CURRICULUM REDESIGN : PERSPECTIVES FROM TWO CHEMISTRY COURSES OF CONTRASTING NATURE AT THE NATIONAL INSTITUTE OF EDUCATION

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Abstract
This paper concerns curriculum redesign for active learning in two chemistry courses at the National Institute of Education. The redesign involves mainly the re-structuring of content to emphasise the essential knowledge. Teaching strategies, learner activities, and instructional media that facilitate student engagement with the course material and encourage the adoption of scientific reasoning and problem-solving approaches are also suggested. In addition, changes in the mode of assessment of the courses that reflect the new foci of the curricula are proposed.

1.INTRODUCTION
Chemistry was first taught at the National Institute of Education as an academic subject 6 years ago. The chemistry courses have undergone several changes since they were first offered, the most notable of which was the adoption of the modular system in 1993. The switch to the modular system reduced the number of teaching weeks from 30 to 26 weeks, resulting in a reduction of formal contact time between lecturers and students, and a reduction of the time available for students to assimilate new material before they sit for examinations. Therefore, the curriculum has to be redesigned to ensure that the students' learning is not jeopardised as a result of these changes. At the same time, course syllabi and structures are also constantly evaluated, and modified, if necessary, to further promote the students' active learning and develop their critical and creative thinking skills. All modifications had to be made within the constraints of the programme structure and the logical structure of the subject.

In this paper, we share our experience in curriculum redesign, using as examples two courses of contrasting nature: a course in redox reactions in the Diploma-in-Education (Dip. Ed.) programme, and a physical chemistry module in the Bachelor-of-Science-with-Diploma-in-Education (B.Sc.) programme. Both courses are taught to first-year students in the respective programmes. We have observed that students were generally not very motivated to learn about redox reactions and physical chemistry, and were unable to comprehend and apply many of the concepts taught in these courses, as seen from their answers to our verbal questions in class, to the tutorial problems, and to questions in formal assessments.

2.COURSE ON REDOX REACTIONS FOR DIP. ED. STUDENTS
(a)Background
The Diploma-in-Education (General) programme is a two-year full-time programme that seeks to train GCE 'A'-level holders and Polytechnic Diploma holders to become generalist primary school teachers in Singapore. The aims of the programme are to prepare well-informed, competent, committed and reflective teachers; to equip trainee teachers with an understanding of key concepts and principles of teaching and learning; and to enable them to apply this knowledge in a variety of classroom and school contexts. In addition to the core modules and prescribed electives on education and curriculum studies, the students are also required to take modules in two academic subjects, such as mathematics and chemistry, so as to broaden their knowledge. Unlike the B.Sc. programme, however, the Dip. Ed. programme does not emphasise rigour and depth in the academic education of its students.

Redox reactions are very commonly encountered, both during the chemical education of 'O'- and 'A'-level students and in everyday life. Respiration, photosynthesis, bleaching, and hair-waving, for example, are all interesting everyday examples involving redox reactions. The underlying principles governing redox reactions also form an important part of the 'O'- and 'A'-level chemistry syllabi.

Students enrolled in the Dip. Ed. programme are generally of lower academic ability compared to students in the degree programmes. They are generally not qualified for admission into the B.Sc. programme, and rarely proceed on to major in any subject at the degree level after they have completed their Dip. Ed. programme.

(b)Weaknesses of Earlier Approach to Curriculum Design
The curriculum for the redox reaction course for Dip. Ed. students was a simplified but similar version of that for the course on redox reactions for students in the degree programme, with excessive content

and too much emphasis on theoretical concepts. This is unsuitable for the target learners' academic ability and motivation, and beyond the scope of the Dip. Ed. programme. Furthermore, the course was structured in such a way that it involved a sequential demand for conceptual learning without an obvious focus or terminal that had chemical reality. The highly theoretical nature of the course and of the problems set in the tutorial worksheet demotivated students.

(c)Redesigned Curriculum for the Dip. Ed. Course on Redox Reactions
(i)Goals
The new goals of the Dip. Ed. course on redox reactions were formulated in the light of Fensham's (1984) suggestions about chemistry curricula for students who are less academically inclined. The main goal of the course was thought to be: to provide an adequate overview of the important principles and applications of redox reactions for students who are unlikely to major in chemistry at the degree level. In addition, since the Dip. Ed. students are trained to become primary-school teachers, with the important task of laying the scientific foundation for potential scientists and engineers of the next generation, it is important that they develop an ability for scientific reasoning and an appreciation of chemistry, at least from a non-specialist's point of view. It is also desirable that the students are made aware of the kinds of real problems that chemists have to deal with, and the approaches taken to solve these problems. In addition to the above goals in the cognitive domain, two goals in the affective domain were also envisaged for the course: the students should ideally have some experience of the power of knowledge of redox principles, and should be able to experience, with joy and excitement, some interesting and spectacular redox phenomena, in the form of guided experiments or lecturer's demonstrations.

(ii)Objectives
In line with the general goals above, the following specific objectives were set for the course: at the end of the course, students should be able to:
(a)define oxidation and reduction in terms of electron transfer;
(b)identify a redox reaction and name the oxidising and reducing agents in the reaction;
(c)balance simple redox equations;
(d)explain the use of standard reduction potentials as indicators of the reducing and oxidising power of chemicals;
(e)explain the difference between a galvanic cell and an electrolytic cell;
(f)explain the operation of commercial cells (batteries) using redox principles;

(g)explain the difference between rechargeable and non-rechargeable batteries;
(h)explain other common redox-based applications, such as bleaching, hair-waving, antiseptics, anti-oxidants in food, and metal extraction; and
(i)explain everyday redox phenomena such as photosynthesis, respiration, corrosion, and combustion.

It may be noted that objectives (a) to (e) refer to the underlying concepts and principles of redox reactions, whilst objectives (f) to (i) refer to the practical applications of redox reactions. These new objectives reflect the overall reduction in content of the course and the shift in emphasis from theoretical aspects to practical applications.

(iii)Course Structure
A clearly-modelled course structure helps students to organise their thinking and to plan their learning (Baume and Baume, 1992). It also helps students see the relationship among the various topics in the course and how the learning of these topics contributes to the achievement of the aims of the course. It has also been found that courses based on the buttressed building model, which brings into sharp focus a central, organising theme in the course, have consistently led to greater student involvement in their learning (Baume and Baume, 1992). Moreover, if the central theme chosen is of relevance to industry, society, or the students' everyday lives, the students will become aware of the relevance of the course at the outset, and will be able to appreciate the relevance of each of the supporting topics in the course. It was therefore decided that the course on redox reactions be designed based on the buttressed building model, with the central theme being "Useful Redox Reactions". A diagrammatic representation of the structure of the course is shown in Figure 1.

(iv)Teaching Strategies, Learner Activities, and Instructional Media
Lectures, interactive lecture notes, overhead transparencies, and the

whiteboard remain as the main media for lesson delivery. In particular, we have found the use of transparency overlays to be very effective in providing stepwise illustration of the development of a topic, e.g. the construction of a galvanic cell.

Figure 1.Diagrammatic representation of the structure of the Dip. Ed. course on redox reactions.

The use of an advance organiser that illustrates the course structure is used to help students form links between new knowledge and previously-learnt knowledge and remind them constantly of the central theme of the course. Articles from popular magazines and newspapers which relate to applications of redox chemistry are also given to students to demonstrate the relevance of the subject and to motivate their interest in the subject. Everyday objects that can be linked to redox reactions, such as bottles of bleach, hair-waving lotions, antiseptics, or vitamin C, are also used.

Opportunities are also provided for the students to view interesting demonstrations and conduct experiments on redox reactions, to give the students some vivid mental images of the experimental side of chemistry, spice up class sessions, and illustrate abstract principles.

We are also considering asking students to carry out simple library research about specific practical applications of redox chemistry or everyday examples of redox phenomena, and to present their findings to the class. This would give the students an opportunity to practise first-hand the application of theoretical concepts to the explanation of real-life situations, and allow them to reflect on the concepts of redox reactions regularly in class. The students' research reports and presentations can be assessed to reflect the importance attached to information-processing and presentation skills. These skills are of particular relevance to the students' future careers as teachers.

(v)Assessment

The mode of assessment of the course on redox reactions is also changed to reflect the change in emphasis of the course. The highly theoretical or abstract questions in the formal assessments and tutorials are replaced by questions which more accurately reflect the practical applications of redox chemistry or the everyday encounters of the students with redox phenomena. A portion of the questions require the students to think and apply what they have learnt in class. For example, students are asked to suggest explanations for common redox phenomena and provide the rationale behind certain industrial practices such as the casting of scrap iron pieces into effluents from copper mines to recover more copper from the waste water.

3.PHYSICAL CHEMISTRY COURSE FOR FIRST-YEAR B.SC. STUDENTS

(a)Background

The B.Sc. programme is a four-year programme which aims to educate the students in the basic sciences that will provide them with a firm foundation as future science teachers and professionals. Students in this programme are required to major in two academic subjects, at least one of which must be a science subject. In addition, students have to take modules in pedagogy.

Physical Chemistry is a compulsory chemistry degree course which is divided into four modules spread through four years. Physical Chemistry I is the first module of the course which is offered in the second semester of the first year. This module serves as an introduction to the subject of physical chemistry, and covers three main topics: the first law of thermodynamics, thermochemistry, and the physical behaviour and microscopic model of gases. The students are expected to understand and be able to apply the thermodynamic theories to solve hypothetical as well as simple practical problems, derive the mathematical relationships between different thermodynamic variables, and design simple experiments involving the verification or application of a theory in specific situations. The module therefore involves a lot of logical reasoning and mathematical manipulations.

In the first year of the B.Sc. programme, students take an average of 8-10 compulsory modules, each with their load of assignments, tutorial worksheets and tests to handle. Students are often left with little time and energy to really read and think of what they are learning.

(b)Teaching and Learning Problems in Physical Chemistry I

Since the syllabus for Physical Chemistry I is rather heavy, the conventional approach to teaching is lecturing, where students play a passive role as listeners. The students are usually taken through the subject content without in-depth discussion. In order to cope with the heavy syllabus, students tend to memorise mathematical equations with little understanding of their physical significance.

Owing to their tight schedules, most students do not have time to try out the tutorial questions. As a result, the tutorials, which are designed for interaction and discussion, often degenerate into a session where the lecturer explains his solutions and the students simply copy down answers.

The physical chemistry module also offers three experiments for students to gain practical experience. However, the experiments show little relevance to what is being taught in the lectures.

(c)Redesigned Curriculum for Physical Chemistry I

In redesigning the curriculum, attention was focussed on restructuring content knowledge to aid students' learning, re-organising the lecture, tutorial and practical activities to promote deep learning, and modifying the assessment scheme to reward deep learning. These points are illustrated below using the topic "Gases" as example (Fig. 2).

(i)Course Structure and Objectives

The content is re-structured with emphasis on the essential part of the knowledge. For example, the experimental approaches used to derive and verify the Ideal Gas Law, $PV = nRT$, and measure the Gas Constant R are introduced in the lecture to help students appreciate the logical development involved in the derivation of the equation, the physical significance of thermodynamic variables, and understand the limits of the applicability of the Ideal Gas Law.

Hence, at the end of the course, students should be able to:
(a)derive the Ideal Gas Law, both from experimental data and from the microscopic model of gases;
(b)state the conditions under which the Ideal Gas Law is applicable;
(c)apply the equation to solve hypothetical problems; and
(d)design experiments to verify the Ideal Gas Law and demonstrate its practical applications.

Figure 2. Conceptual structure of the topic "Gases".

(ii)Teaching Strategies and Learner Activities

The re-structured teaching strategy for the topic "Gases" is represented in Fig. 3.

In the redesigned curriculum, cooperative learning will be encouraged by merging individual lecture and tutorial sessions into combined lecture-tutorial sessions where group work and student presentations can be organised and monitored. The lecturer focuses his teaching on the main points whilst the students will have to teach themselves on the supplementary materials through team- and peer-teaching.

Tutorial questions will be set to allow the students to derive the various theories for themselves and discuss how they may design an experiment to verify a theory or demonstrate the simple application of the theory. As the tutorial questions are rather complex, they can be assigned to groups of students to solve collaboratively.

The practical session is aligned with the theory-learning. The students are asked to design an experiment for the verification of a theory or to measure a physical constant, and demonstrate their procedures in the laboratory class. In this way, the students' learning of theory can be reinforced and deep learning can be promoted. At the same time, students will be cultivated with the principle of not accepting or rejecting a theory unless it is experimentally verified. Hence, students actually have the chance to think, plan, experience and reflect during the practical sessions, in accordance with Kolb's Learning Cycle (Kolb, 1984).

Practical
(Verify theory
experimentally)

Design experiment according
to tutorial proposal

Figure 3. Re-structured teaching strategy for the topic "Gases".

(iii)Assessment

The students' participation in class, in-lecture presentations, and their solutions to the group tutorial problems will be assessed as part of the continuous assessment. The students will also be given interim tests to provide feedback on their learning.

The students' laboratory work will be assessed based on their pre-lab preparation, in-lab performance, and post-lab reports. The submitted reports will be assessed based on the proficiency of scientific writing, data processing technique, observation and discussion, and analysis of the experimental errors. A 3-hour practical test is also being designed.

Finally, the examination paper will also be designed to address both the theoretical (factual and higher-level knowledge) as well as the practical/applied aspects of knowledge.

4.CONCLUSION

Numerous improvements to the curriculum for the Dip. Ed. course on redox reactions and the B.Sc. course on physical chemistry have been suggested in this paper. Broadly speaking, our proposals address the problems by re-structuring content to emphasise the essential knowledge, re-organising the lecture, tutorial and practical activities to promote deep learning, and modifying the assessment scheme to reward deep learning.

Some of the changes suggested above have been implemented already. For example, the hair-waving and dyeing processes have been used to illustrate the importance of redox reactions. These examples were chosen particularly because the majority of students were females, and were likely to be motivated by topics related to hair beauty. These examples indeed made the students sat up and listen attentively.

We will continue to implement the modified curriculum in stages and refine it further based on the results obtained.

5.REFERENCES

Baume, C. and Baume, D. (1992). Course design for active learning. Effective Learning and Teaching in Higher Education, Module 2, Part One. Sheffield: CVCP Universities' Staff Development and Training Unit.

Fensham, P. J. (1984). Conceptions, misconceptions, and alternative

frameworks in chemical education. Chemical Society Reviews, 13, 199-217.

Kolb, D. (1984). Experiential Learning - Experience as the Source of Learning and Development. New Jersey: Prentice Hall.