
5	Problem-solving on paper, singly	2.20
	Teaching with chalk and talk	2.20
7	Practical activity	2.30
8	Problem-solving in groups of 2/3 persons	2.50
9	Role playing	2.65
10	Teaching with colour transparencies	3.15
11	Problem-solving verbally from seat	3.35
12	Problem-solving in groups of more that 3 persons	3.50

Overall and in terms of learning, working summary questions came out on top, followed by teaching with "chalk and talk" and problem-solving at the chalkboard. The students found that problem-solving verbally from their seats or in groups of more than 3 persons was least effective. As would be expected, those activities that involved moving from one place to another got the highest "interest" rank.

That chalk and talk ranked so high and the colour transparencies ranked so low were, for me, surprises.

In the focus group discussion the students made the following comments:

The versatility and flexibility of "chalk and talk" was responsible for its effectiveness.

Doing the summary questions was a good, quick way to work with the main concepts in the chapter.

Going to the blackboard was terrifying; they certainly did NOT like it, but it was effective in making them think through the steps in problem-solving.

The end-of-chapter problems were good, but time to get them done was a problem.

Practical activities helped make some concepts "real".

The colour transparencies were the same as in the text, which they had already seen. Maybe if it were something new, interest would be higher.

Games were great as they provided review and also made them "see" the information in new ways.

Role playing was fun and helpful but most likely scored so low because it was done only once. They felt its use should be increased.

Problem-solving with another person enabled them to help each other but too many people in the group brought confusion. Problem-solving verbally from their seats did not give enough time to think.

Comments made on other aspects of the course, along with some recommendations, are as follows:

1. Three hours is a LONG time (on Mondays). In spite of the breaks, it is tiring. Make Mondays 2 hours (start at 8:30) but keep the tutorials at 3 hours.

2. Keep the pre-lecture quizzes ("even though I get low marks") because it ensures that "I read the chapter at least once" and also it makes the lecture presentation more understandable. One student suggested that the instructor only mention the main points. Another recommended that a summary be made at the end, pointing out the main points of focus.

3. Keep the games. In fact, after the first occasion, some students approached me, individually, to say how much they had enjoyed that activity and asked that games be made a regular feature.

When all is said and done, the most important question remains: Did chemistry learning improve?

It is a difficult question, since there was no control group: each year's group is very different. I do believe, however, that the new course structure can be credited, at least in part, to the fact that the final quarter's results show a record number of A/A-'s for the course.

In addition, the following positive outcomes were achieved:
Compared to previous years,

The students

- spent more time working chemistry problems and getting help from the teacher;
- seemed more comfortable with many chemistry concepts, even when they did not master them;
- became more comfortable in interacting with the teacher and were less reticent in asking for help;

The instructor

- became more aware of the many variations of student conceptual problems in chemistry and therefore sought to develop alternative/more creative ways of helping;
- spent more time meeting students' real needs than assumed needs;
- increased interaction with the students, resulting in a more student-centred, "user-friendly" and relaxed classroom, at least for most of the week.

CONCLUSION

The two main objectives of the experiment were achieved: students spent more time DOING chemistry than LISTENING to chemistry, and the various teaching approaches used allowed for the accommodation of multiple intelligences.

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