

**FORM FOUR CHEMISTRY TEACHERS'
CONCEPTUALIZATION OF
PEDAGOGICAL CONTENT KNOWLEDGE**

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**FACULTY OF EDUCATION
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KUALA LUMPUR**

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PEDAGOGICAL CONTENT KNOWLEDGE**

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**FACULTY OF EDUCATION
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Abstract

Pedagogical content knowledge (PCK) was defined as the knowledge of teaching resulted from the integration of pedagogy and subject matter knowledge. This study looked into the conceptualization of pedagogical content knowledge and the teaching processes of the four Form Four Chemistry teachers while teaching topic 3 ‘Chemical Formulae and Equations’ in the Form 4 Chemistry curriculum.

The four Chemistry teachers were chosen from various schools based on their given consent and availability for observations. The methods of data collection consisted of classroom observations, interviews, field notes, and documentation. The classroom observations were conducted on all the lessons taught in topic 3. Both the interviews and classroom observations were audibly recorded and transcribed. Coding was done on the data to form sub themes which were later collapsed into themes. The coding of the data was guided by the research questions and new themes were allowed to emerge from the data. The data collected from various sources were triangulated with each other.

The findings of this study showed that: (i) the chemistry teachers perceived content knowledge, pedagogical skills and student as essential components of their teaching; (ii) the PCK attributes of the chemistry teachers developed and grew with their teaching experience but at different rates; (iii) the teaching processes of the teachers were mostly similar to those in the PRA model; and (iv) the teachers lacked a few aspects such as assessment on students’ conceptual understanding and own teaching, student knowledge and new comprehension.

As a whole, the teaching of the four Form Four chemistry teachers was teacher-oriented, algorithmic, using chalk-and-talk approach which did not support thoughtful and meaningful and optimal learning among the students. A framework of collaboration was

proposed to help the chemistry teachers develop and expand their PCK evenly and holistically. At the same time, a few topic specific PCK which can be used as training materials in the professional training program for pre-service and in-service Chemistry teachers were identified.

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Abstrak

Pengetahuan pedagogi kandungan, *pedagogical content knowledge* (PCK) ditakrifkan sebagai pengetahuan pengajaran hasil daripada integrasi pedagogi dan isi kandungan. Kajian ini telah mengkaji konsepsi pengetahuan pedagogi kandungan dan proses pengajaran empat orang guru kimia Tingkatan Empat ketika mereka mengajar tajuk tiga 'Formula kimia dan persamaan kimia' dalam kurikulum Kimia Tingkatan Empat.

Pemilihan keempat-empat orang guru kimia Tingkatan Empat dari pelbagai buah sekolah adalah berdasarkan persetujuan mereka dan kesesuaian jadual waktu mereka untuk pemerhatian pengajaran bilik darjah. Kaedah pengumpulan data terdiri daripada pemerhatian pengajaran di bilik darjah, temubual, nota lapangan dan dokumentasi. Pemerhatian mereka di bilik darjah terhadap pengajaran semua tajuk tiga dilaksana dan dirakamkan secara audio. Kedua-dua data yang dikumpul melalui temubual dan pemerhatian pengajaran dirakamkan secara audio dan ditranskripsikan. Pengkodan dilakukan pada data yang telah dikumpul untuk mendapat sub-tema yang kemudian dikategorikan menjadi tema-tema. Dapatan daripada tinjauan literatur digunakan sebagai garis panduan ketika membuat pengkodan dan pada masa yang sama, tema-tema baru yang muncul daripada data diterima. Data yang telah dikumpul daripada pelbagai sumber digunakan untuk tujuan triangulasi.

Dapatan kajian ini menunjukkan bahawa: (i) keempat-empat orang guru kimia mempunyai persepsi bahawa ilmu pengetahuan, kemahiran pedagogi dan pelajar sebagai komponen yang penting bagi pengajaran mereka; (ii) atribut PCK keempat-empat guru kimia berkembang dan bertambah dengan pengalaman mengajar tetapi pada kadar yang berbeza; (iii) kebanyakan proses-proses pengajaran guru adalah sama dengan yang terdapat dalam model PRA; dan (iv) masih terdapat kekurangan dari segi penilaian

kefahaman konseptual pelajar, penilaian terhadap pengajaran diri sendiri dan kefahaman pelajar (*student knowledge*) dan kefahaman baru di kalangan guru.

Didapati pengajaran guru secara keseluruhannya adalah berpusatkan-guru, algoritmik, *chalk-and-talk* dan tidak menggalakkan pembelajaran fitrah dan bermakna dan pembelajaran optimal di kalangan pelajar. Satu kerangka kolaborasi telah dicadangkan untuk membantu guru kimia mengembangkan PCK mereka dengan sekata dan menyeluruh. Pada masa yang sama, beberapa PCK spesifik topik yang sesuai digunakan sebagai bahan latihan bagi tujuan latihan profesional guru kimia pra-perkhidmatan dan dalam perkhidmatan telah dikenalpastikan.

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List of Symbols and Abbreviations

CDC	Curriculum development centre
EPRD	Educational Planning and Research Division in the Ministry of Education of Malaysia
HSP	<i>Huraian Sukatan Pelajaran</i> (Curriculum Specifications)
JPN	<i>Jabatan Pendidikan Negeri</i> (The State Education Office)
KPLI	<i>Kursus Perguruan Lepas Ijazah</i> (Postgraduate Diploma in Teaching Program)
LCD	Liquid Crystal Display
NPE	National Philosophy of Education
PEKA	<i>Pentaksiran Kerja Amali</i> /Laboratory Work Assessment
PKPG	<i>Program Khas Pensiswazahan Guru</i> (A special program of the Ministry of Education Malaysia to convert non-graduate teachers into graduate teachers)
PMR	<i>Penilaian Menengah Rendah</i> (Lower Secondary Assessment)
PT3	Pentaksiran Tingkatan 3 (Form 3 Assessment)
RM	Ringgit Malaysia (Malaysian dollar)
SPM	<i>Sijil Pelajaran Malaysia</i> (Malaysian Certificate of Education)
STEM	Science, technology engineering and mathematics subjects

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Chapter 1

Introduction

1.1 Introduction

Vision 2020 was forwarded in 1997 by the 4th Prime Minister of Malaysia, Tun Dato' Seri Dr Mahathir Mohamad (Mahathir, 1997). Since then it has served as the course for Malaysia to become a fully developed country by 2020. Malaysia will develop in its own mould in all dimensions, including the economic, political, social, spiritual, psychological and cultural aspects. In order to achieve the vision, nine strategic challenges have been spelled out of which the Sixth Strategic Challenge was about science and technology, wherein 'Malaysia aspires to become a producer and contributor of science and technology by the year 2020'. Accordingly, a pool of scientifically and technologically skilful local manpower is essential (Raslan Ahmad & Ahmad Razif Mohamad, 2013; Ng, 2014) to minimise Malaysia's reliance on foreign expertise and skilful workers besides giving Malaysia a competitive edge globally and sustaining its status of a developed nation. The Ministry of Science, Technology and Innovation of Malaysia (MOSTI) has projected that the Ministry of Education Malaysia needed to produce 270,000 science students by the year 2020 in order to fulfil the manpower need in science and technical related careers (KPM, 2012).

In order to have a continuous pool of scientifically and technologically qualified manpower, education plays a very important role. The 60:40 Ratio Policy or also known as Technical Science and Literature Policy is one of the strategies in the National Education Policy for secondary education (Ministry of Education Malaysia, 2012). Under the said policy, Malaysia aims to attain sixty percent (60%) of its secondary students enrol in the science stream and the remaining forty percent (40%) in the arts stream at the upper secondary level (Form four). These science students form the strong

base of manpower needed for science, technology, engineering and mathematics (STEM) related careers in sustaining Malaysia as a developed country. The study also shows that young people's interest in science is essential for the future prosperity of a nation (The Royal Society Science Policy Centre, 2014; KPM, 2012).

1.2 Background of the study

Chemistry is offered as one of the pure science subjects together with biology and physics to the science stream students at the upper secondary level (Form Four and Form Five). Generally, science subjects contain a lot of facts, ideas, and concepts (Lawson & Renner, 1975). Students often find science subjects more difficult to learn than other subjects due to three reasons: first, too many new concepts are introduced too quickly in a science course; second, students bring along their naïve theories and beliefs to the classroom; and, third, students' current understanding was always neglected by curricula and instructions (Eggen & Kauchak, 1999, p. 383).

Lawson and Renner (1975) further classified science concepts into concrete-operational and formal-operational concepts. Accordingly, the concrete-operational concepts are concepts 'whose meaning can be developed from first-hand experience with objects or events' and the formal-operational concepts were concepts whose meaning was given through 'imagination or through a logical relationship with the system' (p. 348). As a branch of science, chemistry shares the same features. In fact, it is one of the most difficult subjects in the curriculum as studies showed that even the university students did not understand some of the elementary chemistry concepts (Breuer, 2002; Flood, 2004; Johnstone, 1991, 1999).

Chemistry, as a central science, is defined as 'the study of the properties of materials and the changes that materials undergo' (Brown, Lemay, Jr., Bursten & Burdge, 2003, p. 1). It allows one to understand matter and its behaviour, utilisation and

behaviour for human ends (Nelson, 1983). According to Johnstone (1999), chemical knowledge exists in both macro- and micro-levels. Macro-level knowledge refers to the tangible such as appearance, state, smell, colour and others. Micro-level is the chemical knowledge at the molecular level. Different from the macro-level concepts, many of the micro level chemical concepts fall into the formal-operational category, thus making chemistry abstract and difficult to learn (Cantu & Herron, 1978). It was reported that students need to possess formal operational mental ability in order to comprehend the abstract concepts (Lawson & Renner, 1975). For those students who have not attained the formal-operational stage resorted to using their imaginations to learn about particles like atoms, molecules, ions, electrons, protons, neutrons as they cannot see the particles with their naked eyes (Cantu & Herron, 1978).

Besides being abstract, the upper secondary chemistry curriculum contains certain concepts such as mole concept, stoichiometry, chemical reactions, concentration, and neutralisation which involve calculations. The frequent use of mathematical symbols, formulas, and equations to express the relationships at the macroscopic and microscopic levels had added the complexity of chemistry (Gabel, 1999). To exacerbate the difficulty in calculations, the mole concept and stoichiometry problems often involves very small (macro level) and very large numbers (micro level) within the same problem. The inconsistency in the number size makes students confused and difficult to comprehend the concepts taught (Yalcinalp, Geban & Özkan, 1995). For instance, the weight of 0.0001 moles of magnesium metal is 0.0024g and it contains 6×10^{19} (60,000,000,000,000,000) atoms at the micro level. The three quantities: 0.0001 moles, 0.0024g and 6×10^{19} atoms are actually equivalent to each other but expressed in different entities.

Studies show that students who had attained formal operational thinking performed better in chemistry than those non-formal thoughts operators. The former

could easily understand both concrete and abstract concepts, but not those who had just attained the concrete-operational thinking ability (Cantu & Herron, 1978; Chan, 1988; Lawson & Renner, 1975; Wilson, 1987). Comparatively, chemistry demands students to possess the formal operational thinking more than subjects like biology, physics and mathematics (Wilson, 1987). Despite the fact that poor chemistry performance is due to students' inability in performing formal-operational thinking, students with good chemistry results did not necessarily have a thorough understanding in chemistry as findings show that a significant number of them were still confused over chemical concepts even after extensive learning (Fensham, 2002; Stavridou & Solomonidou, 1998). Studies show that even students who perform well in chemistry examination possess only 'shallow and algorithmic understanding of the chemical concepts' (Fensham, 2002, p. 335). It could be due to the fact that preconceptions on chemical concepts were persistent to change even after formal teaching (Coll & Taylor, 2001). Apart from that, many researchers have concern expressed over students giving macroscopic explanations for chemical phenomena suggesting isolation between knowledge learned and explanations given (Fensham, Gunstone & White, 1994).

The research findings mentioned earlier suggest two causes of students' failure in learning chemistry: first, the abstractness of chemical concepts; and second, students' inability to think at the formal-operational level. It seems like there is a mismatch between the content and the intellectual level of the students (Lawson & Renner, 1975). Subsequently, the greater the mismatch between the two entities, the poorer will be the students' performance.

A study done in Malaysia back in the 1980s showed that about one-third of our upper secondary students faced difficulties in learning chemistry as they were still in the late concrete-operational level (Chan, 1988). As a result, they had difficulties in mastering basic chemical concepts such as ions, isotopes, chemical bonding, periodic

table, writing and balancing chemical/ionic equations. They perceived writing and balancing chemical/ionic equations as the highest difficulties because they failed to learn these abstract concepts meaningfully with their concrete operational thinking (Cantu & Herron, 1978). Poor performance in chemistry was reported to bring about serious consequences such as high attrition rates in a foundation science program (Wilson, 1987).

The main aim of the Integrated Curriculum for Secondary School Chemistry is to help students acquire a strong foundation in both chemical knowledge and skills while also acquiring problem-solving skills, thinking skills, scientific attitudes, and noble values (*Kementerian Pendidikan Malaysia*, 2006). In order to help students understand the subject matter knowledge and achieving curricular goals, it is essential for chemistry teachers to be competent in the subject matter knowledge and deliver this knowledge effectively. In other words, a teacher needs to possess good pedagogical content knowledge (Shulman, 1986b). A competent and effective chemistry teacher helps students to acquire a strong foundation in chemistry, inculcate and sustain a strong interest in it and most important of all, inspires students to further their studies in STEM related areas hence attaining the 60:40 Ratio Policy.

In order to look into the teaching of chemistry, it is necessary to look into the 'what' and 'how' at teaching chemistry, in other words the pedagogical content knowledge (PCK) of the chemistry teachers. There are two key elements in Shulman's (1987) PCK conception: firstly a teachers' ability to transform his/her personal understanding of the content into a form which is understood by the students and secondly a good understanding about students' learning difficulties. He also proposed subject matter knowledge as a pre-requisite criterion for PCK. PCK is one of the seven knowledge bases needed by a teacher to teach successfully (Shulman, 1987). The other six knowledge bases are: (i) content knowledge; (ii) general pedagogical knowledge;

(iii) curriculum knowledge; (iv) knowledge of learners and their characteristics; (v) knowledge of educational contexts; and (vi) knowledge of educational ends, purposes, and values; and their philosophical and historical grounds (p. 8).

Good PCK is essential for a successful and good teaching (Shulman, 1986b). On the contrary, teachers with weak PCK not only fail to teach effectively (Krueger & Sutton, 2001) but also create few learning opportunities for their students, thus denying them from entering into the formal stage of learning (Lawson & Renner, 1975). Although possessing strong subject matter knowledge is important for teachers, it alone is insufficient for them to teach effectively. It was evidenced that mathematics teachers with very strong content knowledge, but inadequate knowledge about the learning difficulties of their students tend to overestimate the amount of learning achieved by their students, hence, many of the Form Three students with excellent results in mathematics failed to understand mathematical concepts taught (Clements, 2004). A similar finding was noted in chemical education wherein ‘what is taught is not always what is learned’ (Johnstone, 1999, p. 45).

Teachers with good PCK possess a repertoire of strategies and representations which they could use to represent a particular concept to their students (Shulman, 1987). Hence, PCK is a solution for better teaching and is the most direct route to improve students’ science achievement (Krueger & Sutton, 2001). It is believed that a good PCK comprises an understanding of subject matter knowledge, knowledge of transformation of content and knowledge of students’ learning difficulties.

To talk about PCK, it is necessary to mention about teacher preparation programs as this is where teachers acquire PCK. Basically, teachers in Malaysia acquire their training from the public universities or teacher education institute. Universities offer four-year education degree program and a one-year diploma education program for those who have a basic degree. Another postgraduate teachers’ training program that

is the Postgraduate Diploma in Teaching Program (*Kursus Perguruan Lepas Ijazah*, KPLI) is offered in the teacher education institutes. The main components learned in the education degree program are subject matter knowledge and teaching methods, whereas the postgraduate education programs place more emphasis on the teaching methods.

Many studies reported that teacher training programs have failed to train in-service teachers adequately (Calderhead & Shorrock, 1997; Grossman, 1990; Korthagen & Kessels, 1999; Shulman, 1987). Furthermore, the program lacks emphasis on pedagogy and fail to integrate theory and practice (Stones, 1994). Many measures such as prolonging program duration, extending internship in school, adding depth to subject matter knowledge and putting more emphasis on instructional skills, just to mention a few, have been taken to remedy the situation, yet the effort will remain futile if the training institutions still persist to view teaching as the delivery of curriculum (Stones, 1994). Additionally, teaching is a cultural activity which is difficult to change (Stigler, 2009).

The disappointment in the teacher training program in the United States had led to the recruitment of teachers based merely on subject matter knowledge, personal character and communication skills and not teaching qualification (Shulman, 1986b). The rationale was the belief then that everybody can teach according to the famous statement by George Bernard Shaw 'He who can, does. He who cannot, teaches' (Shulman, 1986b, p. 4). Though experience is regarded as the best teacher in learning to teach (Grossman, 1990), the recruitment of postulants with subject matter but who are ignorant of classroom realities could be dangerous (Berliner, 1987).

A study was conducted on the satisfaction of the school heads in a state in Malaysia on the performance of the graduates from the teacher education institutes. The findings showed that the school heads were satisfied with the graduates' daily duty performance, but the graduates needed to upgrade their teaching skills (Tan, Filmer Jr.

& Asmah Mohammed, 2001). A similar finding was noted for KPLI graduates (Lau, 2004; *Kementerian Pendidikan Malaysia*, 2005a). Another research revealed little correlation between the academic performance of the teachers during training and their in-service performance appraisal (Tam, Choong, & Rosli, 2005). Student teachers with excellent performance in the institutes might not be excellent in the schools. School heads often commented these graduates lacked instructional skills and communication skills.

1.3 Statement of problem

The fading interest of students in school science and towards science careers has been the central topic of investigation in many nations (Jack & Lin, 2014). Similarly, Malaysia is facing the issue of its students lacked interest in the STEM subjects (Dermawan, A., 2014, June 7; Fatin Aliah Phang, Mohd. Salleh Abu, Mohammad Bilal Ali, & Salmiza Salleh, 2014; Razali Hassan, Halizah Awang, Baharuddin Ibrahim & Siti Hajar Zakariah, n.d.). The lack of interest among students nationwide in the science stream was not something new (Lee, Zainal Ghani, Yoong, Khadijah Zon, Loo, Munirah Ghazali & Sharifah Maimunah Syed Zin, 1996; Siow, Chang, Lee & Chien, 2005; Muhammad Zaini Mohd Zain, 2010). In fact, the Form Four science enrolment never achieved sixty percent since its implementation in 1967 (Fatin Aliah Phang et. al., 2014). Table 1.1 shows some of the ratio of the science stream enrolment and arts stream enrolment in Form Four in Malaysia for the years 2010 to 2013.

Table 1.1

Enrolment of Form Four Science and Arts Stream Students at the secondary level in Malaysia (2010-2013)

Year	Enrolment		
	Form Four Science	Form Four Arts	Ratio of Science students : Arts students
2010	134750	219084	38 : 62
2011	130049	211769	38 : 62
2012	128559	218907	37 : 63
2013	128349	225483	36 : 64

(Source: Ministry of Education Malaysia, 2012, 2013)

A similar trend was noted in the ratio of the science and arts stream enrolment in Sarawak (a state in Malaysia) too (Table 1.2). The enrolment of the science students was slightly above thirty which was relatively lower than the national enrolment.

Table 1.2

Enrolment of Form Four Science and Arts Stream Students at the Secondary Level in Sarawak (2005-2012)

Year	Enrolment		
	Form Four Science	Form Four Arts	Ratio of Science students : Arts students
2005	10546	31300	34 : 66
2006	11224	33413	34 : 66
2007	11375	34027	33 : 67
2008	12131	37089	33 : 67
2009	10985	36000	31 : 69
2010	10805	35337	31 : 69
2011	10942	35526	31 : 69
2012	10969	35915	31 : 69

(Source: Ministry of Education Malaysia, 2013)

The science students learn three pure science subjects at the upper secondary level: biology, chemistry and physics. By having a strong foundation in pure science subjects, these students were likely to be the future enrolment for the STEM related studies at tertiary, diploma and certificate levels after completing their School Certificate examination (SPM). As the science student enrolment is still far from sixty percent at the upper secondary level, therefore it is important to ensure they remain and acquire a strong foundation in the science subjects.

Analysis of the SPM results of three science subjects in Sarawak shows that though the passing percentage of the three subjects were relatively high, ranging from 87% to 98% for the years 2006 to 2013 (Table 1.3).

Table 1.3

The SPM results of pure science subjects based on passing percentage and percentage scoring grade D and E in Sarawak for the year 2006-2013

Year	Biology		Chemistry		Physics	
	Passing percentage (%)	Percentage of candidate scoring grade D and E (%)	Passing percentage (%)	Percentage of candidates scoring grade D and E (%)	Passing percentage (%)	Percentage of candidates scoring grade D and E (%)
2006	88.00	42.20	95.19	44.30	96.35	42.46
2007	92.10	40.50	87.20	44.92	96.40	42.62
2008	93.43	36.25	94.92	46.87	97.55	39.75
2009	93.91	40.10	84.80	43.75	97.68	33.15
2010	95.72	37.33	91.32	44.56	97.28	36.96
2011	95.86	35.40	89.24	40.58	98.19	33.63
2012	97.12	31.36	91.46	44.95	96.55	33.05
2013	96.97	35.07	90.39	46.57	97.90	32.34

(Source: MOE)

A closer look shows that almost half of the passing percentage of chemistry subject was contributed by candidates scoring grade D and E (43-46%). In other words, almost half of the candidates merely attained a minimal pass in chemistry as compared to biology and physics. The high percentage of students achieving minimal pass in the SPM chemistry paper suggesting a weak foundation which might prohibit the students from furthering their study in the STEM related fields at the higher levels.

Based on the argument of Shulman (1986b) that teachers with good PCK teach effectively, therefore one could infer that the performance of students in chemistry is related to the PCK of the teachers. Furthermore, Tobin (1998) also said that science teachers were key to students' achievement as they influenced what and how students were taught. Based on the high percentage of the SPM students obtaining a minimal pass in chemistry, it was anticipated something might be lacking the PCK of the

teachers therefore it is necessary to look into the PCK of the chemistry teachers (Bucat, 2004).

Research done in Malaysia shows that 42.8% (N = 901) of the Form Four science students enrol in science stream because of effective science teachers (Lee et al., 1996). The finding implies that how a teacher teaches could give an impact on the interest and confidence of his/her students in learning the subject taught. It was supported by Medley (1979) saying that “the effect of schooling on the individual pupils depends to a considerable extent on who his teacher is” (p. 11). It was reported that science is best taught by teachers who specialised in the subject and a teacher who knew and loved a subject taught with inspiration (The Royal Society, 2014).

Besides anticipating there was a lack in certain aspects in the PCK of the chemistry teachers which needed to be investigated, this study was deemed necessary for another two reasons. Literature review showed that many studies done on chemistry education in Malaysia were on problems encountered by students in learning the mole concept, chemical formula and chemical equation. There were not many studies done on the chemistry teachers and their PCK. For instance, library research showed that only about 9% of the studies done on chemistry education for the year 1993-2013 were on the chemistry teachers whereas 68% of the studies were on students. Therefore it was high time to look at the chemistry education from another perspective: from the teaching of the chemistry teachers: the ‘what’ and ‘how’ of the teaching as either investigating the pedagogical skill or the content of teachers alone is deemed inadequate and useless (Hasweh, 1987; Shulman, 1986b; Veal & MaKinster, 1999). Additionally, PCK was proposed by Shulman (1986a, 1986b, 1987) to assess the teacher’s expertise and UNESCO (2003) also suggested to use ‘what, how and how much people learn’ to evaluate the quality of education matters of a nation (p. 96). On the other hand, in order

to grasp a better understanding of teachers' teaching or PCK, it would be appropriate also to get to know how the teachers conceptualise PCK.

1.4 Purpose of the study

This study aimed to look at the chemistry teachers' conception on PCK and how they actually carried out their teaching while teaching the topic 3 'Chemical formulae and equations'. The topic was chosen because it contained some of the basic and essential concepts of chemistry such as the mole concept, chemical formulae, chemical equations and stoichiometry as shown in Figure 1.1.

2. Formula and Chemical Equations

This learning area aims to provide an understanding of the concepts and principles related to formula and chemical equation.

The content of this learning area is as follows:

- Relative Atomic Mass and Relative Molecular Mass
- Mole Concept
- Chemical Formula
- Empirical Formula and Molecular Formula
- Balancing Chemical Equation

(Kementerian Pendidikan Malaysia, 2006, p. 12)

Figure 1.1 The content of topic 3 in the curriculum specification of Form Four chemistry

The concepts in topic 3 were difficult to learn and difficult to teach as well (Larson, 1997; Okanlawon, 2010). The concepts would be further discussed in Chapter Two.

1.5 Objectives of the study

In relation to the purpose of the study, the following objectives were proposed:

- (i) to investigate the conceptualisation of PCK of selected Form Four Chemistry teachers on the topic 'Chemical formulae and equations';

- (ii) to investigate how selected Form Four chemistry teachers carry out their teaching processes on the topic ‘Chemical formulae and equations’ .

1.6 Research questions

Based on the objectives of the study two research questions were outlined:

- (1) How do selected Form Four chemistry teachers conceptualize their PCK while teaching the topic ‘Chemical formulae and equations’?
- (2) How do selected Form Four chemistry teachers actually carry out their teaching processes while teaching the topic ‘Chemical formulae and equations’?

1.7 The theoretical framework of the study

The theoretical framework of this study consists of Shulman’s definition of PCK, the PRA model, and constructivist theory.

1.7.1 Pedagogical content knowledge (PCK)

PCK was first proposed by Shulman (1986b, 2015) as a better theory of teaching for policy and ideological claim. Shulman referred PCK as the professional knowledge of teachers developed through their understanding, practices and experiences. It is “the processes that teachers employed when confronted with the challenges of teaching particular subjects to particular learners in specific setting” which is so special and unique like other professionals (Shulman, 2015, pp. 9).

This study looked into the conceptualization of PCK of the chemistry teachers, the conception of the teachers would be compared with the PCK definition proposed by Shulman (research question 1). Shulman’s PCK

definition is fundamental and consists of two constructs: student knowledge and pedagogical knowledge (representations and instructional strategies) with subject matter knowledge as prerequisite requirement which teachers need to comprehend the content knowledge before planning and teaching.

Shulman (1987) claimed that teachers have to know the characteristics of the learners such as background, abilities, and interest of the students. He added that teachers should also possess knowledge of the perceptions, misconceptions and learning difficulties of the learners while learning a specific topic/concept. By knowing the students' difficulties and misconceptions, the teachers could plan, formulate and sequence their teaching according to the characteristics of the students. Besides learning difficulties, Daehler et al. (2015) have refined student knowledge as teachers' understanding on students' thinking and reasoning, however, this study did not intend to look into students' thinking and reasoning.

The pedagogical knowledge refers to teachers' knowledge of teaching 'which goes beyond knowledge of subject per se to the dimension of subject matter for teaching' (Shulman, 1986b, pp. 9). It is the ways of representing and formulating the subject in the forms such as analogies, illustrations, examples, explanations and demonstrations to make it comprehensible to the students. (Daehler et al., 2015; Shulman, 1986b). Daehler et al. (2015) suggested a few ways of measuring teachers' pedagogical knowledge in terms of their abilities in: (a) organising instruction, (b) anticipating, eliciting, interpreting and addressing learning difficulties encountered by their students, and (c) sequencing and representing the content during instruction in a way that promote students' understanding. In this study, the focus would centre on the teachers' planning,

sequencing and representing the content based on the learning difficulties they anticipated of their students.

1.7.2 Pedagogical Reasoning Action Model (PRA)

The second research question looked into how the chemistry teachers actually carried out their teaching processes while teaching the topic 'Chemical formulae and equations'. Teaching processes began at the pre-active phase which involved preparation and planning, the interactive phase takes place during the instruction and post active phase involves processes such as reflection after the teaching session.

Shulman (1987) expressed teaching as 'comprehension and reasoning' and 'transformation and reflection' and he derived the conception of pedagogical reasoning and action 'from the view of the teacher, who is presented with the challenge of taking what he or she already understands and making it ready for instruction' (pp. 14). Subsequently, 'pedagogical reasoning and action consist of a cycle through the activities of comprehension, transformation, instruction, evaluation, and reflection' (pp. 14).

The PRA model of Shulman contains six processes: comprehension, transformation (preparation, selection, adaptation and tailoring to student characteristics), instruction, evaluation, reflection and new comprehension. The starting and the ending of the model is comprehension. The starting comprehension is about the comprehension of the subject content before instruction, whereas the terminus comprehension is new comprehension and insight into the subject content taught, students and the teachers themselves.

The teaching processes of the chemistry teachers obtained from this study would be compared to those processes in the model. The outcome through

the comparison would help the researcher to identify processes the chemistry teachers lacked of. Subsequently, the findings could help to identify aspects or the processes that the teachers need to strengthen in order to develop their PCK. The PRA model was further elaborated in Chapter Two.

1.7.3 The constructivist theory

The constructivist theory highlights the contributions of individuals to what is learned during learning and development (Schunk, 2000). Geary (1995) expressed that the theory held the assumption that learners were active learners and must construct knowledge for themselves. Bruning, Schraw, and Ronning (1995) supported that individuals formed and constructed much of what they learned and understood, in addition, they acquired and refined their knowledge and skills through interaction with the situation.

PCK is developed and constructed by teachers and it could not be found among discipline experts (Shulman, 2015). Clarke and Hollingsworth (1986) claim that PCK development is a constructivist and non-linear process. The new information is built upon prior knowledge from different domains, upon experiences from practice involving interactions with colleagues and students. Teaching is an on-site job, in this notion, learning (to teach) is taken as a process of participating in socio-cultural practices that structure and shape cognitive activity (Lave & Wenger, 1991). Based on this view, teacher knowledge is assumed to reside in the individual and also distributed among people and the environment (Greeno, Collins, & Resnick, 1996).

Besides being constructed and developed by the teachers, PCK seems to possess characteristics such as flexible, personal- and context-bound, action-oriented and tacit, hence the professional knowledge of a teacher has been often

topic, individual and context specific (Cooper & Loughran, 2015). It also develops over time based on teachers' experiences of teaching a topic repeatedly.

PCK is influenced by a few factors such as teaching experience since it is developed through classroom practice (Van Driel et al., 2001); subject matter knowledge, students, pedagogical knowledge, context and beliefs (Magnusson, Krajcik & Borko, 1999). It could be enhanced by special interventions through teacher education and professional development programs (Henze & Van Driel, 2015) (pp. 121). Shunk (2000) suggested constructivism must be evaluated from the process, learners construct knowledge and the factors that may influence that process.

The relationship between the three components in the theoretical framework can be presented as in Figure 1.2.

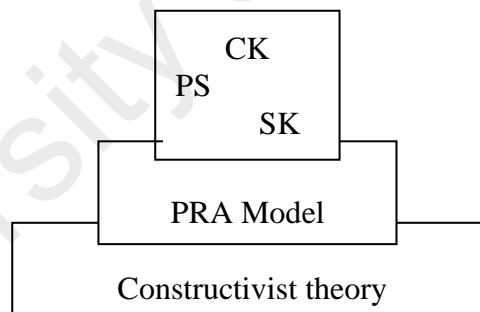


Figure 1.2. The theoretical framework of the study

This study intended to look into the PCK of the teachers from three aspects: content knowledge (CK), pedagogical strategies (PS) and student knowledge (SK) based on the definition of PCK model of Shulman (1986b). The PCK of the teachers were anticipated to grow and develop as they went through the cycle of six processes in the PRA model. On top of that it was anticipated that each teachers possessed his/her own unique PCK which was constructed by

themselves. Therefore the construction of the PCK of the teachers was sitting on the constructivist theory as in Figure 1.2.

Based on the theoretical framework and also the complexity PCK and how teachers constructed their PCK, it was deemed suitable to use various techniques to collect data such as classroom observations, interviews, field notes taking and documentation. The classroom observations enabled the researcher to look at the actualisation of the PCK of the teachers and interviews helped to explore the teachers' conception of PCK. The documentation on the other hand provided another rich source of data and evidence. The data collected from the various sources were used to triangulate with each other.

1.8 Conceptual framework

There was a gap between the abstract chemistry subject matter knowledge and students' mental capability as one-third of the upper secondary level students were still at their late-concrete stage of mental ability (Chan, 1988). In order to bridge the gap, chemistry teachers need to teach the subject matter knowledge in a way understood by the students. Thus, they need to possess a good PCK. Figure 1.3 shows the conceptual framework of this study.

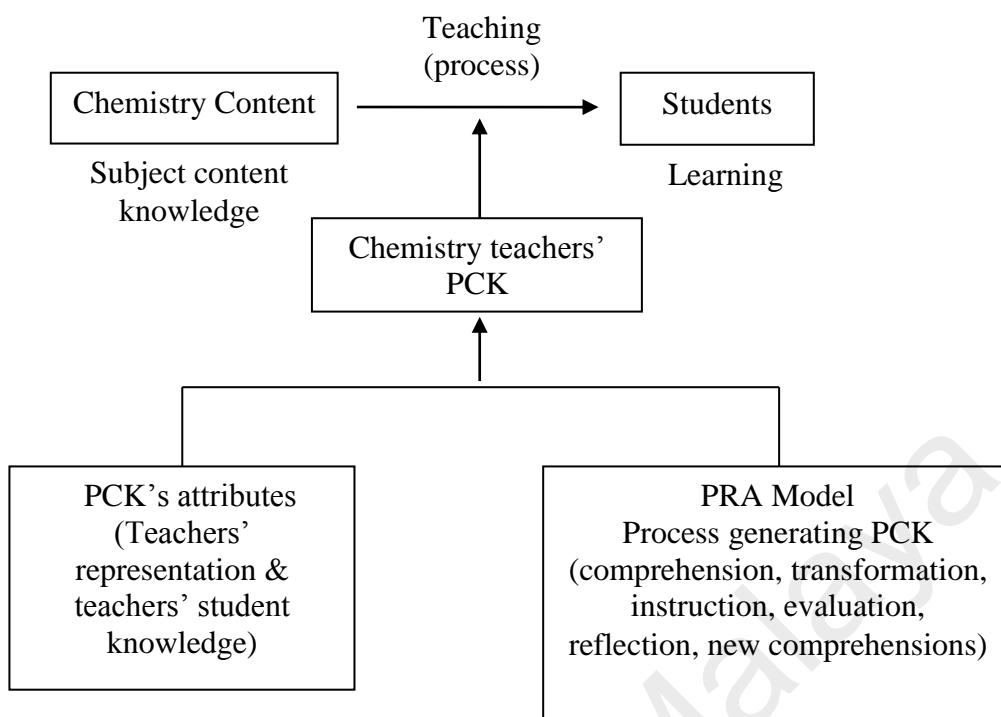


Figure 1.3 Conceptual Framework of the Study

Shulman (1987) stressed that, ‘to teach is first to understand’ (p. 14), teachers need to understand the subject matter knowledge first before they can teach effectively. Upon understanding the subject matter knowledge they transform their understanding into a form which is teachable to the students. In other words, they transform what they have understood of the content in the form of representations to help the students to do the same. The representation can take the forms of examples, demonstrations, explanations, and others, to present the subject matter knowledge. However, it is insufficient to have a strong subject matter knowledge alone in order to teach effectively, a teacher also needs to understand his/her students well or possess ‘student knowledge’. This student knowledge includes aspects like students’ background, interest, learning styles, preconceptions, misconceptions, learning difficulties and others. A teacher who understands his/her students well will be able to adapt his/her teaching to suit the characteristics of the students.

This study studies PCK from two aspects – the chemistry teachers' conceptualization of PCK and how they actually carried out their teaching based on their conceptualization. The teaching process or the teaching activities of the chemistry teachers studied would reveal their skilfulness, resourcefulness, and weaknesses in terms of PCK displayed. The PCK is also studied through two lenses based on Shulman's definition: first, from the perspective of PCK attributes; second, from the perspective of the processes generating PCK as in the PRA Model (1987).

According to Shulman, PCK consists of two key components: teachers' representation of the content knowledge and teachers' student knowledge. He advanced six processes which generate the PCK of a teacher and he named it the PRA Model. The model covered activities of the chemistry teachers at the pre-active, interactive and post-active phases of teaching (Jackson as cited in Clark & Peterson, 1986, p. 258). It consists of a complete cycle of the teaching episode right from preparation to post teaching reflection and new comprehension.

The comprehension and transformation are processes in the pre-active phase of teaching. Transformation is further broken into four processes: preparation, representation, selection of instructional techniques, and adapting the representation and tailoring this adaptation to suit the characteristics of the learners. This act of shifting from 'personal comprehension to preparing for the comprehension of others' is the essence of 'pedagogical reasoning' thus the saying 'teaching as thinking and planning' (Shulman, 1987; p. 16).

The main processes in the interactive phase are instruction and evaluation. The instruction process involves a whole range of activities taking place in the classroom which includes classroom management, delivery of content, interaction with students and assessing students' understanding. Besides assessing students' understanding during teaching (interactive phase), teachers also assess students at the completion of a topic

(formative evaluation) or at the end of a program (summative evaluation). The common methods used by teachers to assess students' understanding were questions (oral and written), quizzes, tests, written work (exercise and homework) and others. Summative assessment is often in the form of pencil and paper tests, and the types of questions are the multiple choice question, structure, and essay questions.

Reflective teachers looked back on the lesson just implemented (Shulman, 1987). Through self-evaluation, they got to know the strengths and weaknesses of a lesson thus gain the insights into the subject content, teaching, student, and self. These insights help to bring about the future improvement in their teaching of the same content.

The processes in the PRA Model are not necessarily compartmentalized and sequential. Some processes might happen at different phases of teaching. For instance, a reflection could happen at pre-active, interactive and post-active phases of teaching as teachers might reflect-in-action and reflect-on-action.

Some processes could occur simultaneously like the four sub-processes in the transformation process, that is preparation, selection, representation and adaptation and tailoring to student characteristics tend to integrate with each other and happen simultaneously. It is the interaction of these processes with each other that leads to the development and generation of a teacher's PCK (Shulman, 1987). The processes are dynamic as they undergo continual development and integration. Figure 1.4 shows the processes in the Pedagogical Reasoning and Action Model of Shulman (1987).

A Model of Pedagogical Reasoning and Action

- (1) Comprehension: Of purpose, subject matter structures, ideas within and outside the discipline
- (2) Transformation:
 - (i) Preparation: Critical interpretation and analysis of texts, structuring and segmenting, development of a curricular repertoire, and clarification of purposes
 - (ii) Representation: Use of a representational repertoire which includes analogies, metaphors, examples, demonstrations, explanations, and so forth
 - (iii) Selection: Choice from among an instructional repertoire which includes modes of teaching, organizing, managing, and arranging
 - (iv) Adaptation and tailoring to student characteristics:
Consideration of conceptions, misconceptions, and difficulties, language, culture, and motivations, social class, gender, age, ability, aptitude, interests, self concepts, and attention
- (3) Instruction: Management, presentations, interactions, group work, discipline, humor, questioning, and other aspects of active teaching, discovery or inquiry instruction, and the observable forms of classroom teaching
- (4) Evaluation: Checking for student understanding during interactive teaching
Testing student understanding at the end of lessons or units
Evaluating one's own performance, and adjusting for experiences
- (5) Reflection: Reviewing, reconstructing, re-enacting and critically analyzing one's own and the class's performance, and grounding explanations in evidence
- (6) New Comprehension:
Of purposes, subject matter, students, teaching, and self.
Consolidation of new understandings, and leanings from experience

Source: Shulman (1987, p. 15)

Figure 1.4 A Model of Pedagogical Reasoning and Action (PRA Model)

The intended outcome of teaching is students' learning with understanding. According to Perkins (1998), most teachers put in endless efforts to equip students with a good repertoire of knowledge, well-developed skills, and an understanding of the meaning, significance, and use of what they have studied (p. 39). Perkins further

explains the meaning of understanding is ‘the ability to think and act flexibly with what one knows’ (p. 40). While evaluating students, teachers may recognise students’ understanding from their ability in giving explanations, justifications, extrapolations, making relations, and application of the knowledge studied in a new situation.

To sum up, the researcher would study Form Four Chemistry teachers’ PCK based on the attributes in PCK and the processes generating PCK in the PRA model proposed by Shulman.

1.9 Definition of terms

The key terms used in this study are most appropriate for the content of this study only. These are as follows:

(i) Pedagogical content knowledge (PCK)

PCK is one of the knowledge bases of teaching, a special amalgam of content and pedagogy that is uniquely the province of teachers and is defined as the professional knowledge of teaching (Shulman, 1986b, 1987). The PCK in this study refers to the initial definition of Shulman, which consists of two constructs: teachers’ student knowledge and representations used in the instruction while teaching the topic ‘Chemical formulae and equations’ with subject matter knowledge as the pre-requisite requirement. PCK is dynamic, it grows and develops with experience. The attributes of PCK may not develop equally, but as it became more developed, the attributes became less distinctive. An effective teacher is said to have good PCK.

(ii) Knowledge base

The knowledge base in this study refers to the body of understanding; knowledge, skills, and dispositions that a teacher needs to perform effectively in a given teaching situation. In order to teach effectively, a teacher needs to possess seven knowledge bases, namely subject matter knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners and their characteristics, knowledge of educational context and knowledge of educational ends, purposes, and values; and their philosophical and historical grounds.

(iii) Teaching process

The teaching process in this study refers to the steps taken by the Chemistry teachers while teaching a new concept. The steps are preparation, presentation, application and review and evaluation. It encompasses processes at the pre-active, interactive and post-active phases of teaching.

(iv) Form Four science students

In Malaysia, Form Four and Form Five refer to the upper secondary level in the secondary education. Students sat for the Lower Secondary Assessment (*Penilaian Menengah Rendah, PMR*) at Form Three before they could go to Form Four. The enrolment of the students into the Science or Arts stream at Form Four was based on their PMR results. A minimum of grade C in the Science and Mathematics subjects was one of the criteria. The PMR examination is replaced by the Form Three Assessment (*Pentaksiran Tingkatan Tiga, PT3*) in 2014.

(iv) **Chemistry teacher**

A chemistry teacher in this study refers to a teacher teaching Form Four Chemistry.

(v) ***Bahasa Melayu***

It means Malay language. It is the national language of Malaysia and is used nationwide as the medium of instruction in the national types of primary and secondary schools.

(vi) **Student knowledge**

Teachers' knowledge on their students such as students' background, interest, learning styles, preconceptions, misconceptions, learning difficulties and others.

(vii) **Postgraduate Diploma of Teaching Program or *Kursus Perguruan Lulusan Ijazah (KPLI)* for Secondary School**

A one-year teacher training program offered by the teacher training institute to postgraduate students after they had secured a basic degree or higher qualification in certain disciplines.

(viii) **Algorithmic approach**

Algorithmic approach is a mechanized habit or a response to a problem rather than a way of reasoning through the multiple knowledge levels required by a problem (Okanlawon, 2010b). Mechanistic learning has been shown to block reflective competence on the part of the students.

(ix) Active learning

Active learning is defined as anything in the classroom that involves students doing things and thinking about the things they are doing (Okanlawon, 2010b). Students participate actively during the lessons.

1.10 Significance of the study

The findings from this study could be useful for training purposes. It could be applied in the teacher education program and the professional developments of the pre-service and in-service chemistry teachers respectively. It could help to improve their teaching, especially on the topic 'Chemical formulae and equations'. The findings on the successful topic-specific PCK could be compiled as individual cases and shared among chemistry teachers.

The findings from this study could provide a guideline and criteria in selecting the supervising teachers to supervise the teacher trainees during their practicum. A competent supervising teacher made a great impact on the career development of the novice teachers during teaching practice (Berliner, 1987). The findings also gave teacher educators a better understanding of the problems encountered by novice teachers. By incorporating practical examples related to the real classroom environment, it ensured a better link between the theory and practice.

For the policy makers, the findings could give some suggestions in refining and revising of the teacher training curriculum so that equal weightage would be placed on pedagogical skills or instructional skills and content knowledge. The introduction of PCK in the teacher training program hopefully could better prepare pre-service teachers and hence ensure a smoother transition from a novice teacher into a competent one. The findings from this study might highlight the importance of the inclusion of PCK as one

of the criteria assessing the competency of teachers' in public examination and yearly appraisal.

The study also brought benefits to the participants as they tended to do a lot of reflection on their practice. This study gave them an opportunity to revisit the relationship between teaching and learning, their perceptions on teaching and learning, more importantly, this study provided a platform for the participants to get their voices heard.

Above all, this study gave the researcher an opportunity to explore and understand what actually is teaching, what are needed in teaching and how one acquires the knowledge and skills of teaching. A better understanding about teaching would definitely help the researcher to become a better teacher educator in the teacher education institute.

Finally the findings from the study would contribute to the empirical literature of PCK particularly of specific domain that is chemistry and on the topic 'Chemical formulae and equations'. The research findings would expand the PCK literature on the teaching of chemistry in the Malaysian context.

1.11 Limitations of the study

A researcher uses his/her own set of concepts and principles to study a phenomenon in a particular context through specific questions thus setting the limitation of a research (Shulman, 1986a). As teaching is a complex activity, what a research may reveal is only a small portion of a large picture and may not be able to address the real complexity of teaching. Nevertheless, studies on various contexts may contribute to the continual growth of bodies of knowledge on teaching.

This study was confined to selected Form Four chemistry teachers thus the small sample size of the purposeful sampling would not favour generalizing the findings

obtained. Additionally, the context of the four chemistry teachers might be different from those teaching in other parts of Malaysia. However, the findings on the successful topic-specific PCK of the chemistry teachers might be documented as cases and used as teaching resources for pre-service training and in-service teacher professional development.

1.12 Summary of the chapter

This chapter began by introducing the 60:40 Policy implemented by the Malaysian education ministry to produce a pool of manpower who will further their studies in STEM related fields when they completed their secondary education. The enrolment of the science stream students in Form Four is still below the target since its implementation in 1967. Almost half of the candidates sitting for the chemistry subject at SPM attained a minimal pass which most probably would prevent them from furthering their studies and also engaging in STEM-related careers. The chapter continues to describe the important role of chemistry teachers in equipping their students with a strong foundation in chemistry. The abstractness of chemistry versus the incompatibility of the cognitive ability of students required chemistry teachers to have good PCK. In order to identify the pedagogical aspects which might be lacking among the chemistry teachers, it was high time to look into their teaching processes. With that, this study focused on PCK, the professional teaching knowledge of teachers instead of pedagogy; then classroom observations were used as one of the data collection methods besides interview, field notes, and documents. The chapter then outlined the purpose, objectives, and research questions. Finally, the limitation and the significance of the study were expressed. In the following chapter, the literature review on science education, chemistry education, teacher education, PCK, chemistry PCK, and the conceptual framework of the research were presented.

Chapter 2

Literature Review

2.1 Introduction

In Chapter One, the background, purpose, problem statements, objectives and research questions of the study were outlined and supported by the theoretical and conceptual framework, significance and the limitations of the study. A literature review of the various key themes in the teaching of chemistry and PCK is presented in this chapter.

2.2 Teacher

According to Dillon and Maguire (2001) teachers are in an extremely privileged position in the community because they are educating other people's children, a critical and influential task in any society (p. 4). The science community assigns some metaphors to describe teachers: they are seen as broadcaster, gardener, entertainer and tour guide. Basically, teachers are seen as a source of knowledge, a guide and a caring person. With the gradual progression of teaching as a profession, the role of teachers has also changed, from that of "trained instructors" to "educated professionals"; from "dispensers of information and skills" to "facilitator of knowledge, attitudes, values and skills" (Holly, 1989, p. 102), and also as "a mediator of learning" for students with preconceptions (Tobin, Tippins, & Gallard, 1994; p. 49). In the Malaysian context, though the trend is shifting from the traditional role to that of the constructivist teacher (Lee, 2002), it is generally observed that our teachers still maintained the traditional role of "expert technician" (Schon, 1983) and "transmitters" (Holly, 1989), feeding students with a predetermined curriculum in a measured dose while trying to attain education goals.

Having to deal with different students in the classroom makes teaching a complicated job. Currently, education reformers are looking at education from a different view. In the past, they asked why the students cannot read, now they ask why the student's teacher cannot or would not teach (McLaughlin, Pfeifer, Swanson-Owens & Yee, 1986). Teachers often claim that they are teaching without realizing learning, in fact, does not take place, it is because many of them tend to overestimate the amount of learning students gain from their teaching (Clements, 2004). According to Clements (2004), mathematics teachers with a strong mathematics subject knowledge background often set a high cognitive target for their students yet they fail to provide equivalent opportunities for the students to realize the target. Instead, they tend to use low-order thinking questions to guide students to the desired answers. Consequently, students are denied the opportunity of formulating and applying their own ideas and strategies. Similarly, findings from chemical education research also shows that "what is taught is not always what is learned" (Johnstone, 1999, p. 45). From the views of PCK, though these teachers possess a strong grasp of their content, they seem to be ignorant about their students' learning problems, in other word, they lack one of the key components of Shulman's (1987) PCK conception – student knowledge. According to Shulman (1987) student knowledge is extremely important for teachers to do successful teaching regardless of the subject domains.

The vital role of teachers is to create and provide learning opportunities to students in the classroom. The generation of these learning opportunities depends very much on what teachers think, believe, feel, assume and do in the classroom (Dillon & Maguire, 2001). Teachers' personal belief, values and past experience influence their teaching styles (Barnett & Hodson, 2001).

UNESCO (2003) uses “what, how and how much people learn” as a criteria to evaluate whether a nation’s education is good or bad and certainly teachers are very much responsible for it (p. 96). In Malaysia, the chemistry curriculum is predetermined by the Ministry of Education. As practitioners, teachers have little say in the curriculum which is designed and prepared by the Curriculum Development Centre (CDC). The greatest professional challenge of the teachers is to make students learn what they are supposed to learn, helping them make sense of what they learn through making connections and applying of the knowledge (Holly, 1989). On the other hand, teachers need to put in great effort to understand the curriculum too. Many teachers, in fact face difficulties in understanding, interpreting and teaching the curriculum (Fensham, 2002). It is because the curriculum was developed by distant experts whose views were normally different from that of the practitioner (Barnett & Hodson, 2001). Studies show that even the exemplary biology, chemistry, and physics teachers who were involved in the preparation of the revised secondary science curriculum in biology, chemistry and physics, respectively, had different interpretations of thoughtful learning in their classroom practices (Ng, 2004).

Teachers play a very crucial role in bringing change to the schools and the success of a school depends very much on them. They are seen as “the ultimate key to educational change and school improvement” (Dillon & Maguire, 2001, p. 7). Important changes in the schools will not happen unless the teachers change; it is their behaviour in the classrooms that finally determined whether a schools meet or fail to meet the challenge of our time (Combs, 1965). In fact, “it is teachers who in the end, will change the world of the school by understanding it” (Stenhouse, 1975, p. 208).

Currently, in order to produce a more knowledgeable future generation, more subjects are offered in the schools. Hence, students have to study more subjects, the

curriculum is getting more crowded, the teachers are teaching more and faster, yet they are less satisfied with their teaching and students' learning (Elkind, 1981). Teachers are comparatively more highly educated and experienced than ever before. Teacher education programs are producing teachers with higher qualifications, unfortunately, they still fail to uplift the image of teacher as they are frequently "criticized publicly and praise is unusual" (Holly, 1989, p. 110). It is inadequate to improve the technical expertise of teachers to help them cope with their teaching and uplift their traditional image (Maguire & Dillon, 2001; Holly, 1989). Dillon and Maguire (2001) found out that how teachers perform is not because they have or have not learned certain skills. In fact, their commitment, enthusiasm and morale are influenced by their backgrounds, biographies, hopes and dreams, opportunities, aspirations and frustrations.

Some teachers lack technical language (Lortie, 1975) and are unarticulated; they cannot even tell how they know their students understand what is taught (Parkay & Standford, 1995). It is because teachers have few opportunities to reflect on what they do in the class and a large portion of their knowledge is implicit in nature (Mulhall, Berry, & Loughran, 2003). In order to avoid remaining a technician who only transmits knowledge, teachers have to be continuous learners, to be teachers who practice lifelong learning (Shulman, 1986b; 1987) and should keep on asking themselves "Am I teaching a subject or am I teaching students?" (Gunter, Estes, & Schwab, 1999, p. 14).

Basically, a good teacher has the ability to adjust his/her teaching according to context, taking factors like students, subject matter, facilities, emotional climate and others into consideration and ensuring their students feel comfortable to learn (Barnett & Hodson, 2001). To Finlayson, Lock, Soares and Tebbutt (1998), a good science teacher needs to have good competency, classroom management and a strong background knowledge of the subject. Studies show that teachers who lack content knowledge face

difficulties and do not have confidence in their teaching (Finlayson & et al., 1998; Hashweh, 1987), therefore, it is important for teachers to possess a thorough understanding of the subject areas they are teaching.

In conclusion, as an influential figure and a role model of many students, teachers are the ultimate key to educational change in the development of a school. Besides having the ultimate responsibility in providing learning opportunities to the students, other demands and expectations on teachers are ever increasing. These demands and expectations cannot be fulfilled by the continual technical enrichment and professional development. A teacher's performance is very much influenced by the implicit factors of motivation, beliefs and others. To conclude, a teacher's performance in the classroom is determined by many factors, both implicit and explicit, some of which were encountered during pre-service and many during in-service. Teachers are encouraged to practise lifelong learning in order to improve teaching.

2.3 Chemistry curriculum

Curriculum refers to “a list of courses and topics to be taught, often with instruction recommendations” (Anderson & Mitchener, 1994, p. 12), or “an overall framework for an instructional program” (Armstrong, Henson, & Savage, 2005, p. 4). Malaysia practises a centralized education system whereby the subject curriculum is designed by the Curriculum Development Centre (CDC) with the help of a panel consisting of the CDC officers, exemplary teachers, experienced teachers of the subject area, university lecturers and teacher educators from the teacher education institutes. The SPM Chemistry curriculum is disseminated in the form of a syllabus (*Kementerian Pendidikan Malaysia*, 2006) (Figure 1.1) and curriculum specifications (Appendix A) (*Kementerian Pendidikan Malaysia*, 2005). The syllabus outlines the curriculum

purposes, objectives, curriculum organization, scientific skills, thinking skills, scientific attitudes, noble values and the structure of the content knowledge. The syllabus is supplemented with the curriculum specifications which contains National Philosophy, National Philosophy of Education, and National Science Education Philosophy. Similar to the syllabus, it also outlines the learning objectives, suggested activities, learning outcomes, and new vocabulary in English with its Malay translation (This study was done during the time when chemistry was taught in English). Other curriculum materials such as textbook, modules, and information technology (IT) courseware are also provided to the schools. The aim of the Malaysian chemistry curriculum is to produce active learners with chemical knowledge and skills in the chemical field, who are capable of applying their knowledge and skills in making decisions and solving problems based on scientific attitudes in their daily life. A professional teacher is expected to be familiar with the curriculum material of the subject that he/she is teaching and also the curriculum materials that his/her students are studying in other subjects (Shulman, 1986b).

2.4 Teaching

Shulman (1987) highlighted two major recurring themes in education reform reports in the United States about three decades ago: firstly, the professionalization of teaching and secondly, teaching deserves a professional status. These reports proposed that teaching should be elevated to “a more respected, more responsible, more rewarding and better rewarded occupation” (p. 3). In order to achieve the proposed status, Shulman (1987) argues that it is necessary to raise and articulate clearly the education and performance standards of teachers, and teachers shall be regarded as professionals just like doctors, lawyers, engineers and other professionals. The urgency had brought about

the searching of a missing paradigm in the research on teaching and teacher knowledge (Shulman, 1986a, 1986b, 1987).

Many scholars describe teaching as a complex activity (Barnett & Hodson, 2001; Calderhead, 1987, 1988; Calderhead & Shorrock, 1997; Dunkin & Biddle, 1974; Holly, 1989; Mulhall, et al., 2003; Newton, 2000; Parkay & Standford, 1995; Shulman, 1986a, 1986b, 1987; Smith & Neale, 1989; Sockett, 1987; Tigchelaar & Korthagen, 2004). Others descriptions seem to reveal the unique characteristics of teaching and delineate its complexities. Teaching is a highly stressful activity for both novice and experienced teachers due to its uncertainties (Barnett & Hodson, 2001), an universal activity (Duke, 1990), problematic (Borich, 1995; Loughran & Berry, 2005), exciting yet demanding (Parkay & Standford, 1995), a lonely and insulated profession (Locks-Horsley, Stiles & Hewson, 1996; Schon, 1983;), the most difficult job in the world because “learning is the most complex phenomenon on the planet” (Stones, 1994, p.312), a rewarding occupation, yet tantalizing and challenging (Maguire & Dillon, 2001), its implementation often deviates from the initial planning (Loughran & Berry, 2005), an activity involving teachers and students working jointly (Shulman, 1986a, p.7), and most important of all, it provides opportunities for students to learn (Brown & Atkins, 1988). In brief, it is hard to define teaching due to its many facets and complexity (Shulman, 1987). It is not easy to learn how to teach due to its complexities subsequently it is not easy to become a professional teacher (Parkay & Standford, 1995).

Teaching is complex because it uses and integrates various types of knowledge simultaneously (Shulman, 1986b; Smith & Neale, 1989). Shulman (1987) proposes teachers need to have seven knowledge bases to teach effectively and successfully. The seven knowledge bases are: content knowledge, general pedagogical knowledge, curriculum knowledge, PCK, knowledge of learners and their characteristics, knowledge

of educational contexts, and knowledge of educational ends, purposes, and values. On the other hand, Smith and Neale (1989) state teachers need to know the subject matter, content knowledge, instructional strategies knowledge and student knowledge in order to teach.

Apart from integrating the knowledge bases, teachers need to integrate these knowledge bases with their actions in a multiple way while teaching (Duncan, 1998). In other words, they perform multitasking. During teaching, they have to attend to their students who are unique, varied and unpredictable individuals (Sockett, 1987), then they have to respond to the environmental distractions, diagnosing students' learning difficulties and spotting their misconceptions, monitoring their progress and making necessary adjustment, plus many other routine or non-routine works and duties (Armstrong, Henson, & Savage, 2005, p. 9).

A school is organized by problems such as “discipline problems, curriculum problems, resource problems, parent and family problems” (Borich, 1995, p. 33). While trying to cope with these problems, teachers have to “think on their feet” in order to make many complex and quick decisions while giving an immediate response in their hectic and fast-paced classroom (Barnett & Hodson, 2001; Borich, 1995; Clark & Peterson, 1986; Tigchelaar & Korthagen, 2004; Wilson, et al., 1987). A teacher in fact makes a decision every two minutes during class time whereby many of the decisions were made on an unconscious basis, “new” and require immediate contextual judgement (Clark & Peterson, 1986; Schon, 1983; Yinger, 1986). Many teachers do not know why and how the decisions were made because teaching has become their second nature and “is like breathing” to them (Holly, 1989). She further claims that although teachers may be unaware of their actions and decision at the point of engaging them, their

behaviour is purposeful and reasonable, and this has contributed to the complexity of teaching.

Teachers work in isolation. In the process of preparing to teach, teachers have to figure out how to teach by interpreting, communicating within themselves about puzzles and insights, making adjustment of the curriculum to suit the students and finally, having to test the ideas in the classroom all by themselves (Brandt, 1992; Dillon & Maguire, 2001; Holly, 1989; Schon, 1983; Shulman, 1986b). Teaching is unpredictable and contextualized as every class is a unique community on its own wherein both teacher and students having their personal preferences in teaching and learning respectively (Barnett & Hodson, 2001). More often than not, teachers have to make adjustments and changes in their planning in order to meet different students' needs and preferences. As a result, the implementation of the actual teaching often differs from the actual planning.

Many parties, both outside and within teacher education see teaching merely as a delivery of curriculum. They assume teaching is a simple skill which is equal to telling. This "dangerous view" has oversimplified the teaching process (Stones, 1994). It is difficult to define what constitutes good teaching and "no one method of teaching is superior" (Holly, 1989, p. 103).

Teaching can be generally categorised into three task domains, namely pre-active, interactive (Jackson, 1968, cited in Clark & Peterson, 1986, p. 258) and post-active (Clark & Peterson, 1986), the three domains may occur simultaneously or sequentially indicating the dynamic nature of teaching (Reynolds, 1992). Although "the centre of teaching and learning is the interaction between the teacher and the learner" (Eble, 1976, p. xi), the pre-active and post-active domains contribute to the success and the smooth running of the interactive domain, that is the teaching itself.

The pre-active task is related mainly to the preparation done before the actual teaching episode whereby teachers comprehend, critique, adapt and plan content, materials and choosing the teaching methods (Reynolds, 1992; Shulman, 1987). During the interactive phase, teachers implement what they have planned to make necessary adjustment of time and materials; at the same time, they also evaluate students' understanding on what is taught. Reflection is the main task in the post-active phase of teaching domain, here, teachers reflect on the lesson and also the response of the students with the aim to improve future teaching.

Shulman (1986a) believes “teachers learn and the learners teach” (p. 7), suggesting teaching and learning can happen in both directions between the teachers and students. Teachers teach and at the same time they can learn from their students to implying the teaching-learning is a dynamic process. By continuing learning to teach in the real classroom setting, teachers continue to expand their teaching repertoire with on-the-job experience.

Although many people regard “more means better” and “results means everything”, the cost of chasing for “high scores” and quantity is a lack of understanding in learners (Newton, 2000, p. 1). Students learn either by rote learning or by understanding, in fact, they can be trained to give acceptable answers without understanding (Herron & Nurrenbern, 1999). Priority should be given to learning by understanding as it has more potential than memorization, it is “more sure, more durable, and more valuable for the learner” as it requires learners to make the connection of isolated pieces of knowledge, to think with flexibility and to solve problems (Newton, 2000, p. 4). Hence, students' understanding about what they have learned may serve as an indicator for the quality of learning and teaching. To Gunter et al. (1999), a successful learning outcome is one where learners can make connections between the new and old

knowledge, thus teachers can assess students' understanding through asking questions or providing opportunities for the students to explain what they understood.

The knowledge base is “the secret of an expert system’s expertise, the body of understanding, knowledge, skills, and dispositions that a teacher needs to perform effectively in a given teaching situation” (Wilson et al., 1987, p. 106). Basically, scholars believe that teachers need to possess some minimal knowledge bases in order to teach well. Although different scholars proposed different types of knowledge bases they do agree on some fundamental knowledge bases such as subject matter and pedagogy. Shulman (1987) has identified teachers need seven knowledge bases in order to teach successfully. His model had undergone some modifications (Shulman, 1986b, 1987). The seven knowledge bases are content knowledge, general pedagogical knowledge, curriculum knowledge, PCK, knowledge of learners and their characteristics, knowledge of educational context and knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. Earlier knowledge base model emphasised on knowledge of self apart from knowledge of the milieu of teaching, curriculum, pedagogy and subject matter. Grossman on the other hand thought that it is necessary to possess four knowledge bases for teaching that is pedagogy, PCK, school contexts and subject matter. Barnett and Hodson (2001) advance that exemplary teachers use four kinds of knowledge in their teaching, namely: (1) academic and research knowledge; (2) PCK; (3) professional knowledge; and (4) classroom knowledge (p. 426).

As an individual teacher has his/her own repertoire of teacher knowledge, it is common to see that some teachers are successful and some are less successful in engaging similar strategies in their classroom for the same curriculum (Barnett & Hodson, 2001). Teachers teach the same thing in different ways and are different from other teachers. It

was reported that teachers build up this collective teacher knowledge through talking to each other within the community of teachers and also through experience.

To sum up, although many researchers had prescribed certain descriptions to teaching, yet each description can give only a glimpse of the whole picture of teaching. The most appropriate and most frequently used or the best fit definition of teaching seems to be “teaching is a complex activity”. It is complex because it requires various types of knowledge, skills and it deals with the students of different characteristics. The diversity and the dynamics of students make the classroom an unpredictable place. What is challenging is that teaching is not identical to learning. It is difficult to define good teaching, basically, teachers need to have a thorough understanding of the subject matter knowledge, students’ learning difficulties, and pedagogical skills to teach in accordance with the guideline of the curriculum goals. Teaching has the features of multidimensionality, simultaneity, immediacy and unpredictability (Armstrong & et al., 2005, p. 9), therefore it is not easy to learn how to teach and be a professional teacher.

2.5 The teaching of chemistry

Secondary school students tend to show negative attitudes toward chemistry and the enrolment in the chemistry course in the tertiary level is on the decline (Clee & Reed, 1993; de Jong, 2000; Johnstone, 2000). It is commonly observed that students could recite formulae and enjoyed doing their laboratory sessions, but they did not understand what was going on. Similarly, it was noted that university students failed to connect practical work with chemical theories. The reasons may be due to overcrowding, vague and out-dated chemistry curriculum and also little correlation between secondary and tertiary chemistry curriculum (de Jong, 2000). Additionally, most countries are facing problem in

seeking qualified and competent chemistry teachers to teach Chemistry (Johnstone, 2000).

Chemistry is a subject consisting of abstract concepts, principles and ideas (Cantu & Herron, 1978; Lawson & Renner, 1975) and many of the chemical concepts exist in both macroscopic and microscopic levels. Johnstone (2000) outlines three forms in the nature of chemistry: (1) the macro and tangible: what can be seen, touched and smelt; (2) the submacro: atoms, molecules, ions and structures; and (3) the representational: symbols, formulae, equations, molarity, mathematical manipulation and graphs (p. 35). Many students face difficulty “in connecting macroscopic chemical events with hypothesized changes taking place at the atomic level and the symbolic representations (formulas, equations, symbols) used to describe those events” (Herron & Nurrenbern, 1999, p. 1358). The simultaneous introduction of the three levels is overloading and difficult for students (Fensham, 2002; Johnstone, 2000).

Based on the information processing model of teaching chemistry proposed by Johnstone (2000), the function of the working memory is either to process or hold information. Both functions compete for the limited space in the working memory. The students are novice learners of chemistry with little or no existing knowledge of the concept presented. If there is too much information to hold at one time, students may choose to bend in order to store it in the long term memory, this “bending” process leads to misconceptions and rote learning (Taber, 1997).

Other factors which may influence the learning of chemistry are the students’ level of mental development (as mentioned in Chapter one), misconceptions they brought to the classrooms and language used by teachers in the classrooms. Goh and Chia (1993) report the choice of terms used in the questions influences how students respond. It was observed that the use of macroscopic terms tends to make students respond to everyday

language and the use of scientific language encourages students to respond using microscopic terms. Thus, teachers have to be aware of the words used in their questions (written and oral) since inappropriateness in the choice of the language used might cause misconceptions among the students. There is evidence showing that the teacher's choice of words in explanations can confuse students (de Jong, 2000; Johnstone & Selepeng, 2001).

The main focus in chemistry education research is understanding and improving Chemistry learning (Herron & Nurrenbern, 1999). Fensham (2002) lists five problem areas which are prevalent in the teaching and learning of chemistry: (a) students' misconceptions; (b) students' spatial recognition and visualisation; (c) problem solving in chemistry; (d) modes of instruction and sequence of instructions; and (e) chemistry as problematic knowledge (p. 336). Herron and Nurrenbern (1999) also identified a few issues which are related to the knowledge of students' learning difficulties and instructional strategies which have been drawing attention from chemistry education researchers in the past as well as current. The issues are:

1. What is there about ideas such as temperature and milliliter that make them easier to grasp than ideas such as mole, entropy, and carboxylic functional group?
2. Can we predict those ideas that will be difficult to understand?
3. Can we modify instruction to make difficult ideas more accessible?
4. Is it better for students to work individually or in groups?
5. Should materials be presented via lecture, reading, or direct experience?
6. How should ideas be sequenced to promote maximum learning?
7. What examples and non-examples should be used to illustrate ideas?
8. How (and how often) should ideas be illustrated?

9. How much time is necessary to understand or grasp a concept?

(Herron & Nurrenbern, 1999, p. 1354)

Briefly, the questions were related to three domains consisted of subject matter knowledge (question 1); student knowledge and their learning difficulties (questions 2 and 9); instructional strategies and representation of content (questions 3, 4, 6, 7 and 8). These issues also fit into the main foci in the chemical education studies that is: (1) what chemistry content is taught; (2) how the chemistry content is taught; and (3) the learning of chemistry (Fensham, 2002). A shift from the behaviourist theory to constructivist theory is noted by Herron and Nurrenbern (1999) which had given a significant impact on chemical education research. Herron and Nurrenbern comment that behaviourists tend to narrow things down by identifying variables which will ensure performance improvement, and have a belief about the existence of knowledge “out there” and teachers are responsible to transfer the knowledge into students’ heads which are taken as “empty vessels” (p. 1354). Constructivists on the other hand try to broaden the view of learning; they regard students as active learners who are capable of actively constructing their own knowledge based on what they had already known. With the growing interest in getting insights into what is happening in the students’ heads, the direction of the chemical education research has moved into that of obtaining information about learning which encompasses the information-processing theory. Hence Herron & Nurrenbern (1999) highlight that the chemical education researchers need to have a good foundation in cognitive science in order to conduct both qualitative and quantitative research and to collect data from various sources. They claimed that researchers need to ensure they can communicate their research findings in a language understood and practised by the chemistry teachers to bring about effective changes in teaching and learning. As a result,

qualitative research, longitudinal studies, action research and ethnographic techniques become dominant in chemical education research, bringing about a wider scope of knowledge revealing new aspects of teaching and learning.

Although research has added knowledge to chemical education, it does not have much impact on the teaching of chemistry teachers as most of the findings have not been translated to the classroom and little is being practised by them (Bucat, 2004; de Jong, 2000; Fensham, 2002; Kempa, 2002). The big gap between theories and findings from research and the practitioners, the chemistry teachers, is probably due to the inaccessibility of these research findings from the teachers or if accessible, the knowledge is not useful.

Teachers continue with their old practices and their problems in teaching and learning remain unsolved, and prolonged. They continue with their frustration with the low understanding of students about chemical concepts which they fail to overcome by repeating explanations and demonstrations, and in fact, teachers and students seem to reason and operate in different contexts (de Jong, 2000). Bucat (2004) suggests it is high time to turn the direction of chemical educational research on PCK, “a knowledge about teaching and learning” (p. 215) and also subject matter knowledge which he believes will give a more productive and practical path for future chemistry research. In addition, researchers need to capture and record strategies of the competent teachers to be exposed later to the new teachers to hasten their pace in becoming competent teachers.

Johnstone (2000) proposes two models for the teaching of chemistry, the information processing model and the model of the nature of chemistry. He further argues that learning will be more effective if the teacher “begins where the students are” (p. 36) and teachers get to avoid overloading the students due to their eagerness to share their love of Chemistry with the students.

To wrap up, researchers had conducted numerous studies on chemical education, however, the findings of the research are poorly disseminated and few teachers were able to translate and practise the newly added knowledge in their classrooms. Many researchers are thus concerned with the big gap between theory and practice. The trend in chemical education research also follows the shift from the traditional process-product to that of cognition of teachers and students. The learning of chemistry used to be a difficult task for many students as they are mentally overloaded by the simultaneous introduction of all the three forms of chemistry knowledge. Thus, teachers need to be careful with the teaching sequence, be aware of the prior knowledge of students, and bear in mind the information processing model and the nature of chemistry model. In the Malaysian context, chemistry teachers have little access to research findings and at the same time, there are few professional development programmes to improve and enhance their teaching.

2.6 Student knowledge

Shulman (1987) argued that in order for the teachers to adapt and tailoring their teaching to suit the student characteristics, they need to possess student knowledge which includes their background, interests, preconceptions, misconceptions, just to mention a few. As mentioned in the earlier section, misconceptions is one of the five most prevalent problems in the teaching and learning of chemistry (Fensham, 2002). Subsequently, this section focuses on the misconceptions or alternative conceptions of students as teachers could be the source of misconceptions of students (Taber, 1997). According to Taber (2002a), alternative conceptions are found in all areas of science, such as movement and force in physics, the origin of matter in plants in biology, chemical structure and chemical bonding in chemistry, just to mention a few. Various terms such as

misconceptions, alternative conceptions, children's science, alternative framework, intuitive theories, informal ideas, theories in action, and mini theories were used by researchers to describe the alternative idea students brought into the chemistry classes (Taber, 1994). He proposed that formation of misconceptions was because students learn by constructing their own meaning through constructivism (Taber, 2002c).

Literature reviews revealed a few causes which form the foundation of the misconceptions of the chemistry students:

- (a) Students have their own views and explanations for natural phenomena based on their experience. The said views and explanations were often different from the scientific explanations (Driver & Oldham, 1986; Taber, 2002a). As a result, the students could not make sense of what the teacher said and assimilate the new concept into their conceptual schemes (Huddle & Pillay, 1996) or cognitive structure (Taber, 1997). Instead, they would simply accommodate the new concept through rote learning or by altering the information to fit into their conceptual schemes (Kelly, 1955, cited in Huddle & Pillay, 1996);
- (b) Many concepts in chemistry are highly abstract, which are not tangible and difficult to comprehend (Johnstone, 1999). For instance, some of the concepts such as elements, compound, atoms and electrons were beyond the ability of the students to form with their senses. In order to make unfamiliar familiar teachers commonly used analogies and metaphors to explain the concepts (Taber, 2002c). Johnstone (1999) cautioned that the use analogies might lay down the foundations for misconceptions due to their simplification and unreal. In addition, Taber (2002b, 2002c) argued

the poor understanding of the students of the analogue and metaphors would prevent them from understanding the intended concept;

- (c) The mismatch between the mental ability of students and the abstract concepts. Huddle & Pillay (1996) argued that the main reason why the university students could not fully understand the chemical equilibrium and stoichiometry concept was because the said concepts were first taught to them before they have attained the stage of formal operational thought. The abstractness of the concepts were too abstract for them to understand;
- (d) Words from everyday language were used with different meanings in the teaching of the abstract concepts (Bergquist & Heikkinen, 1990; Johnstone & Selepeng, 2001) and may cause confusion (Larson, 1997). For instance, students could not differentiate between strong acids and concentrated acids (Taber, 2002b). A concentrated solution is often referred as a “strong” solution in everyday life, whereas in chemistry a weak acid solution could be concentrated and a strong acid could be diluted; and
- (e) Inaccuracy of the definitions found in textbooks. Taber (2002c) highlighted many flawed definitions of the chemical concepts in the student textbooks. These faulty definitions became the source of misconceptions among the students and also teachers who are not very strong in their subject knowledge. Taber (2002b) pointed out that it is necessary for teachers to make sure that school textbooks and reference books contain consistent, non-problematic definitions; and
- (f) Taber (2002b) highlighted a concept definition often contain complicated sentence which made students have difficulties in understanding. In addition, the definition might contain concepts which students did not fully

understand which prevent them from understanding the intended concept. In chemistry, the concepts were often interrelated and certain concepts served as pre-requisite concepts in order to understand the intended concept. For instance, “alkene” is defined as a type of hydrocarbon with a double bond, the teacher have to make sure students understand the meaning of “hydrocarbon” and “double-bond” before they could understand the concept “alkene”.

It was found that students came to a college from different schools seem to hold common misconceptions. The common misconceptions could be a coincidence or implications for the teaching of teaching in the schools where the students came from (Taber, 1994). Students across culture and age range possess numerous misconception on chemical concepts. Boo’s (2001) study reveals confusion on mole concept and hydrocarbon series among undergraduate student teachers. There is also evidence of chemistry undergraduates and postgraduates with good academic records possessing alternative conceptions about chemical bonding (Coll & Taylor; 2001). Students can have strongly held belief resulting misconceptions are extremely resistant and difficult to alter as unless the teacher could help them to view the same concept in a more plausible, intelligible and fruitful way (Posner, Strike, Hewson & Gerzog, 1982).

Teachers may become the source of students’ misconceptions (Taber, 1997) due to weak subject matter content. It is not uncommon that teachers lack understanding of chemical concepts such as the mole (Furio, Azcona, Guisasola & Ratcliffe, 2000). In addition, it is noted that inappropriate teaching procedures and sequences prevented students from understanding the abstract concepts and blocked them from entering into the formal-operational stage (Lawson & Renner, 1975). It is important for chemistry

teachers to understand the subject content matter thoroughly to avoid confusion of their students. Although misconceptions are often taken as “a block to effective learning”, it may be used positively as “a bridge on the journey to the desired learning” by teachers too (Taber, 1997, p. 94).

Ben-Zvi et al. (1988) reported students faced acute difficulties in dealing with the abstract concepts such as the mole concept that were required to perform stoichiometric calculations. In addition, the students needed to understand well the principle involved in the ration and proportional calculations. Other related skills included balancing the chemical equations, determining the amount of each reactant presents, decide on the limiting reagent for the reaction and calculate the amount of one of the products.

The review of the literature has collected some steps which could help teachers in identifying and prevent the misconceptions of their students. For instance, by probing and doing exercises, teachers can find out the examples of misconceptions of the students (Taber, 2002a). Teachers can use “Kelly’s triads” (Taber, 2002b) to reveal the misconceptions of the students by spotting the similarities and differences between the three diagrams presented (Taber, 2002b). In addition, the teachers need to have good subject knowledge, able to apply their pedagogical knowledge to introduce the concept in a logical way and manageable steps to help students construct their knowledge (Taber, 2002d).

2.7 Subject matter knowledge (content knowledge)

Pedagogy without content is as useless as content without pedagogy (Shulman, 1986b; Veal & MaKinster, 1999). A teacher’s content knowledge is vital for teaching because it determines the availability of students’ learning opportunities and it also influences their instructional decisions (Lederman et al., 1994).

Since the introduction of the “missing paradigm” by Shulman in the mid-1980s, subject matter knowledge has gained renewed emphasis in the teacher education program and also teaching evaluation (Shulman, 1986b, 1987). Certain states in the US had raised the entry point in subject matter knowledge for the intake of student teachers with the intention to increase teacher quality. It is used as an indicator for teaching evaluation as well (Shulman, 1987).

Subject matter knowledge is made up of two components, the substantive knowledge and syntactic knowledge. Substantive knowledge is the knowledge about the big ideas, principles, concepts and facts in chemistry content. Syntactic knowledge, on the other hand is the knowledge about how substantive knowledge is structured and organised. Chemistry teachers need to have a good understanding of the facts and structures of the subject in order to represent it in a way that is accessible to the students.

2.8 Pedagogical Content Knowledge (PCK)

The term pedagogical content knowledge (PCK) was introduced by Shulman in 1986 to represent the missing content paradigm that education researchers had been ignoring all this while. Since then it has drawn much attention from the educational researchers and successfully shifted the focus of educational research to the so-called “missing paradigms”. This movement had strengthened the professionalizing of teaching (Carlson, 1999).

According to Shulman (1986b), PCK is not something new because even as early as in the 1950’s, both content and pedagogy were regarded as one indistinguishable body of knowledge whereby content is about what is known and pedagogy is about how to teach it (p. 6). As its name implies, it is the blending or amalgamation of pedagogy and subject content knowledge. Shulman (1987) categorised PCK as one of the seven

knowledge bases needed by teachers to perform effective and successful teaching. The seven knowledge bases form the basis of teachers' understanding in helping students to understand the content taught. Basically, PCK is developed when a teacher's content knowledge overlaps with his/her pedagogical knowledge (Cochran, DeRuiter & King, 1993; Tuan et al., 1995).

The research findings on PCK have added knowledge and expanded the available literature related to it. Subsequently, researchers identified inadequateness in Shulman's PCK conception and they began to refine, modify, expand and derive new PCK conceptions. Theoretically, PCK is an academic construct (Loughran, Mulhall & Berry, 2004). In the modified versions of its conceptions, constructs are added either singly or in a combined manner. Similar to teaching, PCK is also complex, difficult to define and articulate by the holders, thus, researchers often face great difficulty in trying to capture and document it (Loughran & et al., 2004). The following conceptions are some of the modified PCK conceptions posed by various researchers.

2.8.1 Conceptions of PCK

Shulman (1986b) defines PCK as the unique knowledge of teaching possessed by teachers, "the particular form of content knowledge that embodies the aspects of content most germane to its teachability" (p. 9), he wrote:

... pedagogical content knowledge, which goes beyond knowledge of the subject matter per se to the dimension of subject matter of teaching. The category of pedagogical content knowledge includes the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstration – in a word, ways of representing and formulating the subject that make it comprehensible to others.... Pedagogical content knowledge also includes an understanding of what makes the learning of specific topic easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds

bring with them to the learning of those most frequently taught topics and lessons

(p. 9-10).

It is noted that Shulman's PCK conception consists of two main elements: the element of how teachers represent the content knowledge and also the knowledge about the difficulties faced by students while learning a particular topic in the content (Loughran, Mulhall & Berry, 2004). It involves how teachers interpret and transform the subject matter knowledge with the intention of facilitating students' learning. It also encompasses the teacher's knowledge of the learning difficulties faced by students in the subject matter knowledge taught.

Shulman (1986b, 1987) argues that when a teacher is said to teach with PCK, it means he/she has gone beyond understanding the content subject, and has acquired the knowledge of how the students learn in terms of their difficulties and preconceptions about a topic. Additionally, by restructuring the subject content the teacher is able to present it in a form suited to the diverse interests and abilities of the students.

Simply, PCK is the knowledge of teaching, a unique province of teachers which distinguishes a teacher from a content specialist (Cochran, King & DeRuiter, 1993; Shulman, 1987; Veal & Makinster, 1999). "PCK concerns the manner in which teachers relate their subject matter knowledge (what they know about what they teach) to their pedagogical knowledge (what they know about teaching) and how subject matter knowledge is a part of the process of pedagogical reasoning" (Cochran & et al., 1993, p. 263).

On the other hand, Smith and Neale (1989) outline three components of PCK as knowledge of students' misconceptions; instructional strategies and knowledge of "shaping and elaborating the content" (p. 4). Teachers with good

PCK are aware of their students' typical errors in a particular topic. As such, they are able to prepare their lessons with suitable strategies and effective elaboration which lead to students' conceptual understanding.

Based on research findings, Grossman (1990) argues that teachers draw upon more than subject matter knowledge and general pedagogical knowledge while teaching. General pedagogical knowledge is the knowledge of how to organize a classroom and manage students during instruction (Baxter & Lederman, 1999). Grossman (1990) expands PCK conception to include four central components, namely: (1) knowledge and beliefs about the purposes of teaching a subject at different grade levels; (2) knowledge of students' understanding, conceptions, and misconceptions of particular topics in a subject matter; (3) curricular knowledge which includes knowledge of curriculum materials available for teaching particular subject matter, knowledge about both the horizontal and vertical curricula for a subject; and (4) knowledge of instructional strategies and representations for teaching particular topics (p. 8-9). She states that both knowledge and beliefs about the purposes of teaching a subject is the "overarching conceptions" of teachers' teaching, which is often reflected in their teaching goals (p. 8). Teachers with student knowledge will ensure the appropriateness of the content and instructional strategies used in their teaching and an appropriately planned lesson is a lesson which takes into consideration students' characteristics such as their prior knowledge and ability, hence leading to meaningful and effective learning. The third component emphasises the necessity of teachers to know what students have learned from the same discipline earlier and also from other disciplines. A better understanding of students' prior knowledge will help to facilitate teaching. The final component is

the teacher's choice of instructional strategies. A teacher needs to know which strategies are most appropriate for teaching a particular topic and for particular levels and particular students. Grossman points out defining PCK into different components serves as a heuristic tool for researchers to investigate particularly the "missing paradigm" of teaching (Shulman, 1986a).

Cochran, DeRuiter and King (1993) commented that the Shulman's PCK conception is compartmentalised and static. They argue that teachers' knowledge on teaching should be dynamic and developing and growing continuously. Based on this constructivist view; they named their modified version of PCK "pedagogical content knowing" (PCKg), the expertise of teaching with a dynamic nature. It consists of an integration of four types of teacher knowledge, namely subject matter knowledge, knowledge of pedagogy, knowledge of students, and knowledge of environmental contexts. The emphasis is on the last two components with teachers' understandings of their students as a central role in teaching.

The assumption underlining this conception is that as teachers' experience grows, all the four components in PCKg grow too. While the components may grow in an integrated manner if the teachers experience the four components simultaneously, the growth of the components may not be always equal. PCKg development is often accompanied by conceptual change and conception integration as a result of thousands of hours of teaching, observing and reflecting by teachers on their own as well as others' teaching. As PCKg develops and expands the distinction between the various constructs will blur out (Tuan et al., 1995).

Veal and MaKinster (1999) regard 'PCK as knowledge possessed by an expert' (p. 1). Upon examining the literature of PCK, they point out the lack of a hierarchical relationship among the attributes in the PCK conceptions. Based on the attributes identified from the literature, they design a PCK taxonomy, which displays relationship and connections among the attributes. The taxonomy consists of three levels with increasing specificity namely: general PCK, domain specific PCK and topic specific PCK. The general PCK is related to the knowledge of concepts and strategies specific to the teaching of science subjects. For example, what is unique in teaching science/science subjects as compared to other academic disciplines is the laboratory works. As there are different branches of science, therefore there is domain specific PCK for biology, chemistry and physics respectively. Although generally, all the science domains involve laboratory works, chemistry uses more chemicals and involves titrations which is distinctive from the biology and physics laboratory work. Additionally, although common concepts may be taught in different domains, different emphasis and different teaching styles and methods were engaged. For instance, both physics and chemistry curriculum teach the concept of an atom, particle and thermodynamics, yet these concepts are taught from different perspectives with different emphases in their respective domain. In physics, the study of atom focus more on the atomic structure, whereas in chemistry the study on atom tends to emphasize on the interaction between different atomic and molecular structures based on their properties, reactions and bonding (Science of Everyday things, 2002). The topic specific PCK is the current trend of research in PCK. Topic specific PCK is the specific knowledge of teaching a particular topic and concept. A teacher with a solid repertoire in topic specific PCK is likely to have a good knowledge about

general PCK and domain PCK too. For instance, chemistry teachers having a good PCK in the topic “Chemical formulae and chemical equations” are inferred to have good domain PCK in chemistry also good general PCK as well. Veal and MaKinster (1999) believe that the existence of PCK taxonomy serves as a foundation for future research in science teachers’ development.

Similar to the PCK conception of Cochran, DeRuiter, & King (1993), the PCK taxonomy is developmental too. Besides being developmental, the levels of and the attributes in the PCK conception are hierarchical. At the base of the PCK attribute taxonomy is the subject content which implies that a strong subject content knowledge is vital for the development of PCK. On top of this subject content knowledge is the knowledge of students. The third level of the taxonomy contains other eight embedded attributes of PCK such as pedagogy, curriculum, classroom management, nature of science, environment, context, assessment and socioculturalism (Figure 2.1).

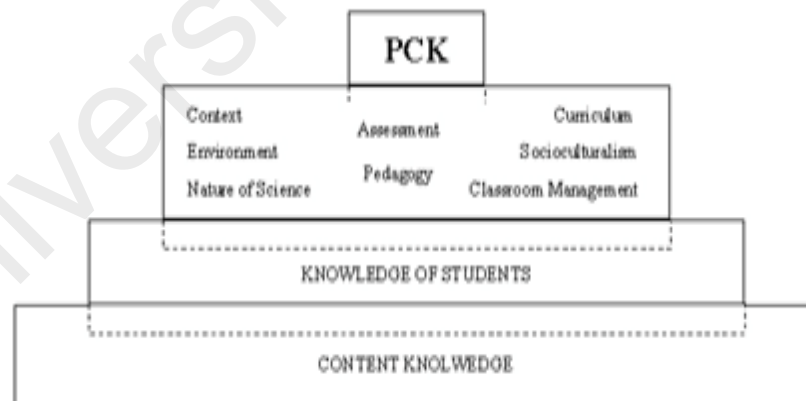


Figure 2.1. The taxonomy of PCK attributes of Veal and MaKinster (1999)

Attributes at various levels in the taxonomy indicate different priorities; among the ten attributes, the most significant attribute is the subject content knowledge which is situated at the base of the pyramid, followed by the

knowledge of students which sat on top of the subject content knowledge. The remaining eight attributes occupying at the tip of the pyramid are of equal significance, but are less significant as compared to the two mentioned earlier. According to Veal and MaKinster (1999), teachers need to possess a thorough understanding of the knowledge of subject content and student knowledge before they learn and develop minor attributes in the PCK taxonomy. They believe that a strong grasp of the subject content knowledge and student knowledge is a prerequisite for a teacher to learn and develop the rest of the attributes in the PCK.

Similar to attributes in other PCK conceptions, the development of one attribute may often lead to the development of the others wherein the attributes integrate with each other and they may develop separately or collectively. However, Veal and MaKinster (1999) caution that the layering of the attributes in a “pyramid of knowledge” does not imply a linear process for a teacher to become an effective teacher, rather the pyramid grows in size with time. The minor attributes of PCK within the same layer are not necessarily arranged in a hierarchical manner.

Barnett & Hodson (2001) believe that good teachers employ four categories PCK in their teaching, which are: (1) knowledge of learners’ existing knowledge; (2) knowledge of effective teaching/learning strategies according to particular content; (3) alternative ways of representing the subject matter; and (4) curricular saliency. Knowledge on curricular saliency enables the teacher to determine the depth of the content and contextualisation. Their components of PCK are similar to those suggested by Marks (1990) in the teaching of mathematics. Table 2.1 shows a summary of the attributes of various conceptions of PCK.

Table 2.1

Summary of Some of the Definitions and Conceptions of PCK

Attributes & components of PCK	Definition and concept of PCK						
	Shulman 1986	Smith & Neale 1989	Grossman 1990	Marks 1990	Cochran et al. 1993	Veal & MaKinster 1999	Barnett & Hodson 2001
Subject matter knowledge		√		√	√	√	√
Student knowledge	√	√	√	√	√	√	√
Representations and instructional strategies	√	√	√	√			√
Context					√	√	
Curricular knowledge			√	√		√	√
Purpose for teaching subject matter			√				
Assessment						√	
General pedagogy					√	√	
Nature of Science						√	
Classroom management						√	
Socioculturalism						√	

Source: adapted from Figure 2 Domains of teacher knowledge: Four alternatives (Carlson, 1999, p. 137).

From the discussion presented, one could see that there is no universally accepted conceptualisation of PCK. Differences occur with respect to the attributes scholars included in their conceptualisation of PCK. Three attributes seem to dominate in most of the conceptions in Table 2.1: student knowledge, subject matter knowledge and knowledge of instructional strategies which involves representations of knowledge. Although some conceptions may contain fewer attributes in comparison to that of Veal and MaKinster (1999), many of the minor attributes are in fact either clustered under an attribute (Cochran et al.,

1993; Grossman, 1990) or taken as the knowledge bases upon which teachers drawn when they teach (Shulman, 1986b).

PCK seems to demonstrate certain characteristics. First, similar to teaching, it is complex and difficult to define explicitly. Second, it is a construct made up of attributes. The attributes are not only interrelated and connected with each other, they integrate with each other, and operate collectively (Cochran et al., 1993) overlapping with each other, and gradually become instinctive (Grossman, 1990), finally the resulting PCK differs from the attributes (Baxter & Lederman, 1999; Cochran et al., 1993). The integration of PCK attributes is vital to effective science teaching; in fact the more integrated the attributes, the stronger and more developed is the PCK (Smith & Neale, 1989; Tuan et al., 1995). Third, the attributes are expected to develop and expand continuously. The fourth characteristic is that PCK is only useful when it is applied (Davis, 2004).

According to Tuan et al. (1995), PCK has a micro aspect which deals with the real classroom teaching, focusing on how teachers present the content to students (Shulman, 1986b, 1987) and a macro aspect that is the degree of overlapping between the domains in PCK (Cochran et al., 1991; Cochran, et al., 1993). Teachers are said to have a more developed PCK if they can think of the domains in more integration, thus the degree of integration among the various knowledge domains within PCK can be used as an indicator to assess the difference in the PCK of teachers with different levels of experience.

PCK is expected to expand and grow with the teaching experience of a teacher. It is generally agreed that experienced teachers tend to have a richer repertoire of instructional strategies, a good understanding about the students and confidence in the content that they teach. However, it is not uncommon that under

certain situations, experienced teachers may have little or no PCK, particularly when they have to teach a subject outside their subject areas (Hasweh, 1987; Marks, 1990; van Driel, Verloop & De Vos, 1998) and also when the teachers fail to learn from their experience because they do little or no reflection on their experience (Berliner, 1987). Berliner (1987) claimed that experience is not a synonym for expertise (p. 60). Teachers are encouraged to practice life-long learning in order to develop PCK throughout their teaching career (Shulman, 1986b; Veal & MaKinster, 1999).

The importance of PCK in teacher education is noted from the recurring suggestions from researchers to teach it explicitly in the teacher training program (Anderson & Mitchener, 1994; Geddis, Onslow, Beynon & Oesch, 1993; Shulman, 1986a, 1986b). Geddis et al. (1993) term it crucial for student teachers to learn this knowledge of experienced teachers or “wisdom of practice” while learning to teach, and at the same time bridging the gap between the pedagogical and content aspects of science teacher preparation.

Sockett (1987) critiques Shulman’s PCK conception for overlooking the tacit knowledge of experienced teachers. He argues that experienced teachers do not necessarily articulate all their wisdom and experience at a particular moment as tacit knowledge is often difficult to articulate. However, one may not deny the preciseness with which Shulman describes PCK as the best knowledge of teaching which lies

...at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students (p. 15).

As mentioned in the earlier chapter, chemistry subject contains a lot of abstract concepts and facts which requires teachers to engage in a lot of representations. The challenge faced by the teachers lies in their ability to translate subject matter in a form which is teachable and accessible by the diverse group of students with appropriate strategies. Some of representations commonly used by chemistry teachers to explain chemical concepts are chemical equations, formulae, chemical symbols, diagrams, models and other means (Geddis et al., 1993). It is realised that teachers, particularly novice teachers need to have some teaching experience to understand, integrate and use their PCK (Veal & MaKinster, 1999) and also successfully translate subject matter knowledge into their classroom practice order (Gess-Newsome & Lederman, 1993). Therefore, it is anticipated that novice teachers may face difficulties in translating the subject matter knowledge which they mastered from disciplinary science coursework into their classroom practices.

Upon viewing various conceptions of PCK, it is almost certain that “there is no universally accepted conceptualisation of PCK” (van Driel et al., 1998, p. 677). Some components seem to be commonly agreed among scholars as the main domains in PCK such as knowledge of representation of the subject matter and understanding of students’ specific learning difficulties. Other attributes may be clustered into a major attribute or as the knowledge base teachers draw upon while teaching. PCK is expected to expand and develop with a teacher’s experience and the attributes may grow individually, collectively, in stages and at different pace. It is generally agreed that teachers need to understand the subject matter knowledge before they could think about good PCK and good teaching. A teacher

gets to examine the subject matter in terms of its structure and significance, interpret it and transform it into a representation that can be understood by learners before he or she can transform it into PCK (Marks, 1990). It is clear that the learning opportunities of students depend on a teacher's understanding of subject matter knowledge (Veal & MaKinster, 1999). A teacher needs to have a repertoire of representations for disposal and the ability to recognise learning difficulties in order to deploy PCK effectively (Chew, Ang, Chin, Ho, Lee & Low, 2002). Thus PCK is also termed as knowledge of effective teaching (Geddis et al., 1993) and successful teaching (.

2.9 Development of teacher's PCK

Although little is known about how teachers develop their PCK, two ingredients are identified to contribute to its development, that is, subject matter knowledge and teaching experience (Lederman, Gess-Newsome & Latz, 1994; Tuan et al., 1995; van Driel et al., 2002; van Driel et al., 1998) whereby an adequate subject matter knowledge is a prerequisite of PCK development (van Driel et al., 1998).

The growth and the development of the attributes of PCK could happen in stages, collectively or individually and at different rates. Often the development of one attribute triggers the growth of other attributes (Cochran et al., 1993; Veal & MaKinster, 1999). For instance, the PCK of a chemistry teachers takes place in stages. The chemistry student teachers possess some amount of PCK before entering the teacher training program. Their perceptions and ideas on teaching (Davis, 2004) and the subject matter knowledge which they learned in school and university form the foundation of their PCK even though there is vagueness and fragmentation in their knowledge structure of the subject matter from their disciplinary course (Gess-Newsome & Lederman, 1993). Evidence shows that the

development of PCK becomes more integral and involves more attributes while the teachers begin teaching in the school.

Basically, the development of PCK is perceived as the integration of the subject matter knowledge and pedagogical knowledge (Marks, 1990) and as a synthesis from the simultaneous development of the various domains (van Driel et al., 1998). As a result, prospective and novice teachers tend to have inadequate or no PCK at their disposal. Besides deriving PCK from formal training, the development of PCK is embedded in classroom practice (van Driel et al., 1998), it is possible to enhance novice teachers' PCK through intensive intervention with short-term skills-oriented workshops (Clermont, Krajcik & Borko, 1993).

As a knowledge of effective teaching, PCK therefore is influenced by factors which affect teaching. Teaching is influenced by factors such as personal learning history, beliefs, conception of teaching and learning, teaching preferences, teacher education, teaching practice experience and others (Grossman, 1990; Hauge, 2000; van Driel et al., 1998). Some of the factors are complex and sometimes even competing, some are explicit, such as curriculum and others implicit such as teacher's intention and beliefs about the teaching and learning of science and students (van Driel et al., 1998). Other factors are beliefs, knowledge, teacher preparation (Grossman, 1990), reflection (Berliner, 1987; Tuan et al., 1995), teachers' preference or values (Gudmundsdottir, 1990; Tuan et al., 1995).

2.9.1 Studies done on science education PCK and chemistry PCK

Since its introduction three decades ago, PCK has been accepted by researchers and teacher educators as an essential component of the knowledge of teaching (Shulman, 1987). Subsequently, many studies had been carried out.

Scholars had looked into various aspects of PCK such as the impact on teachers' beliefs and classroom practice (Grossman, 1990; Hasweh, 1987); the role of values in the development of PCK of history teachers (Gudmundsdottir; 1990); and the pedagogical reasoning ability development among pre-service teachers (Peterson & Treagust; 1995). Recently, the scholars have focused on measuring and assessing the construct of PCK (Padilla & Garritz, 2015; Smith & Banilower, 2015), a model of teacher professional knowledge and skill, including PCK for science education was proposed (Gess-Newsome, 2015), and also finding relationship between PCK and affective aspects (Daehler, Heller & Wong, 2015; Park & Suh, 2015).

In chemistry PCK, scholars had explored various aspects such as the PCK development of in-service chemistry teachers (Veal, 1999) and pre-service chemistry teachers (Tuan et al. 1995; van Driel et al., 2002), models of PCK development of chemistry teachers (the Technical-Tactical-Functional model), the PCK evolution among the prospective secondary chemistry teachers (Veal, 1999).

The studies on chemistry PCK has gradually shifted from PCK in general to topic specific investigations (Clermont, Borko, & Krajcik, 1994; De Jong et al., 2005; Geddis, Onslow, Beynon, & Oesch, 1993; Loughran, Mulhall, & Berry, 2004; Mulhall et al., 2003). The successful strategies used in teaching a specific topic were identified and documented. The documented topic specific PCK (strategies) was useful in the training of pre-service chemistry teachers. Okanlawon (2010) looked into students' difficulties in stoichiometry and he concluded PCK as the productive path for chemistry teachers to overcome students' difficulties. He suggested that a successful chemistry teacher should be capable of organising and presenting subject matter with various pedagogical

strategies to ensure meaningful learning of their students. Subsequently, a good chemistry teacher should possess content knowledge, subject matter knowledge and pedagogical knowledge and the integration of the three knowledge was the PCK. Additionally, he suggested that an effective chemistry teacher required four major components of PCK proposed by Grossman (1990) – (1) knowledge and beliefs about the purpose of teaching a subject at different grade levels, (2) knowledge of students' understanding, conceptions and misconceptions of particular topics in a subject matter, (3) knowledge of curriculum materials available for teaching particular subject matter as well as knowledge about both the horizontal and vertical curricular for a subject (p. 8); and (4) knowledge of instructional strategies and representations for teaching particular topics (p. 9).

2.9.2 Methods used to assess PCK

Since its introduction in 1986, researchers have developed an array of methodologies and techniques to assess PCK. Due to its complexity and as a multi-dimensional (internal and external) construct, it is not easily assessed (Baxter & Lederman, 1999; Park & Suh, 2015; Smith & Banilower, 2015) and a single instrument in fact cannot capture its complexity (Henze & Van Driel, 2015). Most assessments of PCK are qualitative in nature (Baxter & Lederman, 1999; Henze & Van Driel, 2015). Basically, the methodologies used in PCK studies since its introduction could be categorised into three groups: (a) convergent and inferential techniques, (b) concept maps, card sorts and pictorial representations, and (c) multi-method evaluations (Baxter and Lederman, 1999). Each category of methodologies has its own strength and weaknesses.

The convergent and inferential techniques consisted of Likert-type self-report scales, multiple-choice items and short answer formats. Although the techniques were widely used to measure teachers' attitudes and beliefs, they have not received much attention due to their predetermined nature and simplification of context (Baxter & Lederman, 1999). Additionally, self-reported data could not reflect the teaching process and cognitive thinking of the teachers. The data provided by the participants are also limited by their willingness and capability to share information.

Concept mapping and card sorts help to reveal the knowledge structure of the teachers, including changes, organisation and relationships among key terms such as concepts, idea, principle and others (Baxter & Lederman, 1999). However, the use of concept mapping and card sorts are too restrictive because the data provided by the research subjects were very much influenced by the views and ideas of the researcher. Scholars also questioned the underlying assumption that concept mapping and card sorts reflect the internal knowledge structure as two individuals of same performance may possess a very different knowledge and also differences in the knowledge organisation (Phillips, 1983).

Literature shows that most studies of PCK engaged multiple methods (Baxter & Lederman, 1999; Hashweh, 1987; Henze & Van Driel, 2015; Hewson & Hewson, 1989; Li, 2001; Padilla & Garritz, 2015; Park & Suh, 2015; Smith & Neale, 1991). Data collected from the multiple sources such as interviews, concept maps, and video-prompted recall were triangulated to infer a general profile. The engagement of multi-method is important in PCK research because the multiple sources of data generated from various tasks revealed various aspects and therefore provided a rich view of PCK (Baxter & Lederman, 1999). Hashwah

(1987) reported that data collected with a variety of techniques enable him to gain an insight into PCK and also obtain unexpected findings. The multi-method helps to address the confirmability and validity issues (Baxter & Lederman, 1999; Li, 2001) as triangulation helps to balance the limitations of each technique (Park & Suh, 2015). However, the use of multi-method might be cumbersome and difficult to duplicate and at the same time, it is time- and energy-consuming to administer and analyse (Park & Suh, 2015).

Scholars are actively trying to develop suitable techniques to capture and document the development of chemistry PCK (Loughran, Berry & Mulhall, 2006; Loughran, Mulhall & Berry, 2004). Among some of the widely used data-collecting techniques are paper and pencil tests such as CoRes (Content Representations) and PaP-eRs (Pedagogical and Professional experience Repertoires) (Cooper & Loughran, 2015), concept maps, pictorial representation, classroom observations and interviews. Multi-methods seem to be a common practice (Baxter & Lederman, 1999; Tuan et al. (1995) For instance, semi-structured interviews allow researchers to do in-depth probing on the interviewees thus enabling to rich data to support classroom observations. Post teaching interviews allow researchers to view the nature of PCK. Written documents such as course work assignments, journals, and lesson plans provide a rich source of data too.

Researchers worldwide had carried out numerous studies on PCK and chemistry PCK since its introduction by Shulman in 1986. Many of the earlier studies focused on subject matter knowledge across all the discipline such as English, history, mathematics and science, trying to look into the missing paradigm in traditional educational research. The trend of the PCK research has

gradually shifted to domain specific and topic specific. The collection of the successful teaching of the experienced and expert teachers can be used as guidelines to enlighten teaching and learning. A gradual shift from qualitative to quantitative research was noted in the study PCK and chemistry PCK such as measuring the relationship between PCK and chemistry university professors' beliefs (Padilla & Garritz, 2015) and other affective aspects of PCK.

This study aimed to look into the conceptualization of PCK of the selected chemistry teachers and how they carried out their teaching processes while teaching the topic "Chemical formulae and equations", a multi-method is deemed suitable. The multi-method chosen included classroom observations, interviews, document analysis, and field note takings.

As an internal and external construct, PCK constitutes "what a teacher knows, what a teacher does, and the reasons for the teacher's actions" (Baxter & Lederman, 1999, p. 158). The internal construct is situated in the long-term memory of the teachers and it refers to the "teachers' understanding of content-specific examples that best represent specific topics, and knowledge of common student difficulties with specific topics" (p. 148). As a cognitive structure, PCK cannot be observed directly, furthermore not all of the teachers' knowledge is retrieved during a specific teaching episode. Kagan (1990) and Socket (1987) expressed concerns about those portions of knowledge which are not retrieved.

Similar to any other techniques when used in isolation, observation-based technique alone can provide only a limited access to a teacher's PCK because it is not possible to observe all aspects of a teacher's PCK (Park & Suh, 2015). Additionally, teachers may not or may not be able to directly translate what they knew in the class (Gess-Newsome, 2015). However, in comparison, a teacher's

actions are a more accurate representation of what they know than self-reported data (Baxter & Lederman, 1999; Van Driel, Beijaard, & Overloop, 2001). Additionally, the classroom is the location of PCK, the action in the classroom is fast and the instructional moves may be planned or occur in the response to something unexpected (Gess-Newsome, 2015) therefore classroom observation provide a suitable tool to assess PCK in the classroom.

Literature shows that the use of interviews enable researcher to elicit rich information about teachers' own science understandings, anticipated student difficulties and how they would help students understand the content taught (Daehler et.al, 2015; Smith & Ranilower, 2015). The use of interview could be problematic due to the tacit nature of the teachers' knowledge and the teachers did not have a language to share the said knowledge with the researchers (Cooper & Loughran, 2015). Additionally, teachers also have difficulties in articulating it (Loughran & et al., 2004). Kagan (1990) suggested using the open-ended prompts and structured interviews to help the teachers to articulate their knowledge. In order to obtain a better picture of the teachers' PCK, it is crucial for the teachers to articulate in a language of their own.

In order to investigate the teaching processes of the selected Form Four chemistry, this study focuses on the six processes in the PRA Model (Shulman, 1987). Shulman concluded these six processes help teachers to generate their PCK. The processes are: (1) comprehension; (2) transformation which consists of preparation, representation, selection and adapting and tailoring to student characteristics; (3) instruction; (4) evaluation; (5) reflection and; and (6) new comprehension. These processes involve mental processes of reasoning and understanding, therefore it is essential to look into the cognitive structure of

teachers embedded in the long-term memory while assessing the processes. The outcomes of the processes can be accessed via documents such as lesson planning and test scripts of the students. Baxter and Lederman (1999) reason that a combination of approaches is needed to gather information about “what teachers know, what teachers believe and their reasoning” (p. 159) in order to assess a better view of PCK.

2.10 Pedagogical Reasoning and Action Model (PRA Model)

Shulman had identified six processes in his PRA Model that support the development of PCK among teachers (1987) (Figure 1.2, p. 17). The six processes consist of – comprehension, transformation (preparation, representation, selection, adaptation and tailoring to student characteristics), instruction, evaluation, reflection and new comprehension.

2.10.1 Comprehension

Comprehension here refers to the comprehension of the subject matter knowledge one is going to teach. Teachers need to understand subject matter knowledge in order to carry out good teaching and enhance student understanding (Cochran et, al., 1991). Hasweh (1987) refers teaching as an interaction between at least three elements that is teachers, students and subject matter (p. 109) and a teacher needs to know the content he/she is going to teach in order to teach adequately. Yet Shulman (1986b) argues that “comprehension alone is not sufficient. The usefulness of such knowledge lies in its value for judgments and action” (p. 14).

Teachers with more subject matter knowledge are capable in reorganizing material in the textbook to match with their own understanding and spotting

misleading or poorly articulated themes. They are more sensitive to students' misconceptions and made more intra-disciplinary connections in the instruction (Hasweh, 1987). According to Resnick (1983, cited in Wilson et al., 1987) "to understand something is to know the relationships. Human knowledge is stored in clusters and organized into schemata that people use both to interpret familiar situations and to reason about new ones" (p. 477-8).

2.10.2 Transformation

According to Shulman (1987), teachers often reflect critically on and interpret the subject matter before transforming their understanding of the content they are going to teach into a form understood by the students. The forms of representation commonly used by chemistry teachers are symbols, formulae, chemical equations, examples, problems, diagrams, graphs, demonstrations, and experiments. Teachers are likely to engage in the following four processes while doing transformation: preparation, selection, representation and adapting and tailoring to students' characteristics. The four processes may occur either concurrently, at different sequence or be missing altogether.

During the preparation, teachers try to interpret critically and understand the content. They interpret the curricular materials such as the chemistry syllabus, curriculum specification, textbook and other resource materials provided by the Ministry of Education Malaysia such as the teaching courseware. They also try to detect errors in the curricular materials, structure and segment the content, and make necessary adjustments guided by curricular goals and purpose.

The objective of education is to ensure students acquire, understand and retain information delivered by the teachers. In order to ensure learning takes

place, ideas should be presented with support structures and not as isolated facts and information. By comparison, the experienced teachers are more familiar with the most effective ways of helping students learn the information which they need to know than the novice teachers (Arends, 1994). However, the novice teachers do have their own specific representation about the ideas and concepts in the content and their limited repertoire of representations will grow with experience (Wilson et al., 1987).

It is important for teachers to represent the subject matter at the same time taking into account the representations students are constructing as a means of understanding the content taught (Wilson et al., 1987). Successful teachers must be able to transform their understanding in ways of representation understood by students. In brief, teachers need to possess two types of knowledge that is, knowledge of the subject matter and knowledge of communicating the subject matter in a way understood by the students (Dewey, cited in Wilson et al., 1987, p. 110). Dewey called this ability to transform the understanding as teachers had “psychologised” or transformed the subject matter for the purpose of teaching.

Shulman (1986b) stated “learners are unlikely to appear before them [teachers] as blank slates” (p. 10). As a result of interacting with the surrounding world, students make observations of physical phenomena and have their own explanation for the phenomena and they bring these preconceptions which are often misconceptions to the class. If teachers are to be fruitful in their chosen strategies in their teaching, they have to reorganise the understanding of the students, and be aware of students’ misconceptions (Chin, Lee, Boo & Lee, 2002; Shulman, 1986b). Based on the misconceptions identified, they create opportunities for students to reorganise and restructure their existing knowledge

and at the same time accommodate the new knowledge through integration with the existing knowledge. The process of constructing and reorganising these conceptions is normally a slow one (Stavridou & Solomonidou, 1998) therefore it is necessary for the chemistry teachers to sequence their teaching so as to match with the students' progress.

Besides knowing students' learning difficulties, teachers need to take into consideration other factors such as their expectations, prior knowledge, abilities, gender, language and motivations before choosing the types of representations for the class. Even with a sound understanding of the content and student knowledge, teachers need to decide the amount of content they are going to teach to the class besides selecting suitable representations for the instruction. It is impossible for the teachers to teach everything in the content to everyone (Gunter et al., 1999). The product of the transformation process can take the form of "a plan, or set of strategies to present a lesson, unit or course" (Shulman, 1987, p. 17).

2.10.3 Instruction

Instruction is the central component of teaching and it is aimed at transmitting knowledge and understanding to students (Wilson et al., 1987). It is a step-by-step procedure that was designed to achieve specific learning outcomes. At the same time, it is essential to place the concern for students as the foundation of all instructional planning (Gunter, Estes & Schwab, 1999). To Shulman (1987), instruction includes "organising and managing the classroom; presenting clear explanations and vivid descriptions; assigning and checking work; and interacting effectively with students through questions and probes, answers and reactions, and praise and criticism" (p. 17).

Gunter et al. (1999) suggest three guidelines for planning an instruction. First, teachers must be clear on “the needs of the students and the goals of education” (p. xv); second, it is essential to formulate objectives and evaluation procedures while planning for the instruction; and finally, teachers need to choose suitable materials and procedures to deliver the content. The chemistry curriculum specifications are widely referred by the teachers from the schools as it contains the learning objectives, learning outcomes and learning activities of every topic. Nowadays, it was noted that the textbook and reference books also contain similar learning outcomes at the beginning of every topic.

According to Gunter et al. (1999), learners develop their potential by learning in more than one way. Thus, it is necessary for the teachers to engage a variety of approaches in their teaching in order to enhance students’ potential. They describe the characteristics of effective instructional models as those allowing students to participate actively in the learning process and allowing students to learn in a sequence.

2.10.4 Evaluation

There were two types of evaluation – formative or summative. According to Shulman (1987), the main purpose of doing evaluation is to find out the learning progress of students, whether they understand the content taught and also as a tool to grade and rate the students for certification. Besides the “on-line checking for understanding and misunderstanding”, teachers evaluate their own teaching as well by looking at the lesson and materials employed (p. 19). Tan et al. (2002) state that “good lesson preparation and planning is not complete without an evaluation of students’ understanding and the self-reflection of the teacher’ (p.

118). They further argue that a fair and accurate evaluation is extremely important to provide an accurate report about students' learning. Evaluation in the class can take various forms such as questioning, individual or group work, quizzes, written reports, tests and others.

2.10.5 Reflection

According to Holly (1989), when a teacher reflects, he/she asks about the “why” and “what” of doing thing, and how a decision was made, based on what grounds and why a certain decision was preferred. Berliner (1987) suggests that experience that is reflected upon is of value to teachers to improve their practice. To reflect, teachers have to question themselves on what they were doing, to monitor, to seek alternatives, to solve problems, to evaluate, to identify their weaknesses and strengths and make necessary adjustments for future teaching. It seems that teachers who reflects on their own teaching are only able to make changes to their teaching, thus improving their practice.

2.10.6 New comprehension

Upon going through the whole process from preparation to the implementation of a teaching episode, teachers are expected to achieve new comprehension of curricular goals, content, students and the pedagogical processes (Shulman, 1987). A new insight and understanding of the whole teaching and learning process is going to improve the teaching of the same topic in the future.

Shulman (1987) pointed out that although the six processes in the PRA Model are listed in sequence, it is not necessary for them to happen in that order.

Some processes may not happen at all and some may be more dominant and more elaborated.

2.11 Teaching Experience

A teacher normally possesses two types of teaching experience; that is teaching experience as a student teacher (teaching practice) and teaching experience as an in-service teacher in the real world of schools.

2.11.1 Teaching experience during teacher training program

Many student teachers tend to regard the student teaching experience as the only real learning, the most important and central experience they could recall among all the courses they went through in the teacher education program (Hauge, 2000). Others take it as only an experience without learning (Johnston, 1994). Due to the artificial nature of the teaching practicum, student teachers do not regard themselves teaching the classes assigned to them because they are not free to plan what they want to teach, everything is predetermined and goes according to what the supervising teachers intended.

An unsupportive supervising teacher influences how a prospective teacher views teaching (Hauge, 2000). Literature shows that “supervising teachers make the greatest impact on the career development of the novice during the student teaching experience” and they are equated with models for expertise (Berliner, 1987, p. 80). The findings from studies indicate that those supervising teachers who fail to be a good example are unhelpful and may hamper the development of the student teachers as teachers (Johnston, 1994). Besides the pressure exerted by the supervising teachers, student teachers are also constrained by the evaluation

pressure of their training program. Due to their fear of getting poor grades, they often choose not to try out new strategies, avoid taking risks and making mistakes. The pressure from the supervising teachers and evaluation pressure from the training program often makes the student teachers frustrated. Thus, they find it more difficult to adjust themselves to the confusing and contradictory roles of teachers and students simultaneously (Johnston, 1994).

Student teachers seem to possess a few assumptions about their experience (Johnston, 1994). First, they equate experience as learning by doing; second, they believe experience leads to increased confidence; third, experience helps to build up a stock of teaching skills and ideas. However, research findings show little evidence about the teacher students' understanding and transferability of the experience gained; in fact, they prefer to use trial and error during their teaching practice (Johnston, 1994).

2.11.2 In-service teaching experience

It is generally accepted that as one spends more hours teaching in the classroom, one's experience increases accordingly. Thus, novice teachers are assumed to have an inadequate knowledge base to teach effectively. However, both Berliner (1987) and Reynolds (1992) comment that the experience does not equate with expertise, though it is often a condition for one to become an expert, thus, it is not necessarily true that teachers with more experience are more expert in teaching (Reynolds, 1992). Berliner (1987) argues experience is unnecessary the best teacher in learning to teach as it teaches differently to different teachers, however, those experiences which are reflected upon and examined are very good teachers.

2.11.3 Novice teacher

According to Berliner (1988), novice teachers are generally pre-service teachers and beginning first-year teachers (p. 7). Then there are the so-called advanced beginners who are teaching in their second and third year. In this study, a novice chemistry teacher is a teacher teaching within the first three years of their career. When novice teachers enter the new workplace, they need to adjust themselves to “fit-in” to the tradition and norms of the school and at the same time they also seek recognition of colleagues as fellow professionals (Barnett & Hodson, 2001). Novices are given as many, if not more tasks than the veteran teachers and are expected to perform like experienced teachers (Berliner, 1987), while they are still trying to familiarise themselves with the job. As it takes time to cultivate a good relationship with students and PCK, it is unrealistic to expect new teachers to achieve it overnight (Dillon & Maguire, 2001).

Reports from past studies reveal that the novice teachers are very concerned about their survival and classroom management during the transition period from student to pedagogue (Fuller & Brown, 1975). As such, they devote less time thinking of the content and finding ways to communicate it to their students. It is only when their experience and competency increase, that they shift their concerns from behaviour to learning.

Novice teachers are also caught in between the conflicting demands between reality and theory. They experience conflict between their personal views of science and science teaching and their actual classroom practice (Brickhouse, 1990). However, while struggling for survival, they are also forced to think seriously about how to transform their understanding of the subject matter knowledge with suitable representations to be taught to their students (Wilson et

al., 1987). As they begin to experiment with different strategies, dealing with different children in the school setting, they progressively build up their teaching repertoire. Some pre-service teachers are capable of integrating pedagogy and subject matter knowledge during their student teaching (Lederman, Gess-Newsome & Latz, 1994). However, in order to become a professional, novice teachers may practise lifelong learning and take challenges as an opportunity and not a threat (Dillon & Maguire, 2001). As a whole, a majority of the novice teachers overcomes five of the 18 types of problems identified within the first three years of teaching (Berliner, 1987).

2.11.4 Experienced teacher

“The behaviour of an experienced teacher is based on a multitude of experiences with a variety of teaching experiences” (Tigchelaar & Korthagen, 2004, p. 669). They have been confronted with countless unexpected situations which demand an immediate response and decisions, and doing reflection after the events had helped teachers to build a repertoire of strategies to overcome the problems encountered in the classroom. This practical knowledge, while being used frequently, will become tacit knowledge and teachers’ reactions will become routine. They teach so effortlessly and fluidly, making right decisions and choices at the right time that at times their behaviour seems irrational (Berliner, 1988).

As a result of thousands of hours of interaction with the students in the classrooms, experienced teachers have a better understanding of the students than the novice. They can manage class discipline better, teach more effectively to both slow and fast learners, are able to sustain the interest of poorly motivated students and teach with a variety of materials (Berliner, 1987, p. 78). Although it is

common for the experienced teachers to possess a repertoire of strategies and a great store of PCK, they tend to have little or no PCK if they were called to teach a subject which is outside their field (Hasweh, 1987).

2.12 The use of English as medium of instruction

Malaysia implemented the “English for Teaching Mathematics and Science” (EteMS) or in *Bahasa Melayu* PPSMI policy nationwide in January 2003 at three levels that is Primary One in the primary level, Form One in the lower secondary level and Lower Six at the post-secondary level in all the government schools. It was uplifted in 2009 (Muhyiddin Hj Mohd Yassin, 2011). Under the policy, the medium of instruction of the science and mathematics subjects was changed from the national language, *Bahasa Melayu* to English. Since the data for this study were collected during the period of implementation, an impact was anticipated on the teaching and learning of chemistry.

The rationale for changing the medium of instruction from the national language to English for the mathematics and science subjects was to enable the younger generation to be proficient in the “lingua franca of science and technology” thus giving them the competitive edge over their international peers at this global economy age (Cheah, 2005). Besides, English is a principal international language of science as most of the science books were written in English (Mackay & Mountford, 1978, p. 6). Students who are proficient in English will be able to access the latest developments and new knowledge in science and technology, which are essential for building a nation with a strong economy. Additionally, Malaysians with a good command of English are a great advantage for nation building as well as doing trading with English-speaking countries.

The implementation of ETeMS has given rise to endless debates and critiques from various parties during its implementation. The main concerns were the readiness of

teachers and students to adapt and adjust to the drastic implementation; the time constraints in preparing, disseminating information and materials such as textbooks, curriculum, training modules, and teaching courseware, the training of the teachers, and, most concerned of all, the appropriateness of teaching science using a foreign language. English language is uncommonly used especially by the rural population furthermore, science itself is a difficult subject to learn even with the native language (Childs & O'Farrell, 2003). Literature shows that effective communication in the classroom is essential for educational success (MCEETYA, 2004) and if the language that a student brings to school is not the language of the teacher then it is difficult for both parties to attain mutual understanding (Gardner & Mushin, 2013).

The Ministry of Education of Malaysia conducted training programs to prepare the teachers for the ETeMS. One of the main aims of the program was producing sample lesson plans and scripts in English for the classroom. Additionally, the Ministry of Education also supplied teaching courseware and the ICT equipment to schools to be used by teachers in their lessons. However, there are some concerns about teachers replacing the normal teaching learning process in the class by simply playing the teaching courseware as a strategy to minimise speaking in English (Cheah, 2005). This has distorted the teaching learning process and the teaching becomes very much teacher-centred. Cheah (2005) also pointed out that teachers tend to ask questions that require short answers, use less activities and by doing so they have stopped students' from learning and thinking.

Findings from some of the early studies done on the implementation of the ETeMS are as follows: generally, most of the science and mathematics teachers studied were positive about the switching of medium of instruction and were willing to implement the policy partly because they are proficient in English (Balkis Binti Ahmad,

2004). At the other extreme, there were teachers and students who were not proficient in English (Sadna Nair A/P Ramachandran Nair, 2004). Many teachers preferred to use both English and *Bahasa Melayu* in their lessons so that students were more comfortable in their learning. Findings show that teachers used *Bahasa Melayu* to explain to save time from repeating the explanation (Ganti Mathi A/P S. Kanaratnan, 2004). Finally, the research also found that the implementation of ETeMS had in fact improved the command of English among teachers and students (Cheah, 2005).

Science (including chemistry) is a difficult subject for students to understand even for native speakers (Childs & O'Farrell, 2003). In the learning of chemistry, besides encountering a lot of new terms, students also faced the complication whereby many of the familiar words had a different and specific meaning. For example, the word pure has a new meaning in chemistry which is not the usual meaning of "clean" or "safe" (Johnstone & Selepeng, 2001). They reported the use of an unfamiliar second language to learn science may result in students losing at least 20% of their capacity in understanding and also reasoning what they learn. This is because the students spare a lot of their working space in their short-term memory to understand the unfamiliar language and as a result there was limited space for holding information. Subsequently, students might resort to rote learning and later forgot what they learned. There was evidence showing that non-native speakers faced a disadvantage in learning science using a second language (Childs & O'Farrell, 2003).

In order to enhance the learning of chemistry using English, chemistry teachers were encouraged to take the following steps: (i) be aware of those everyday terms with special meanings that were causing difficulties to students in their learning. Thus, a proper introduction of these vocabularies, supported with explanation and illustrations is important (Childs & O'Farrell, 2003); (ii) both teachers and students had to arrive at some

common understandings of the terms used (Childs & O'arrell, 2003; Johnstone, 2001); and (iii) chemistry teachers needed to encourage students to explain with their own words to avoid mere "parroting" of rote-memorised teacher language (Johnstone & Selepeng, 2001, p. 26).

The chemistry teachers in this study were teaching the Form Four chemistry in English for the first time starting from January 2006. The students were exposed to ETeMS earlier than their chemistry teachers since they were in Form One (2004).

2.13 Summary of the chapter

Some of the critical issues in the PCK research literature were reviewed in the chapter to provide a groundwork for this study. The literature began with the discussion of teacher and teaching in general followed by studies done on the teaching of science. Then, the discussion was presented on chemistry curriculum and the teaching of chemistry. Subject matter knowledge was presented before the discussion of PCK and its definitions. The methods used to study PCK was presented, followed by studies done on PCK. The processes in the PRA model were discussed. The definition of PCK proposed by various scholars was compared and discussed in detail. A new section began by discussing the experiences obtained from the teacher training program. The methodology of the study will be outlined in Chapter Three.

Chapter 3

Methodology

3.1 Introduction

This section begins with a brief outline of the procedures for getting entry to the sites and choosing participants. This is followed by discussions of the data collection methods and strategies used to validate the accuracy of the findings. The management and analysis of the data are also reported.

3.2 Research design

A research design is “a logical plan for getting from here to there” (Yin, 2003). The “where” here refers to the initial set of questions to be answered and the “there” refers to some sets of answers or conclusions about the questions. To get from “here” to “there”, the researcher had to take a few major steps including data collection and data analysis. Research design can be described as the “blue print” of research, a plan that guides the researcher in the process of collecting, analysing, and interpreting data. An appropriate research design helps researchers to avoid collecting irrelevant data for the research questions (Yin, 2003).

This study is set to explore the PCK conceptualization of the selected chemistry teachers and how they actually carried out their teaching processes while teaching the topic “Chemical formulae and equations”. It was mentioned in Chapter Two that teaching is very much influenced by its context and setting (Marshall & Rossman, 1999). As PCK is the professional knowledge of teacher and teaching profession, one can therefore infer that it shares similar features as teaching. Besides being context specific, PCK is also personal

(Gess-Newsome, 2015; Park & Oliver, 2008). Being both context and person specific, PCK is referred as “the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes” (Gess-Newsome, 2015, pp.36).

According to Gess-Newsome (2015), PCK is the application of knowledge to teaching and can be found in the teachers’ instructional plans and in the reasons behind their instructional decisions. Subsequently, PCK involves reflection on action (Schon, 1983). In this notion, PCK is purposeful, explicit and somewhat easily captured by careful questioning and think-aloud methods. Then there is the teaching processes of the teachers which involve what the teachers did in the classroom. Gess-Newsome (2015) argued that what teachers did in the classroom is also based on their PCK as while attempting to carry out instructional plans, the teachers need to monitor student involvement and adjust instruction based on the rapid changes occurred in the classroom. The action is fast and the instructional moves may be planned or occur in response to unexpected happenings in the classroom, as a result, the teaching processes engaged reflection-in-action.

Viewing at the complexity of PCK, it is appropriate to use case study design for this study (Flyvbjerg, 2004; Yin, 1994; 2003). In general, case study supersedes other research methods such as experiments, surveys, histories in doing social studies research due to several unique features. First, it enables one to investigate a contemporary phenomenon within its real-life context yet retaining its holistic and meaningful characteristics under investigation. Second, it could safeguard the contextual characteristics of the phenomena that is the teachers’ teaching and their PCK. In other words, it made a naturalistic inquiry possible (Patton, 2002). Third, it allows the collection of data through multiple methods such as documentation, interviews and direct classroom observations. The multiple

methods of data collection make triangulation of data possible, thereby enhancing the reliability and validity of the findings.

In case study, the objects to be studied lie within the bounded system which could be persons, community, phenomena, program and cultures (Miles & Huberman, 1994). It is chosen because it is “an instance of some concern, issue, hypothesis... it is intrinsically interesting” (Merriam 2001, p. 28). A case study is deemed suitable in this study because it allowed an in-depth understanding of a phenomenon (Merriam, 2001; Patton, 1980) and helped to reveal meaning from the participants who are the subjects immersed in the phenomenon regarding the process they are currently undergoing (Merriam, 2001), in this case the participants referred to the selected chemistry teachers. Since the focus of this study was to explore the PCK conceptualisation and discover the teaching processes of the selected chemistry teachers, therefore deep understanding on their PCK and teaching processes have to be solicited. Researcher needed to examine the teachers’ PCK conceptualization from their and teaching processes from their perspectives. According to Yin (as cited in Ng, 2004), case study is suitable for research questions of “how” therefore it is suitable for this study as the research questions of this study look into “how” the selected chemistry teachers conceptualised their PCK and “how” actually they carried out their teaching process while teaching the topic “Chemical formulae and equations”.

Patton (2002) argued that the using of qualitative methods enable researcher to understand a phenomenon as a whole. He further highlighted that the researcher did not impose pre-existing expectations on the research setting while trying to make sense of the situation. This naturalistic inquiry suited the present study as the researcher did not have any clue as what could be the outcome of this study.

It is generally known that the outcome of a qualitative case study cannot be generalised to the larger population (Merriam, 2001; Miles & Huberman, 1994; Yin, 2003). However, the use of multiple-case sampling adds confidence, precision, validity and stability to findings (Miles & Huberman, 1994). The evidence from multiple cases is more compelling as the finding is more robust (Herriot & Firestone, 1983; Miles & Huberman, 1994) as if a finding holds in one setting and, given similar profile, also holds in a comparable setting (Miles & Huberman, 1994). They further stress that in multiple-case studies, the findings can be generalised among the cases but not to a larger universe.

Miles & Huberman (1994) revealed that the prime interest of multiple-case study is conceptual and to investigate how the phenomenon varies under different settings. They stressed further that the outcomes is stronger than doing a series of case studies over several years. In this study, the objects in the bounded system are teachers teaching the topic “Chemical formulae and equations” in Form Four chemistry in the government secondary schools. Four teachers were selected from four different schools making this study a multiple-case study. The reason for engaging a multiple-case approach is that the researcher wanted to explore how the chemistry teachers conceptualised their PCK and how they actually carry out their teaching processes while teaching the said topic.

3.3 Getting permission to access the sites

The researcher obtained permission from the gatekeeper that is the Educational Planning and Research Division (EPRD) in the Ministry of Education of Malaysia before conducting the studies (Appendix B). The permission from EPRD was later used to apply for permission from another gatekeeper – the State Education Department of Sarawak

(*Jabatan Pelajaran Negeri, JPN Sarawak*) (Appendix C) to carry out the research in the schools.

3.4 Selection of sites and participants

The government secondary schools in the state of Sarawak were chosen because the state's level of SPM Chemistry results showed trend of similarity to the national level of SPM Chemistry results from 2006-2013 (Table 1.2, p.9). There were 132 secondary government schools in Sarawak at the time the data was collected and 47 (36.4%) of the secondary schools were located in the Kuching and Kota Samarahan divisions. The large number of urban and rural secondary schools available in these two divisions provided opportunities for getting the diverse participants for this study. In addition, in order to facilitate the classroom observations, the vicinity of the schools and the better road system connecting the schools in the two divisions were other factors of consideration for choosing these two divisions to conduct the study.

The participants of this study were chosen based on purposive sampling. The chemistry teachers were chosen because they represented themselves and were able to provide rich information on the central issue of this study, that is, the conceptualisation of PCK of chemistry teachers and their classroom practices or how they actually carried out their PCK (Cohen, Manion & Morrison, 2000; Marshall & Rossman, 1999; Patton, 2002; Wiersma, 2000). The purposive samples were selected intentionally based on certain criteria (Creswell, 2012) which would be discussed in the following section. Even though the size of the sample was small, it was able to provide rich and thick data through the multiple data collection methods. Based on the rich and thick data obtained, the researcher was able to make insights and deep understanding of the issue investigated (Patton, 2002;

p. 438). Subsequently, a purposive sampling also had the potential to expand and develop theory as it often opened new territory for further research (Bogdan & Biklen, 2003; Patton, 2002).

3.5 Procedure of sample selection

The researcher scouted for suitable chemistry teachers from one school to another by trial and error. The selection of participants was not based on any predetermined criteria such as gender, experience, qualification and the type of school. Upon getting permission from the school principal, the researcher approached the potential participants to get their consent to participate in the study and their agreement to be observed. The second criteria was to ascertain whether they had started teaching topic 3 “Chemical formulae and equations”. If they had not started the topic then the final criteria was to check their timetables to ensure it did not clash with the rest of the participants. The teachers would be accepted to be the participant in this study if their timetable did not clash with the time table of the other teachers. The last criteria was important because a large portion of the data came from classroom observations, the researcher must ensure there was no clashing in the timetables of the selected chemistry teachers to ensure the classroom observations could be carried out.

Altogether 12 principals were approached, and upon making numerous telephone calls, visiting and meeting the principals and chemistry teachers, finally the researcher managed to get consent from four chemistry teachers to participate in this study. The main reason why most of the potential participants turned down the invitation to participate was the classroom observations. They expressed uneasiness and worries with classroom observations as these would disclose their teaching in the class. They also expressed that

they did not wish to be video-recorded but they could accept audio-recording during the classroom observations. The researcher was aware that audio-recorded data lacked of images as compared to the video-recorded data, yet it was necessary to respect and took into consideration of the choice of the teachers, therefore audio-recording was chosen to record the teaching sessions of the teachers.

The four chemistry teachers came from different schools, namely School A, School B, School C and School D. For anonymity the teachers were given pseudonyms as Andy, Bryan, Catherine and Dennis respectively. Figure 3.1 summarized the process of selecting the participants for this study.

Generally, most of the principals and the senior assistants were friendly and helpful when the researcher approached them. Nevertheless, the researcher did encounter a few rejections as below:

- (i) When the researcher mentioned that she was looking for a suitable chemistry teachers for the study. The principal from one of the schools snapped impatiently and angrily “If you want to do a study on my teachers, you should not ask whether my teachers are suitable or not as if they are not qualified to teach chemistry”. It seemed like there was a misinterpretation of the meaning of “suitable” as “qualified”. The researcher had to clarify the word suitable in terms of the timetable;
- (ii) One principal sounded worried when he was approached and he turned down the offer because the school was newly established;

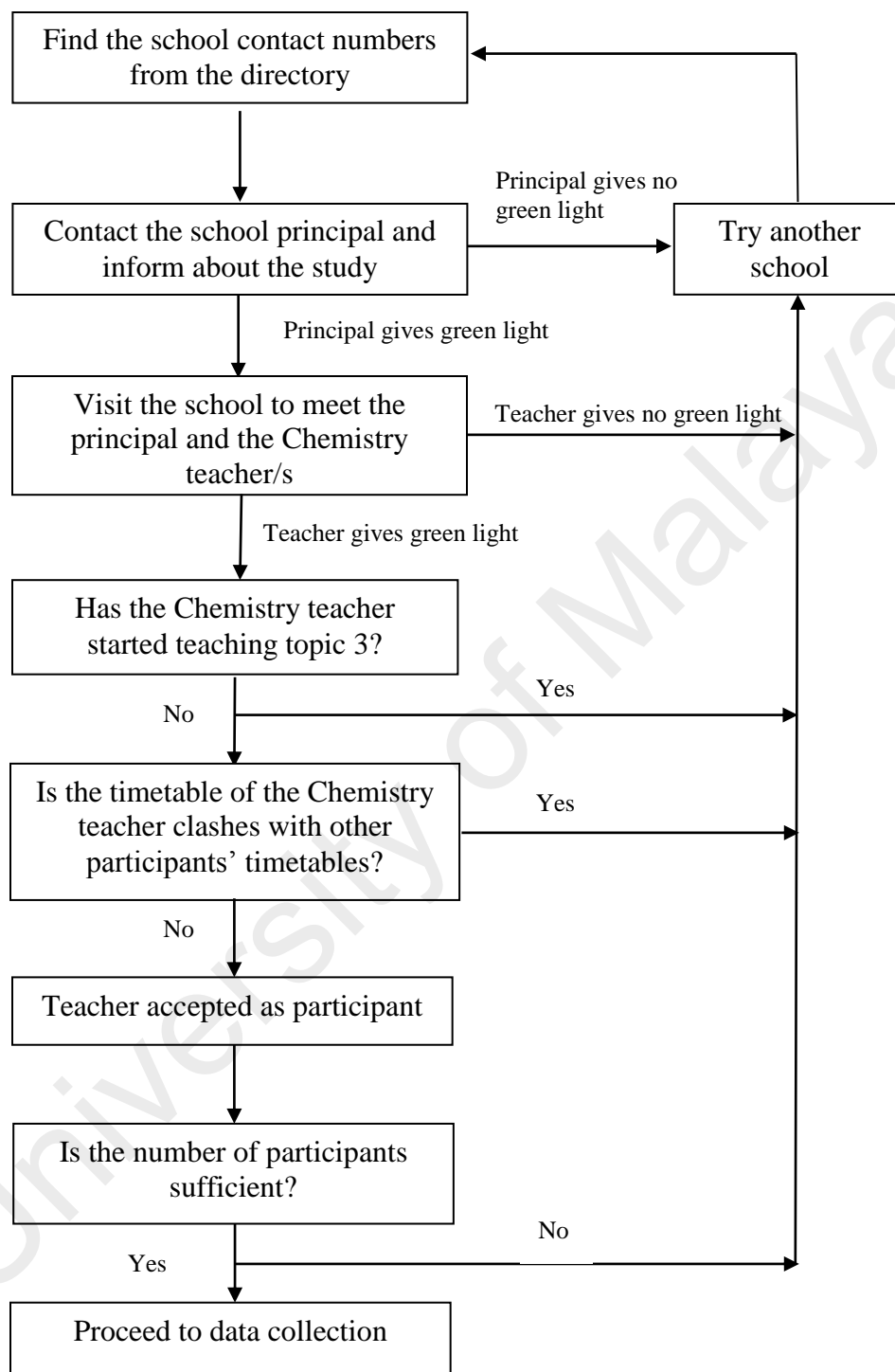


Figure 3.1. Procedure of finding participants for the study

- (iii) One principal insisted that the researcher applied for permission to the chemistry teacher before going to the school even though the researcher assured him that the EPRD and JPN Sarawak had granted the permission;
- (iv) One principal was extremely busy that the appointment kept on postponing. Finally the researcher had to look for other alternatives due to time constraints; and
- (v) The researcher was most disappointed when an expert chemistry teacher turned down to be a participant in this study as her participation could add variety and richness to the findings of this study.

The school authorities of the four schools in this study gave full support during the period of data collection. No restriction was imposed on the researcher and free accessibility into the school compound was given for a period of one to two months.

In qualitative study, the quality of the findings could be elevated through various measures and one of them was collecting of data until “saturation” was reached (Morse, 1995 cited in Charmaz, 2000). In other words, the new data fit into the categories already devised. In this study the number of teachers chosen depended on their suitability of their timetables and the manageability of the researcher of the data collection.

Initially, the researcher planned to study five chemistry teachers upon taking into consideration that only four periods were allocated for chemistry under the secondary curriculum,. Every chemistry teacher taught four periods of chemistry (40 minutes each period) a week and it was anticipated that these teachers would teach topic 3 during the

same period of time and once they finished teaching topic 3 they would proceed to topic 4. And the next round they taught topic 3 would be a year from then.

Ideally, the researcher scheduled observations of two chemistry teachers a day, one before recess and another after recess. Therefore the researcher could observe five chemistry teachers a week starting from the day they began the topic 3 until they finished it. Unfortunately, after several attempts, the researcher still failed to find another chemistry teacher whose timetable could fit into the observation schedule. As a result, the researcher only collected data on four chemistry teachers. Table 3.1 shows the schedule of the classroom observations of this study.

Table 3.1

The Time Table of the Chemistry Teachers

Day	Monday	Tuesday	Wednesday	Thursday	Friday
Teacher	Bryan	Catherine	Dennis	Bryan	Dennis
Time	0800-0920	0835-0950	0830-0950	0800-0920	0815-0925
Teacher			Andy	Catherine	Andy
Time			1040-1200	1205-1315	1000-1120

The sample size of the study consisted of four chemistry teachers. It was noted that there was variation among the chemistry teachers in terms of gender (three male teachers and one female teacher), experience (from 2-17 years teaching experience), and context (sport school, technical school and normal national schools). Accordingly, the “atypical” teachers were theoretically advantageous in studying teaching (Grossman, 1990) and the inclusion of teachers from varied school context was able to increase confidence in the conclusions (Miles & Huberman, 1994).

3.6 Schools

The four schools in this study were different in terms of school type: a sport school (School A), a technical school (School B) and the national type schools (School C and D). School C was established in 1970 and it probably explained why its science laboratory was smaller in size compared to the science laboratories in the other three schools. The science laboratory in School C had only eight benches while the other three schools had 10 big benches in their laboratories. Even though School C had the smallest science laboratory in term of size, Catherine had a large number of students: 36 students in her class. In fact, it was the biggest class among the four teachers, hence the class was crowded.

School A, B and D had morning sessions only whereas School C had both morning and afternoon sessions. As a result, the duration of the chemistry period in School C was cut short to only 35 minutes as compared to 40 minutes in other schools. Consequently, Catherine had only 140 minutes of chemistry per week whereas both Andy and Bryan had 160 minutes, and Dennis on the other hand had 150 minutes as the class on Friday was cut short by 10 minutes. The amount of time allocated influenced the duration taken to teach topic 3.

3.7 Data collection

PCK is made up of both internal and external constructs thus the engagement of a particular method in data collection would tend to give only a distorted view of it (Kagan, 1990). In fact it is a difficult task to uncover and explicate science teachers' PCK because teachers' knowledge of practice is largely tacit (Polanyi as cited in Cooper, Loughran & Berry, 2015). In addition, it was reported also that PCK is often tacit and unconscious, as a result teachers tended to limit their responses and articulation (Park & Suh, 2015). In this

study, it was more suitable to engage multi-methods to investigate PCK in order to gain better insights (Baxter & Lederman, 1999; Kagan, 1990). Nonetheless, some limitations were anticipated in every study as data was “produced” by the researcher who decided the techniques and the types of data to collect (Dey, 1993). With reference to the conceptual framework outlined in Chapter One, the PCK of the chemistry teachers was explored from two perspectives, namely their conceptualisation and also teaching processes. Shulman (1987) outlined two key components: teacher’s representation of content knowledge (instructional strategies) and knowledge on students’ learning difficulties in his definition of PCK with the subject matter knowledge as the pre-requisite condition. He proposed the PRA model consisting of the processes which helped to generate and develop teachers’ PCK. The processes in the PRA model are used as the constructs of comparison with the teaching processes displayed by the chemistry teachers. In order to capture the constructs of PCK and the teaching processes engaged by the teachers while teaching the topic “Chemical formulae and equations”, the researcher engaged classroom observations, field notes, interviews, and documentation (such as lesson plans, scheme of work, test scores, test papers, chemistry syllabus, chemistry curriculum specifications, textbook, practical activity book, reference books, and teaching courseware).

The purpose of collecting multiple forms of data was for triangulation thus strengthening the validity and the reliability of the findings and the confidence in the conclusions. The various methods of data collection will be discussed in the following sections.

3.7.1 Classroom observations

Teaching is an interactive activity between the teacher and the students; it is complex and reflective (Schon, 1983). It was well-documented that there exist discrepancies between teachers' self-reports on their teaching and the actual classroom practices (Lederman, Gess-Newsome & Latz, 1994; Park & Suh, 2015). Park & Suh (2015) claimed that a combination of observation and interview data help researcher to gain more reliable and fuller estimates of individual teacher's PCK (p. 115). Hence, classroom observations, together with other techniques such as interviews, field-note taking, and documentation could give a more reliable and fuller estimates of individual teacher's PCK.

As mentioned earlier, the processes in the PRA model took place at the pre-active, interactive and post-active phases of teaching. Classroom observations were carried out mainly to collect data at the interactive phase that is the implementation of the lesson. The researcher observed all the lessons taught by the chemistry teachers on the topic "Chemical formulae and equations" as a non-participant observer (Creswell, 2012). A non-participant observation is also known as pure, direct or naturalistic observation whereby the observer "neither manipulate nor stimulate the behaviour of those whom he/she is observing" (Punch, 1998). In order to collect the data from its natural setting, the researcher strictly did not interfere with the lesson preparation of the chemistry teachers from a few aspects: the researcher did not inform the chemistry teachers what actually she was looking for. In fact, the researcher carried out most of the interviews after the lessons to avoid imposing any expectations and pressure on the chemistry teachers. The researcher

did not give any comments on the teaching of the chemistry teachers regardless of their performance.

The teaching sessions were recorded with a digital audio recorder to facilitate the data analysis. Initially, the researcher planned to do video recording as it could record both audio and visual images, unfortunately, all the chemistry teachers were not in favour of it, however, they did not mind of the audio-recording, thus the digital audio-recorder was used. The digital audio-recorder was a convenient recording tool as it was handy, small in size, long recording duration and did not need to turn over as when using the conventional tape-recording. The recorder was either placed inside the pocket of the shirt of the male chemistry teachers or hung from the neck of the female chemistry teachers during the recording, the recorder followed the teacher when he/she walked around thus ensure clarity and quality of the sound recorded.

All the chemistry teachers conducted their lessons in the chemistry laboratory. The schedule of classroom observations followed the timetables of the four teachers. Based on the fact that each chemistry teacher taught four periods a week, therefore there were altogether eight sessions of observation a week. The schedule was packed as the researcher had to conduct one to two observations each day from Monday to Friday. The researcher did not request the teachers to change their timetables or to delay the teaching of the topic to unpack the schedule because the researcher did not wish to disturb the yearly scheme of the teachers and also the natural setting of the context as an ethical consideration.

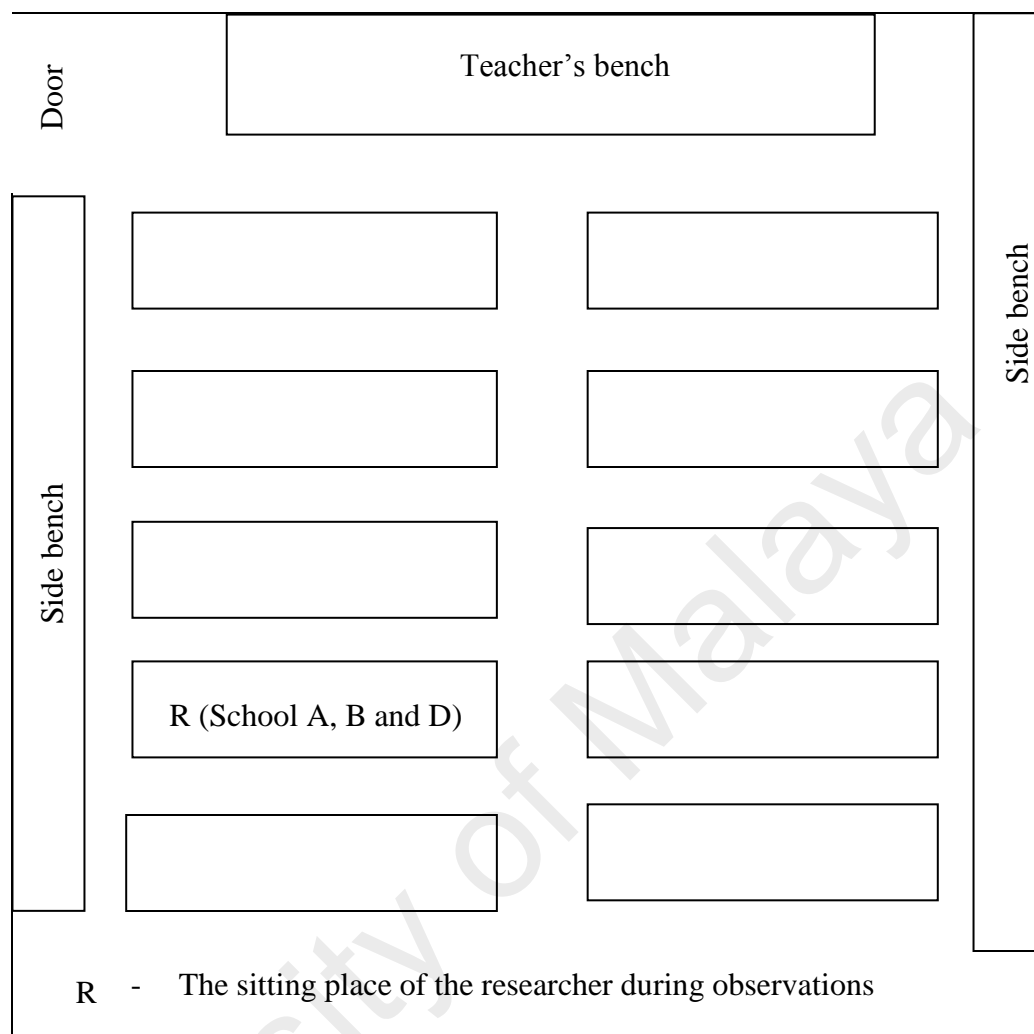


Figure 3.2. The chemistry laboratory plan in School A, B and D

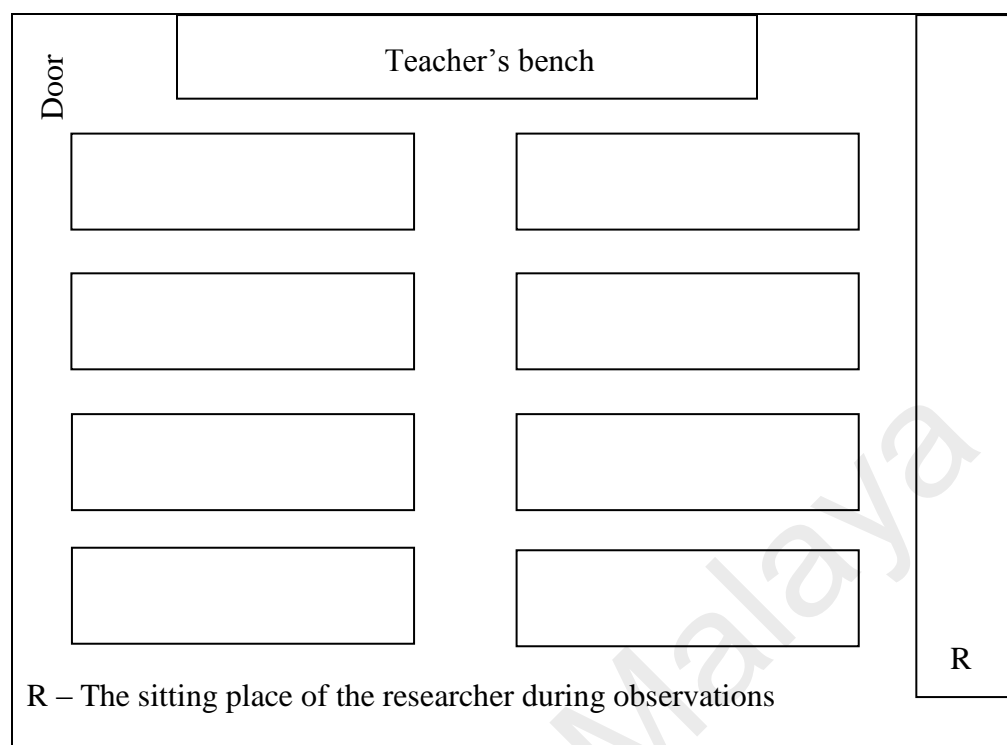


Figure 3.3. The chemistry laboratory plan of School C

The students only occupied the first three rows of benches in the laboratory in Schools A, B, and D. Thus, there was ample space for the researcher to sit during the classroom observations. The scenario in School C was different whereby every bench was seated with four to five students. As a result, the researcher had to sit in the corner of the laboratory at a side bench during the classroom observations. Table 3.2 shows the distribution of the students of the four chemistry teachers and the number of Form Four chemistry classes in the schools.

Table 3.2

Distribution of the Students of the Chemistry Teachers

School	Number of Science classes in Form Four	Class size (Students)
A	1	27
B	4	27
C	3	36
D	1	17

What the teachers taught and said in the class served as a rich source of information (Appendix D). Classroom observations allowed the researcher to see the actual implementation of the planned lessons. During classroom observations, the audio-digital-recorder took care of the verbatim of the participants therefore the researcher paid attention on things which was seen and not heard such as the teacher-student/s interaction, student-student interaction, and things written by teacher/students on the board. The researcher paid special attention to: (i) the instructional strategies including the representations used by the teachers especially those written on the board; (ii) classroom management; (iii) changes made by the teachers in their implementation; (iv) teachers' assessment on students' understanding; (v) the responses of the teacher and the students and (vi) other unexpected events took place in the classroom. The researcher and the teachers often entered the laboratories earlier than the students. The researcher took the opportunities to carry out some interviews. Altogether, 54 classroom observations were conducted and audio-recorded (Table 3.3)

Table 3.3

The Distribution of Classroom Observations of the Chemistry Teachers

Teacher	Classroom Observation				Total
	Teaching	Test correction	Writing PEKA report	Sub-total (Individual)	
Andy	9	2		11	54
Bryan	12	2		14	
Catherine	13		1	14	
Dennis	15			15	

It was observed that besides teaching, the teachers also used their class time to do test correction such as Andy and Bryan. Catherine spent two periods drilling her students writing the PEKA project report. Comparatively, Andy took the least number of lessons to teach topic 3 most probably because he was focused and delivered a lot of facts in each lesson and his students were punctual. Furthermore, he made necessary adjustment on the number of examples based on the time he had. The rest of the teachers took additional three to four lessons to complete topic 3 and the reasons were most probably because their students were not punctual in the case of Bryan and Catherine and disturbance due to the school activities in the case of Dennis. It was noted it took 10 to 15 minutes for every students to enter their class and settle down before Bryan and Catherine could begin their lessons. Dennis often encountered delays as his students involved in a lot of the school activities (representing the school in inter-school competitions) resulting in only a few students being left in the class thus he had to slow down his lessons.

3.7.2 Interview

Interview is a common means of data collecting in qualitative research (Merriam, 1998). It is a face-to-face “conversation with a purpose” between two unacquainted individuals consisted of the interviewer, who asks questions and the interviewee or respondent, who provides the answers (Gubrium & Holstein, 2002, p. 57). Additionally, interviews were helpful in a few ways: (i) it helped the researcher to find out things which could not directly observe about people such as feelings, thoughts, and intentions (Patton, 2002, p. 341); (ii) it helped to obtain information on behaviours, interpretations and past events (Merriam, 1998); (iii) it allowed the researcher to enter the interviewees’ perspective, to find out what was in the interviewees’ mind and to gather their stories (Patton, 2002). In this study, interviews help researcher to access the context of teachers’ actions and the meaning attached to the actions (Park & Suh, 2015). In addition, they supported that a combination of observations and interviews help to gain fuller and more reliable views of teachers’ PCK.

On the other hand, the interviews provided interviewees with the opportunities to share their experiences thus allowing the researcher to attain a more holistic picture about their knowledge and experiences (Mulhall et al., 2003). According to Taylor and Bogdan (1998), there is “an inverse relationship between the number of informants and the depth to which you interview them each” (p. 93), the more the number of interviews with each informant, the fewer informants are needed to have enough data. Shulman (1986) also supported that information would emerge naturally through the frequent conversation between the researcher and the participants (p. 8).

The interviews in this study were of the individual and face-to-face verbal interchange type (Fontana & Frey, 2000). In this study, the interviews enabled the researcher to gather information on: (i) the demographic information and background of the chemistry teachers; (ii) mastery of the content knowledge of the teachers'; (iii) the process of lesson preparation in terms of content, strategies, assessments, objectives, learning outcomes and others; (iv) teachers' student knowledge; and (v) reflection. The researcher also used interviews to clarify and verify ambiguities and confusion noted from other sources of data such as classroom observations, field-notes and documents (Appendix E).

Most of the interviews were conducted after the classroom observations as the teachers were often attaining to their routine before their classes. For instance, one of the teacher was busy with his clerical work as a senior assistant, another one had to attend morning briefing given by his school authority every day before classes began. Additionally, some of them had classes, doing marking, doing some last minute preparation for the lessons and getting things ready for the practical in the laboratory.

Kagan (1990) favoured a post-observation interview over a pre-observation interview to avoid the researcher from holding a predetermined expectation of what to observe and see. On the other hand, it also helped to reduce the possibility of the researcher for imposing of unintended expectation on the teachers thus distorting their initial planning. Comparatively the researcher conducted more post-teaching interviews with the teachers than pre-teaching interviews. Due to the busy schedule of the teachers, the duration of the interviews varied and depended on their available time. The researcher tried to grasp any opportunities to chit-chat with the teachers

whenever they were available prior to the lesson. Appointments were also arranged to conduct the interviews with the chemistry teachers. The post-teaching interviews provided the researcher with the opportunity to get information on the reflection and the new comprehension of the teachers over the lesson just taught. Shulman (1987) mentioned that teachers might acquire new comprehension after finishing a lesson which was the new insight about the content taught, the teaching-learning process, the students, and the teacher him/herself.

The researcher carried out interviews with the teachers using some guiding questions. The questions were adapted from a number of sources such as literature review and also the CoRe template (Loughran, Berry & Mulhamm, et. al., 2006).

Some of the guiding questions were:

- (a) What do you understand about teaching chemistry?
- (b) What are the essential components of teaching?
- (c) What are the big ideas, concepts and principles in the topic that you intend to teach your students?
- (d) What are the possible learning difficulties encountered by your students while learning the topic “Chemical formulae and equations”?
- (e) What are the possible misconceptions of your students about the topic?
- (f) How do you assess the understanding of your students?
- (g) Explain how you prepare your lesson plan.
- (h) How do you decide the strategies in your lesson plan? What criteria do you use to choose the strategies?

- (i) What do you learn from the lesson just finished? Do you gain any new comprehension in terms of the teaching? About your students? About yourself?
- (j) How are you going to teach this lesson again in the future? Do you intend to make any changes?

These questions focused on a few areas/constructs as follows: (i) teachers' perception on teaching and learning; (ii) teachers' reflections; (iii) teachers' student knowledge; and (iv) the content knowledge on the topic "Chemical formulae and equations". Further questions were formulated based on the responses of the teachers.

On the other hand, questions used for clarification and justification on the observations were formulated based on the classroom observations and after listening to the recording and analysis. In order to help the teachers to overcome their fears about the interviews, they were informed and ensured that there was no right or wrong answers to the interview questions (Gess-Newsome et al., 1993; Lederman et. al., 1994).

According to Gubrium and Holstein (2002), an extended, open-ended exchange relationship between the interviewer and the interviewees is an essential element to get meaningful data and keeping the interview going. Subsequently, the researcher had to keep the conversation focused on a particular topic and its related subject matter that emerged in the interview process, apart from getting acquainted with the teachers before the actual interviews took place. During the interviews, the researcher kept a very low profile without imposing any pressure on the teachers. Most of the interviews were conducted informally in a chit-chat mode and every decision of the teachers was accepted and respected. As time went by, the relationship between the researcher and the four teachers turned into friendship. The

interviews were time consuming and the researcher had to be patient in order to attain “deep disclosure” (Gubrium & Holstein, 2002) and good interviews (Bogdan & Biklen, 2003). During the interviews, the researcher did on-the-spot analysis of data to recognize important points and ideas from the feedback of the teachers and to ask further questions based on the feedback. Figure 3.4 shows an excerpt of the interview with Catherine who taught three classes of chemistry.

Researcher	:	How do you prepare your lesson?
Catherine	:	I study the content, make sure on the content first. I study the courseware also before I show to them. I have to study first to see the timing, normally I prepare...to see the timing, what activities (refers to investigations and experiments in the activity book) can I use in that two periods. I have to do the theory then activity.
Researcher	:	I remember you told me like actually you are teaching the same thing to the all the three classes, even though 4A is considered to be more smarter, do you use different ways?
Catherine	:	Hm...different strategies you mean?
Researcher	:	Ya...
Catherine	:	(Pause)
Researcher	:	I mean like how you get to know if 4C, I will do it this way, 4A I will do it this way. Is it of “on the spot” kind of reaction?
Catherine	:	Sometimes...sometimes, because I teach 4A first then 4B which is good, I can “feel” where to slow down. I see the problem in 4A first, then I know the problem will also occur in 4C and even more serious in 4C.... for example, like yesterday 4B when they did the calculations, they were stuck...because they related the number of moles to number of particles then to go to the mass, then go the volume of gas...

Figure 3.4. An excerpt of interview of Catherine

To be a sensitive method of interview, the researcher needed to be objective, neutral, relaxed, and committed to increase the opportunity of obtaining meaningful data during the interviews (Merriam, 1998). Based on the excerpt, one could see that the researcher remained neutral by not giving any comments and suggestions on what the teachers did and said. In addition, the researcher tried to be flexible, made necessary adjustments, maintained neutrality on what the teachers said besides establishing a good rapport with them. In order to create a respectful, non-

judgmental, and non-threatening interviewing environment during the interviews, the researcher kept in mind the importance of not pushing too hard and going too fast on the interviewees.

There is a growing concern about teachers being inarticulate about their own knowledge (Berliner, 1987) and they lack a language to share their knowledge due to its tacit nature (Cooper et. al, 2015). As such teachers need to possess a language of their own in order to make their tacit knowledge explicit. Yet, teaching had become so natural to many teachers that they were unaware of their teaching knowledge (Holly, 1989). As an interviewer, the researcher had the freedom to “raise topics, formulate questions, and move to new directions” during interviews (Gubrium & Holstein, 2002, p. 57) however, the researcher also bear in mind that in order to produce good data, an interviewer needs to ask good questions in a language which was familiar to the interviewees and clearly understood by the them (Merriam, 1998). Park & Suh (2015) cautioned that the feedback of the teachers depends very much on their willingness and capabilities to share information.

In this study, the researcher came from similar background as the teachers. The researcher had an experience of teaching chemistry to Form four students for 10 years which provides a strong familiarity in the content taught by the teachers, the teaching context, the types of assessment used by the teachers, and the examination to be taken by students. The researcher had done a project paper on “How Form four students solved objective mole concept problem” (Chien, 2002) which added on to the familiarity on the learning difficulties encountered by the students while learning the mole concept and stoichiometry. The researcher was familiar with the content and the skills in communicating with the chemistry

teachers. Patton (2002) stated that a researcher's personal experiences and insights were an important part of the inquiry and critical to understanding the phenomenon.

In order to access the knowledge of the teachers, the researcher had taken a few steps to encourage the teachers to articulate their knowledge. For instance, the researcher rephrased the questions and tried to ask the same issue again after a while when the teachers looked confused and request the researcher to repeat the questions. At times, the researcher had to use bilingual by speaking in English and *Bahasa Melayu* during the interviews especially when interviewing Dennis and Bryan. The use of a familiar language encouraged the participants to articulate their knowledge hence enabling the researcher to capture their thinking and understand how they view their worlds (Munby, 1986). While using bilingual, the researcher took precaution to choose words in Bahasa Melayu which have similar meaning with the original version in English. The interviews with Andy and Catherine were conducted solely in English whereas the interviews with Bryan and Dennis were in bilingual, a mixture of English and *Bahasa Melayu*. Consequently, the feedback given by Andy and Catherine were also in English and that of Bryan and Dennis were bilingual.

The researcher had experience in classroom observation as a science teacher educator while serving in the teacher education institute. The said experience was extremely helpful in conducting the classroom observations during data collection. The various experiences had facilitated the researcher in building rapport with the chemistry teachers, the school head, and the laboratory staff. A good rapport with the various personnel in the school eventually led to better mutual understanding between the teachers and the researcher. However, the researcher also understood

that it was crucial and essential to maintain detachment to avoid bias and losing perspective (Patton, 2002).

On average, the researcher carried out more than ten interviews with each teacher and the length of the interviews ranged from a few minutes to over an hour. To enhance the quality of the interviews, the researcher reviewed the interview notes and also the transcript within the shortest time after the interview to detect ambiguities and uncertainties for further clarification and verification (Patton, 2002). The researcher also jotted down ideas and interpretations that emerged from the early analysis of data to be reviewed for future improvement. Hence, interviews played an important part in the data collection because the researcher could access a lot of information about the teachers' opinions, views, thinking, feeling, reasoning and others through the interviews.

3.7.3 Field notes

Field-notes are written accounts, a kind of observer's records taken during observations as well as during interviews (Bogdan & Biklen, 2003; Krathwohl, 1998). According to Bogdan and Biklen (2003), field notes contain two types of materials, descriptive and reflective. The descriptive part captured the setting, people, actions and conversation. It captured the meaning and context of interviews and observations (Bogdan & Biklen, 2003; Krathwohl, 1998). The reflective part of the field notes recorded the "speculation, feelings, problems, ideas, hunches, impressions, and prejudices" of the observers. They also provided space for the researcher to reflect upon analysis, method, ethical dilemmas, conflicts, thinking,

and to raise points of confusion for further clarification (Bogdan & Biklen, 2003, p. 114). This reflective part of field-notes is normally indicated as observer's comment (O.C).

In this study, field-notes were important as they provided a supplement to other data collecting methods. They also revealed the researcher's thinking and actions during data collection thus acknowledging the researcher's control and effect on the data collected (Bogdan & Biklen, 2003). The researcher focused on the non-verbal observations which included teacher-student interaction, student-student interaction, and other happenings in the classes. At the same time, the researcher also took down what was written by the teachers on the board. The field notes were used to triangulate the data collected from other sources. A sample of the field notes taken during Dennis's class while he was teaching the molecular formula (Figure 3.5).

Subtopic today: Molecular formula

1. Dennis showed the learning objectives using the courseware followed by the definitions of empirical formula and molecular formula without giving any explanation however he reminded the students to memorise the definitions
2. Immediately he asked students to try Problem 1 and 2 in the courseware. Then he showed the solutions in the courseware on problem 2 followed by some more examples in the courseware.
3. He explained the experiment determining the empirical formula of magnesium oxide in the courseware.

Comments: Dennis relies on the courseware most of the time in his teaching. He gave little or no explanation on the steps in the calculation of the molecular formula such as how he obtains $30n$. Most of the students looked puzzled. Jumping from the definition to the experiment with making any connection.

(Observation 6)

Figure 3.5. A sample of the field notes taken during Dennis's classroom observation

It is accepted that what the researcher recorded in the field notes involved many judgments and are subjective due to the fact that every individual views classrooms, teachers and learners through his/her own lenses (Turner-Bisset, 2001, p. xi). It was the researcher who decided what to see and what to take note of during classroom observations and field-note taking. However, qualitative researchers do bring along their assumptions, experiences, opinion, beliefs, and preconceptions into the study (Bogdan & Biklen, 2003; Merriam, 1998). Thus, the researcher had to be aware of her presuppositions while engaged in this study “to make the strange familiar and the familiar strange” (Krathwohl, 1998, p. 254). In the process of data collection, the researcher had try to focus at events relevant to the study and by doing a lot of reflection.

3.7.4 Documents

Documents served as an important source of data for triangulation. There are two important official documents in the teaching of Chemistry, namely the Chemistry syllabus and the Form Four curriculum specifications (Ministry of Education, 2006). Besides the knowledge content, the two documents also outline the national education philosophy and national science education philosophy, the aims and objectives of the curriculum and various skills related to the science education such as the thinking skills, science process skills, scientific attitudes and noble values. The teachers kept a copy of record book for their daily lessons which also contained their particulars, scheme of work, students’ informations such as the class list, test scores, and test papers in the record book.

Henze and Van Driel (2015) suggested the use of teachers' lesson plans, authentic lesson materials such as students' assignments and tests, and students' products for triangulation. In this study, the students' written works such as their exercises and answer scripts provided another source of data. Other resources such as textbooks, practical activity books, reference books, courseware, Bryan's power point slides, and hand-out (notes and exercises) used by the teachers were important sources of data which was also collected for triangulation.

3.7.5 Trustworthiness of the findings

Merriam (2001) revealed that all research is concerned of producing valid and reliable knowledge in an ethical manner (p. 199). Consumers of research will only like to make use of the new knowledge if they trust the findings. According to Creswell (2003), validity in qualitative research did not carry the same connotations as it did in quantitative research. Lincoln & Guba (1985) introduced trustworthiness for qualitative studies which is equivalent to validity in quantitative studies. Trustworthiness is more about determining the accuracy or the truth of the findings from the standpoint of the researcher, the participants, or the readers (Creswell & Miller, 2000; Silverman, 2001). A few steps have been taken to ensure the trustworthiness of the findings of this study.

3.7.5.1 Purposeful sampling

It is important to choose good informants who were willing to participate and reflect on the phenomenon under study. The four chemistry teachers in this study fulfilled the characteristics of the informant as they were teaching Form four chemistry and gave consent to participate.

3.7.5.2 Triangulation

Different methods were used to collect data from the four teachers. The data collection methods were classroom observation, interview, field notes and documents. The data collected from the various sources were used to triangulate with each other (Creswell, 2003; Silverman, 2001). For instance, based on the classroom observations, issues identified were recorded in the field notes. To verify the issues identified, the researcher interviewed the teachers and also referred to the documents such as the daily lesson plans and the reflection of the teachers.

3.7.5.3 Member-checking

Data obtained from the classroom observations, interviews, documents and field notes were taken back to the teachers for verification and clarification. This method is also known as respondent validation. For instance, Bryan said he had a “hard way” and a “soft way” of dealing with his students. He was asked to explain further what he meant by “hard way” and “soft way”. On another occasion, Catherine mentioned that she practiced mastery learning, further clarification showed that she had a vague idea of mastery learning.

3.7.5.4 Spend prolonged time in the field

Although the total number of classroom observations of topic 3 of the four teachers ranged from 11 to 15, it took the researcher three to four months to carry out all the classroom observations. The schedule of the

classroom observations were interrupted by school holidays, public holidays, school activities and tests. The prolonged engagement in the field enabled the researcher to develop an in-depth understanding of the phenomenon under study, the site and the people. An in-depth understanding ensured credibility of the findings (Creswell, 2003).

3.7.5.5 Researcher's bias

The researcher tried to remain neutral throughout the data collection especially during the interviews. Sometimes the teachers shared their frustration on their students' performance and school authority, the researcher gave no comments or suggestions and remained a good listener. The researcher was aware that she was not in a position to impose her views and ideas on the teachers so that the data obtained from the study were empirical with no manipulation. In order to avoid researcher bias, the researcher did not inform the teachers what she was looking for during the classroom observation. The researcher confined her questions on the focus of the study that is on the PCK of the teachers and their teaching processes.

The data collected through various methods were used for triangulation to enhance the trustworthiness and reliability of the findings and conclusions. Literature revealed that triangulation could strengthen a study as it provided a cross-data validity checks (Patton, 2002), at the same time it increased the reliability and internal validity of the study (Merriam, 1998). For instance, Catherine viewed herself as facilitator in her teaching. Classroom observations showed that her role as a facilitator was confined to when the

students did the group presentations and in fact she was more of a knowledge dispenser rather than as a facilitator. Another example, Andy viewed his teaching as a two-way process whereby students gave feedback to the teacher and the teacher learned from students as well. Based on the classroom observation the communication in the classroom was mostly one-way where teacher talked and the students listened.

The researcher was aware of the fact that every method possessed its own strengths and weaknesses thus the data collected through various methods served to complement one another and to yield consistency and similar results. However, it was common for one to encounter inconsistencies and contradictions in practice (Merriam, 1998) but, the inconsistencies and contradictories should be regarded as illuminative (Patton, 2002). A summary of the data sources and the research questions is shown in Table 3.4.

Table 3.4

Matric of Data Sources and the Research Questions

No.	Research question	Sources of data
1	How do the selected Form Four chemistry teachers conceptualize their PCK teaching the topic “Chemical formulae and equations”?	Interviews, documents, field notes
2	How do the selected Form Four chemistry teachers actually carry out their teaching processes while teaching the topic “Chemical formulae and equations”?	Classroom observations, interviews, documents, field notes

3.8 Management and analysis of data

3.8.1 Storage of data

The audio-recordings of the teachers were stored as voice files on a computer and a folder was created for each teacher. The individual folder was further subdivided into two – one file for interviews and another for teaching

sessions. It was further labelled with the date recorded and also numbered to indicate its sequence. As a whole, the number of sessions carried out by the four teachers to cover the topic “Chemical formulae and equations” ranged from 11-15 which was equivalent to 22-30 periods. Each double-period lasted between 70-80 minutes depended on whether it fell on Monday to Thursday or Friday and also whether the school had double session. The number of interviews carried out with the four chemistry teachers varied too, which depended very much on the time available of the teachers. The duration of the interviews varied from 10 minutes to 1½ hours.

3.8.2 Transcription of the audio-recorded data

The researcher listened to most of the recorded data before the subsequent classroom observations and interviews. However, as there were eight observations (eight audio-recorded voice files) and a few interviews within a week, the researcher encountered time constraints in analysing all the recordings before conducting the following classroom observation for the same teacher. Subsequently the researcher had to be selective in listening to the voice files and jotted down things that needed verification for the following visit. The researcher sought verification from the teachers either immediately after the class or as soon as time permitted.

Doing transcribing was a time-consuming process, the duration taken to transcribe a classroom observations (70-80 minutes’ recording) varied from three to 10 days depended on the clarity of the recording. About 70% of the observations and interviews were transcribed. The researcher selectively transcribed important

and relevant data. Incomplete information, ambiguities, and confusion were taken note of and later clarified with the interviewees in later interviews.

3.8.3 Data Analysis

The data analysis in qualitative study is an on-going process which went hand-in-hand with the data collection. The overlapping of data collection and data analysis helped to improve the quality of the data collected and also the quality of the analysis. During the data collection, the researcher remained open to the possible emergence of new patterns and insights while still keeping in view the initial ideas (Patton, 2002).

The analytical technique used in analysing the data collected from this study was the constant comparative method. This method was first used by Glaser and Strauss (1967) to develop grounded theory. However, it was commonly adopted and used by qualitative researchers unintended to ground any substantive theory (Merriam, 2001). This method was commonly applied to various kinds of qualitative information, including observations, interviews, documents, and others (Glaser & Strauss, 1967).

The first stage of the analysis was coding; starting with the open coding followed by axial coding and selective coding (Strauss and Corbin, 1998). By doing coding, the data is broken down, conceptualised and later put back together in new ways, to be exact, in a meaningful way. In order to do the coding, the researcher had to examine the data closely, to identify characteristics and properties pertaining to a category. Every category possessed its own characteristics and attributes which in this study were closely guided by the research questions. The characteristics and

attributes would constitute the properties of a category and the properties could exist in a continuum.

The researcher began the open coding by examining the transcripts, the field notes, and also by listening to the voice files closely, identifying concepts /constructs/attributes guided by the research questions. The codes were later grouped together to form a category. Properties and dimensions of the phenomena were identified and appropriate relationships and connections were made. Open coding involved the breaking down, examining, comparing, conceptualizing, and categorizing of data (Strauss & Corbin, 1998). While doing the coding, the researcher constantly made comparisons as well as asked questions about the data which could be an observation, field notes, a sentence, or even a word said by the teachers.

For instance, the representations such as diagrams, analogies, explanations, examples, chemical equations, symbols and questions used by the teachers could be in written forms put on the white board, displayed through the courseware, power point slides, and textbook or in oral forms mentioned by the teachers. During the classroom observations, the researcher jotted down the representations used by the teachers. In order to analyse the representations used by the teachers, the researcher went through the field notes of the classroom observation and listed out all the representations used by the teachers. Table 3.5 shows the representations used by Catherine.

Table 3.5

The Representations Used by Catherine

Coding	Sub-category	Category
Analogy (relative atomic mass in the courseware)	Analogy (diagram)	Explanation
RMM, RAM, A_r , M_r , N_A , STP, $[\text{CH}_2]_n$, C_2H_4	Symbol	Explanation
Apparatus set up of MgO experiment, diagram in courseware, diagram of molar volume	Diagram	Explanation
Definition of N_A , C-12 atomic scale, molar volume, calculations, algorithm, number, mathematical operations	Definition Mathematical formula/statement, symbol, number, measurement unit	Explanation
Simulation (experiment)	Simulation	Lab work
Exercises/homework	Written question	Question
Figure (mind map)	Visual representation	Explanation
Examples	Oral/written question	Question
Unit measurement	Symbol	Explanation
Drawing (of bottle)	Visual representation	Explanation
Tabulation (textbook, courseware)	Visual representation	Explanation
Percentage	Symbol	Explanation
Demonstration	Demonstration	Lab work
Atomic structure model	Visual representation	Explanation
Experiment	Experiment	Lab work
Oral questions	Oral question	Question
Quiz/interactive quiz	Written question	Question
Explanation	Explanation	Explanation

The representations of the teachers were compiled and compared (Table 3.6).

Table 3.6

Categorization of the Representations Used by the Chemistry Teachers

Category	Types of representation		Andy	Bryan	Catherine	Dennis
Explanation	Explanation	Explanation (verbal)	/	/	/	/
	Analogy	Analogy	/	/	/	/
Visual representation	Diagram/drawing	Picture	/	/	/	/
		Figure	/	/	/	/
		Table	/	/	/	/
		Mind map	/	/	/	/
		Calculations (algorithm, formulas, percentage, bracket, number, unit)	/	/	/	/
Definition	Definition	/	/	/	/	
Algorithm	Algorithm	/	/	/	/	
Example	Example	/	/	/	/	
Submacro types	Particles	Atom	/	/	/	/
		Ions	/	/	/	/
		Molecules	/	/	/	/
		Covalent bonding	/	/	/	/
		Ionic bonding	/	/	/	/
		Atomic structure models	/	/	/	/
		Symbolic type	Chemical symbol	Chemical formula	/	/
Physical states (s, l, aq, g)	/			/	/	/
Charges (+, -)	/			/	/	/
Chemical equation	/			/	/	/
Electron configuration	/			/	/	/
Experiment	Experiment			/	/	/
Lab work	Laboratory work/practical	Demonstration	/	/	/	/
		Simulation (courseware)	/	/	/	/
Question	Question	Oral question	/	/	/	/
		Exercise	/	/	/	/
		Homework	/	/	/	/
		Quiz	/	/	/	/
		Interactive quiz	/	/	/	/

Basically, as a branch of science, chemistry itself engaged a lot of chemical symbols, furthermore, topic 3 contained a lot of mathematical calculations therefore the teachers used a lot symbolic representations in their explanations. Subsequently,

these symbolic representations were categorised under the category of explanation. Questions as another type of representation could take the form of written questions as written on the board, in the courseware, power point slides or textbook. The teachers also asked oral questions. Another category of representation took the form of lab work or practical. It could be in the form of hands-on experiment such as the empirical formula experiment, some of the teachers explain the copper (II) oxide experiment by simulation using the courseware. Catherine demonstrated the burning of the magnesium ribbon before the students did it themselves.

The transcript of classroom observations contained rich data and information on instruction, representations, assessment and classroom management of the participants. Therefore the transcripts of the classroom observations became the main source of data to answer the second research question on the actual classroom practices of the teachers. The researcher did a few rounds of coding on the same piece of data with each round focusing on one construct. For instance, in the first round of coding, the researcher looked into the instruction of the teachers, trying to look for information on the pedagogical strategies, assessment, interaction between the teacher and students (Figure 3.6). In the second round of coding, the researcher focused the representations used by the teachers. In the third round of coding, the researcher looked for trends of teaching of the teachers.

Transcript of teaching	Coding/interpretation
<p><u>(a) We had learned about the concept of mole, remember mole represents a certain number of particles.</u> (b) just like the concept of dozen, <u>a dozen represents 12 objects... 12 items, likewise 1 mole represents 6.02×10^{23} particles.</u> (c) so this is <u>an important concept,</u> (d) everybody should remember. (d) 1 mole equals to 6.02×10^{23} particles and (a) you had learned another important formula, that is the <u>relationship between the number of particles and mole,</u> if you have a certain number of particles, you can calculate the number of moles of that substance by using this formula, number of mole is equal to the number of particles divided by Avogadro Constant. This is Avogadro Constant... Avogadro Constant, of course the value for Avogadro Constant is this, (d) <u>you should know this.</u> Just like last time, I explained to you, (f)(b) <u>if let's say you have 6 marbles, how many dozen is that, so 6 divided by 12 equal to 0.5,</u> so this is the important formula, the first formula that we learned, or in another word, we can say, if we know the number of moles, we can find the number of particles, how? (f) <u>By multiplying the number of moles with the Avogadro Constant, so therefore number of particles will be number of moles multiplied by the Avogadro Constant, aright?</u> So this is what we had done last Wednesday. So, I just want to expand on this concept today, so if you look at page 1 of the (i) <u>photocopied note</u> I had given to you, you will see this table, right, on page 1, so for this table you need to use this concept on the mole to fill the table, so (g) <u>I want you to do it individually or if you have any problem, you may discuss with your friends in your own group discuss in pair,</u> right, do it now, I just want to give you about 10 minutes to complete this table, everybody. Before you do maybe you can listen for a while, I will explain to you what you are doing, can everybody see (ii) <u>the screen?</u> Can you read, Benedict, can you read? Let's say you were given a substance, carbon monoxide, (f) for example, <u>the chemical formula is CO,</u> and you were given 1 mole of carbon monoxide, 1 mole, so <u>at this column you are asked to write down the number of molecules, so of course if you got only 1 mole, then therefore you have this number of molecules, right? 1 times Avogadro Constant, if 2 moles then you multiply by 2. Do you understand?</u></p>	<p><u>Instruction</u></p> <ul style="list-style-type: none"> (a) Recall (b) Making connection with prior knowledge/analogy (c) Putting emphasis (d) Teacher's expectation (e) Definition (f) Explanation (g) Evaluation/ assessment <p><u>Representations used</u></p> <p>Questioning Examples Analogies Explanation Definition</p> <p><u>Teaching resources used</u></p> <ul style="list-style-type: none"> (i) Photocopied notes (ii) Courseware <p><u>Conclusion</u></p> <ul style="list-style-type: none"> (1) Explanation is systematic (2) Explanation is very long – too many facts within one explanation (3) Teacher was talking all the time and students gave no response (4) Teacher provided the answers most of the time (5) Teacher-centred teaching (6) Though teacher asked ok, alright? Right? He did not wait for students' response so it was a habitual practice

Figure 3.6. An excerpt of the coding of the transcript of Andy's teaching

It was noted that Andy tried to relate the new concept with the prior knowledge of students by helping students to recall what they had learned. Once in

a while he would highlight the importance of the concepts and definition by saying that “so this is an important concept” and he also told students his expectations in them by saying “everybody should remember” and “you should know it”. The transcript revealed that Andy incorporated definitions, examples, analogies in his explanation.

Andy tried to access his students by posing questions and giving exercises in the photostated notes. However, it was observed that though he posed questions he had a tendency to answer his own questions. The resource materials that he used in the class then included photostated notes and courseware where the courseware was used to assist his explanations.

Finally, the researcher took note of trends and conclusions based on the observations and overall view of the whole excerpt such as (i) the teacher’s teaching was systematic; (ii) long explanation; (iii) students did not give much response; (iv) teacher asked questions which he answered himself; and (v) the teaching was teacher-centred. The coding were later collapsed with those obtained from the rest of the teachers into categories and grouped into themes through axial coding and selective coding.

Interviews provided another rich source of data. The researcher read through the transcripts, extract relevant information and then create a code for the related information. For instance, based on the feedback of Andy in interview 1, 2, and 3 on the teaching courseware: a few statements were extracted (Table 3.7).

Table 3.7

Sample of Coding on Information Extracted from the Interviews of Andy

Statement	Sub-theme	Theme
(i) ...I think KPPM has instructed everyday there must be two teachers using ICT (ii) School level, Head of Department requested the teachers to plan two slots per week (Interview 1)	Requirement to use courseware	Teaching resource
(i) I am quite familiar with the CD content you see (ii) It's better sometimes not to use the CD at all, if you don't know where to find which section that you want for the segment. (Interview 1)	Familiar with the content – preview	Preparation
there are some parts I can do without (Interview 1)	Selective	Preparation
... most relevant and easiest to understand. Because I had seen through two or three CD courseware (Interview 1)	Selection of content	Preparation
Time constraints have to consider... (Interview 1)	Time constraints	Preparation
(i) For this chapter because it is an abstract topic, I try to make use as much of the CD ROM as possible. (Interview 1) (ii) You see I don't mind to use the CD ROM and then I explained again on the board hoping that either by CD ROM if they understand a bit, and then my explanation can reinforce their understanding (Interview 2)	CD as a reinforcement	Pedagogical strategy
(i) ...but I thought if I have something like CD, it's something different, students must be more interested, there are pictures, assimilation you know (Interview 1)	Variation	Motivation

Based on the analysis on the feedback of Andy during the interviews, one could infer that Andy used the teaching courseware for a few purposes: to fulfil the requirement of the ministry of education, to vary his teaching method, to arouse

students' interest and enhance students' learning. He previewed the courseware including his own collection to choose what he described as the easiest and the most relevant for his students and he was selective he did not use everything in the courseware.

Guided by the research questions, the analytical insights and interpretations that emerged during data collection were also other important sources of data analysis (Patton, 2002). Patton (2002) pointed out that “the challenge of qualitative analysis lies in making sense of massive amounts of data” which involved reducing the amount of raw data, identifying significant information and patterns, and constructing a framework to communicate the essence of the data (p. 432).

The quality of analysis depended very much on the analytical intellect of the analyst. During analysis, the researcher interacted with the data to discover patterns, themes, and categories in the data (Patton, 2002, p. 453). Based on the focus of the conceptual framework of this study (Figure 1.1), the researcher communicated the essence of the data and the findings through two frameworks: (i) the components of PCK; and (ii) the teaching processes of the teachers. At the same time, the researcher kept an open mind on the emergence of new themes and categories. Marks (1990) and Patton (2002) commented that the initial categories would overlap with each other and some data may fall on the fringes when the analysis continued. The categories and subcategories of the coding were revised until the process was stabilized (Marks, 1990).

Based on the data obtained from classroom observations, interviews and documents, the following themes were derived for the PCK conceptualisation (Figure 3.7) and the teaching processes of the teachers (Figure 3.8):

Theme	Sub-theme
Content knowledge	Content knowledge
	What to teach
Pedagogy	Pedagogy
	How to teach
Student	Students' interest
	Students
	Motivation
	Class control
Context	Policy
	Curriculum
	Parents
	School authority
	Environment
Nature of science	Science process skills
	Thinking skills

Figure 3.7. The theme of the teachers' conceptualization of PCK

Theme	Sub-theme	Sub-sub-theme
Pre-active phase	Preparation of content	Reading textbook/reference books/ practical book
	Preparing the pedagogical strategies	determine the teaching methods by reading the curriculum specifications/scheme of work
		Creating examples and analogies
	Preparing lesson plan	Writing the scheme of work
		Writing the daily lesson plan
	Preparing teaching resources	Reviewing the courseware
Refine and review power point slides		
Preparing lab work		
Preparing assessment	Preparing questions, quizzes	
Interaction phase	Assessment	Posing questions/giving quizzes/ exercises/test
	Representation	Explanation
		Question
		Lab work
	Classroom management	
Post active phase	Reflection	Writing/making reflection
		Making remarks

Figure 3.8. The themes of the teaching processes of the teachers

This study was based on four teachers teaching in four different schools thus this study was a multiple-case study consisting of four different cases; one site/one teacher was taken as one case. A multiple-case sampling helped to strengthen the precision, the validity, and the stability of the findings and therefore added confidence to the findings (Miles & Huberman, 1994, p. 29). The findings from this study are presented based on the research questions.

3.9 Summary of the chapter

In this chapter, the researcher outlined the procedure in getting access to the sites and the teachers. The rationale for choosing the purposive sampling was spelled out followed by a discussion of the various methods used to collect data. This chapter ended with a brief overview on the management and analysis of the data. The steps used to increase the validity of this study were also discussed.

Chapter 4

Results

4.1 Introduction

This chapter presents the findings on the conceptualization of PCK of the four chemistry teachers (Andy, Bryan, Catherine and Dennis, not their real names) and how they applied the PCK in their teaching processes while teaching the topic ‘Chemical formulae and equations’. As discussed earlier in Chapter 3, data was collected using a number of methods: classroom observations, interviews, field notes and documentation. The data obtained from various methods were used for triangulation. The research findings were presented based on the following research questions:

- (1) How do the selected chemistry teachers conceptualize their PCK in teaching the topic “Chemical formulae and equations”?
- (2) How do the selected chemistry teachers actually carry out their teaching process while teaching the topic “Chemical formulae and equations”?

Some of the feedback and the data obtained was in bilingual and the excerpts were translated and validated as in Appendix F.

4.2 The profile and background of the chemistry teachers

Similarly, all the four chemistry teachers are graduates from the local universities with various academic background. Andy is the only one having a degree in education majoring in Chemistry and Mathematics. Both Bryan and Dennis major in Chemistry whereas Catherine in Geology. Bryan secures his degree after obtaining his teaching certificate whereas Catherine and Dennis acquire their teaching qualifications through KPLI training program (Table 4.1).

Table 4.1

Profile of the Chemistry Teachers Based on Gender, Qualification, Teaching Experience and English Proficiency

	Andy	Bryan	Catherine	Dennis
Gender	Male	Male	Female	Male
Qualification	BSc Education (Chemistry/ Mathematics)	PKPG (Chemistry)	BSc (Geology)	BSc (Chemistry)
Teaching qualification	Degree in education (Majoring in chemistry and mathematics)	Teacher Certificate from Teacher Training College (Majoring Primary mathematics)	Post Graduate Diploma in Teaching for Secondary Education (KPLI) Majoring in KBSM Science	Post Graduate Diploma in Teaching for Secondary Education (KPLI) Majoring in KBSM Science
Teaching experience (year)	17	10	7	3
Teaching experience in Chemistry (year)	11	2 ½	5	1
English proficiency	High	Moderate	High	Low

In terms of teaching qualification, only Andy was initially trained to teach chemistry. Bryan was trained in the teacher training college to teach primary school mathematics, however, he was posted to teach mathematics in a secondary school. After teaching for six years, he joined a special programme offered by the Ministry of Education, *Program Khas Pensiswazahan Guru* (PKPG) to upgrade himself from a non-graduate teacher to a graduate teacher. He majored in Chemistry then. Both Catherine (Geology) and Dennis (Chemistry) underwent one-year KPLI training program majoring in KBSM Science at the secondary level.

By comparing the number of years of teaching in general and the number of year teaching chemistry, one could infer that the teachers did not teach chemistry throughout their teaching career. Comparatively, Andy had the longest experience and Dennis had the least. Additionally, Andy had served for a few years in the academic sector in the state education department. Bryan taught only chemistry since posted to

School B whereas the other three teachers taught other subjects such as KBSM science and mathematics besides chemistry. Catherine was often assigned to teach one class of Form four chemistry and one class of Form five chemistry in School C. It was the first time for her to teach all the three classes of Form four chemistry at the time of data collection. Subsequently, she expressed that it was a great challenge then for her to contract three classes of Form four chemistry on her own. Dennis taught chemistry in his first year of teaching. He was transferred to School D at the third year of his teaching and was assigned to teach chemistry.

Besides teaching, the teachers held various posts and responsibilities in their respective schools. For instance, Andy held the post of senior assistant at the time of data collection. Bryan was the Head of the Chemistry Unit, teacher-in-charge of school examination, student enrolment in public examination, preparing examinations timetables, managing the storage of the test papers of School B during school examinations. Catherine was the Head of the Science Unit, teacher-in-charge of the Leo Club, library teacher, and prefect board adviser. Dennis was the teacher-in-charge of the co-curriculum club for *kompang* which is a local musical instrument.

Bahasa Melayu is the official language of delivery in the national secondary schools in Malaysia. Since the implementation of the PPSMI policy, all the mathematics and science subjects including chemistry was taught in English. Subsequently, the level of English proficiency of the teachers had an impact on their teaching. Both Andy and Catherine were very fluent in English and Catherine had even taught English before. In comparison, Bryan's and Dennis's level of English proficiency could be considered as moderate and low respectively. As a result, both of them tended to use bilingual (English and *Bahasa Melayu*) in their lessons.

4.3 The conceptualization of PCK of the chemistry teachers

The term PCK was new to all the teachers and they were not able to define it per se. Dennis even thought that it means an “examination-oriented teaching”. The teachers were asked to express “their views of teaching chemistry” as PCK is defined as the knowledge of teaching in this study. The teachers were encouraged to use other representation such as drawing, diagram or even metaphor to visualise their views. In addition, they were asked to share what they regarded as essential or important components in their chemistry teaching. Table 4.2 shows the findings of the views of the four Chemistry teachers on teaching and the essential components of teaching.

Table 4.2

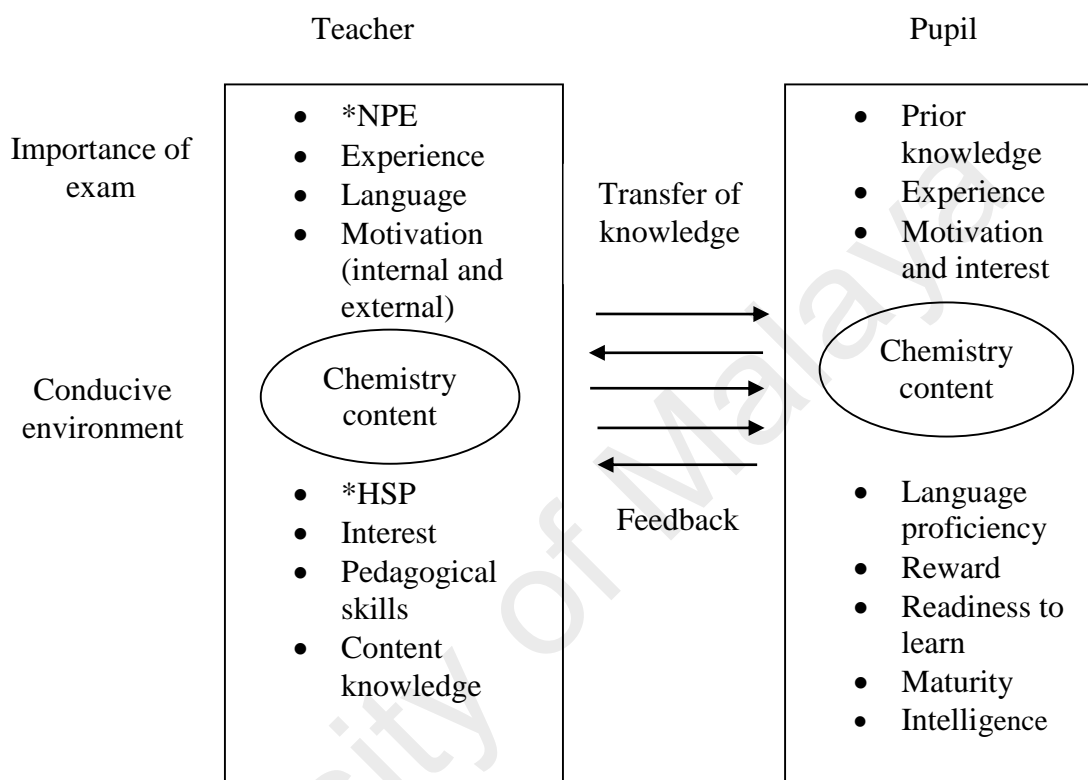
Chemistry Teachers' Views on Teaching and the Essential Components of Teaching

Items	Andy	Bryan	Catherine	Dennis
Teaching	Teacher ↔ students *NEP Environment Motivation/ Incentive Prior knowledge Experience Content Language Curriculum Pedagogical skills Maturity Intelligence	Teacher → input Success = Students' Application	Teacher = facilitator	Teacher → input (+ practical) Success = Students' Application
Essential components of teaching	Content knowledge Pedagogy Environment Motivation Policy Curriculum	Content knowledge Pedagogy Environment Students Parents School authority	Content knowledge Pedagogy Thinking skills Science process skills	Class control Mental preparation (what and how) Students' interest

* NEP – National Education Philosophy

4.3.1 Chemistry teachers' views of teaching

Andy chose to express his views of teaching Chemistry in the form of a diagram and he gave explanation based on the diagram (Figure 4.1).



Teacher Andy's explanation:

1. Teaching is a two-way process.
2. Information transferred not necessary information received
3. Information transferred/received differenced by internal (motivation, interest) and external factors (NPE, reward)

*NPE – The National Philosophy of Education

*HSP – *Huraian Sukatan Pelajaran* (Curriculum Specifications)

Figure 4.1. Andy's framework of teaching

The framework consists of two components: the teacher and the student. Andy viewed teaching as knowledge that was transferred from the teacher to the students and in return the teacher received feedback from the students. It is a “two-way and dynamic process” and its dynamism is indicated by three arrows pointed towards the students and two arrows pointed towards the teacher. The three arrows pointed to the students meant that the teacher input was more than student feedback. Andy also stressed that besides the students learning from the teacher, the teacher could also learn from his students. He also highlighted that the amount of information received (learned) by the students was not necessarily equal to that delivered by the teacher as evidence in his lament that, “you can bring a horse to the water but you cannot force it to drink” (I#1/Andy).

He classified factors influencing the teaching and learning process into three categories: factors influencing teaching, factors influencing students’ learning and factors influencing both teaching and learning. Factors influencing the teaching process were the National Philosophy of Education, the curriculum specifications, pedagogical skills and content knowledge. Whereas factors influencing students’ learning were prior knowledge, reward, their readiness to learn, maturity and intelligence. He put forward two factors that influenced the whole teaching and learning process, namely the examination system and conducive environment. Among those listed factors that influence teacher’s teaching and students’ learning, there were four other common factors which influenced the teacher’s teaching and the students’ learning as well: interest, motivation, language, and experience. He further explained motivation as “internal” and “external” motivation,

Internal motivation like...the goal, what do they want to do, their goal, their ambition. External motivation will be school gave them recognition, like the prizes given by various associations. So these are external motivation. But of course internal motivation is more important. The drive for excellence...

(I#1/Andy)

Bryan explained teaching as a process whereby the teacher gave a little input to individuals to assist them to develop and expand their potential and teaching chemistry meant:

...introducing basic chemical concepts to students and helping them to see and observe their surroundings from the perspectives of chemistry...

(I#2/Bryan)

He gave two examples of application of chemical theories such as “rate of reaction” in cooking:

...As for Form 5, I am teaching Form 5, first topic rate of reaction, let's say the surface area if is the same as me giving an example, if you cook...if you put a whole chicken as compared with cutting into smaller pieces which one is faster...

(I#2/Bryan)

On top of that he said students if understood what they learned about matter then they should be able to explain why and how ice melted using theory of atom, solid, liquid and gas:

...if he sees for example ice, what will happen when he sees a piece of ice? What happen to the molecule, it can move freely...it can rotate? As for me, they need to know. If they understand that...understand that in their daily lives, then they had mastered and understood. That is their ideas...as he applied it....

(I#2/Bryan)

Subsequently, he regarded his teaching a success when students could explain the phenomena in the surroundings with the chemical theories learned.

He commented teaching then is exam-oriented,

...sometimes we forget what should be done for teaching ...we always focus to the exam, because when people come and they questioned...they don't ask about the students, they ask about the exam and they look at the results. As for me if you want to teach the kids, let the students know the basic because we want them to the best we really need time...students here they might a little more time...

(I#3/Bryan)

He further expressed that if the students were forced to memorise facts in order to pass the exam, then if the questions were twisted a little bit, most likely they would not be able to answer. This was an indication that they could not understand the facts therefore it would be quite impossible for them to apply in their daily lives.

Catherine viewed herself as “a facilitator” to assist students to understand the chemistry concepts. Besides that she also viewed teaching as:

It's more of a relationship. If you relate to them nicely, communicate with them nicely then they will do your work. For 4C...scold them you really waste your energy, no use, if they want to do the work make sure they do it with their own heart not because of the teacher. They want to learn or they don't want to learn...

(I#1/Catherine)

She incorporated group discussions and group presentations in her teaching whenever she assigned exercises and homework to the students and she facilitated the group discussions and presentations by correcting the students' answers.

Dennis viewed the teaching of Chemistry as giving input, deliver knowledge and educate. He further expressed that “to educate students, besides correct students when they made mistakes, teachers should show good examples to students also” (I#1/Dennis). He highlighted that students' understanding of the chemical concepts was enhanced by doing practical.

Altogether his students carried two experiments on the topic “Chemical formulae and equations” that is the empirical formula of magnesium oxide and chemical reactions during the data collection.

In comparison, Andy’s views of teaching was more holistic than the rest of the teachers. His views covered definition of teaching with a range of factors influencing his teaching and student learning. The factors ranged from national policy, environment, curriculum, pedagogy, motivation, incentive, interest, experience and language. The holistic views were most likely due to his longer teaching experiences and working experience in the academic sector of the education office. Conversely, the views of the other three teachers focused on the role of teachers as a knowledge dispenser and a facilitator.

4.3.2 The essential components of teaching

When the teachers were asked to list the essential components of their teaching, in comparison, Andy listed the most number that is six essential components. The six essential components: content knowledge, pedagogy, conducive environment, interest and motivation and government policy. It was noted that Andy incorporated the six essential components in the diagram expressing his views of teaching too (Figure 4.1). Bryan also listed six essential components of teaching. Besides content knowledge, pedagogy and environment, his concern seemed to centre on people such as students, parents and school authority. Catherine listed four components of which two of them were related to skills: thinking skills and science process skills, though she did not specifically highlighted in her class. Dennis listed three essential components: class control, mental preparation and students’ interest.

Although the teachers regarded various essential components in their teaching, it was noted that all of them agreed that content knowledge and pedagogy were the most important components in their teaching, followed by students' interest, motivation, attitude and discipline. Others were policy, curriculum, conducive environment and parents' influence.

4.3.2.1 Content knowledge

All four teachers considered content knowledge as an essential component of teaching. To Andy, a teacher must be well-versed in the content knowledge before teaching, he said, "First thing is the teacher...must be well verse...the mastery of the content he is teaching." (I#5/Andy). At the initial stage of teaching chemistry, Bryan read a lot of chemistry reference books before going into the classes. He said, "I don't want students to tell me 'you are wrong' especially teaching in the town school..." (I#2/Bryan). He had an experience teaching in a town school during his teaching practice and comparatively he found that the students there learned faster than his students then. He also cautioned that, "These kids, they remember the wrong things better..." (I#2/Bryan).

What he tried to empathise is that it was very important to teach the concept correctly as students tended to memorise wrong concept for a long time. While reading up for his chemistry lesson, he claimed that he could make up the meaning of the words by reading the whole sentence in the books (textbook and reference books) as he said:

As for reading I feel that there is no problem till to Form 5 chemistry, no problem, I can understand. If I don't understand let's say certain words, then you read the whole sentence somehow you can understand, if I cannot

understand the sentence, I refer to the dictionary, look at the possible meanings, and look at the sentence, and look at the new words, and whether the meaning is suitable because certain words have more than one meanings...

(I#3/Bryan)

He even went to the extent finding the meaning of the words in the dictionary if he could not make up the meaning of the words in English.

Catherine felt that content knowledge and pedagogy were of equal importance and comparatively were more important than other components such as thinking skills and science process skills. In her opinion, it was extremely important for a teacher to know the content knowledge before teaching the class as she said, "I study the content, make sure the content first. I study the courseware also before I show to them." (I#1/Catherine). She further expressed,

...most challenging this is you have to be strong in your theory thing because this one you cannot teach them wrong things...

(I#1/Catherine)

Dennis revealed that apart from reading the textbook and reference books, he also did some mental preparations like asking himself questions such as "what to teach?", "how to teach the topic?" and the like. This implied that he considered both the 'what' which is content knowledge and 'how' which is pedagogy while doing his lesson planning. He claimed that he did not worry too much about his content knowledge although he said he still needed to read the textbook and reference books before teaching his lessons as he expressed:

...must read...have to. Sometimes we forgot the basic thing, I need to do for chemistry too. That is our preparation, the chemical formulas...things in Form 4 and Form 5 were not the same, we all know, but for us to rewind, as for the concept, once we see we will

understand. Our constraint...what do we want to give to our students...to give our students what we understood...
(I#1/Dennis)

By comparison, Andy possessed the best content knowledge among the four chemistry teachers as evidence from the delivery of in-depth and wide range of chemical facts. For example, he was the only teacher who told students about the existence of the macroscopic, sub-macroscopic and micro-levels chemistry and the content was not included in the syllabus. In order to explain to students how and why carbon-12 was chosen as the standard atom in the atomic scale, he told them the history of the development of the atomic scale (Appendix G).

He also reminded the students to appreciate scientists' contribution, highlighted the importance of the science process skills, creative and critical thinking skills and soft skills like communication in his explanations. He stressed that,

Science supposed to make life better generally, and they (students) have to appreciate science, that is the contribution of science toward better man or mankind generally.
(I#4/Andy)

4.3.2.2 Pedagogy

Another component which all four teachers regarded as essential was pedagogy. Andy interpreted pedagogy as how a teacher delivered his/her lessons and he added,

Sometimes you need ICT, sometimes you need 3D materials, sometimes you need to do experiment but it does not mean something that is workable for a teacher is also workable for another teacher. It must suit the style of the teacher.
(I#3/Andy)

He admitted he used “chalk-and-talk” most of the time in his teaching, although he sometimes used group work, laboratory work, inquiry discovery and discussions. It was noted that he did engage courseware and “chalk-and-talk” all the time while teaching topic 3.

Bryan seriously considered the way he delivered his lessons and he said he preferred to teach by interacting with the students and let them “play”. He said

They are not interested in theory...you must bring them to play a bit otherwise they get stressed when you deliver your content. They felt boring too.

(I#3/Bryan)

In addition, he also agreed that teachers should give students chance to talk in order to learn. He emphasized on teaching according to the abilities of the students, “...some of them I think maybe they are slow learner, so we need to slow, follow them...” (I#3/Bryan).

He also stressed that,

...for the good students you can use the activities suggested in the textbook. For the average and weak ones sometimes difficult also, cannot work, so how to do, you have to use your own way, make sure that they understand and they can master the concept.

(I#3/Bryan)

Although he mentioned that he used laboratory work, showing power point slides using Liquid Crystal Display (LCD) projector and discussion most of the time and “chalk-and-talk” sometimes, it was noted that he engaged both power point slides and “chalk-and-talk” all the time to deliver the content for topic 3. Besides that he also asked students to do experiments. His reason for not varying his teaching methods was that,

...sometimes I don't use some approaches from other people and their techniques, when I try to apply sometimes cannot work that's why I don't want to use.

(I#4/Bryan)

Catherine viewed pedagogy of equal importance as content knowledge.

To her, a teacher with good content knowledge but failed to deliver his/her lesson well is not an effective teacher,

Of course the knowledge of chemistry content, you must know, if you have knowledge of chemistry and you don't know how to teach, no use...

(I#3/Catherine)

She said that she often used mastery learning and contextual learning and she had her own interpretation on mastery learning:

In the class really "chalk-and-talk" and then exercises and then sometimes in class discuss the previous experiment. I want to discuss every experiment right after it, the next day or the next class. They know one, once experiment finish they know how to do the report already. I told them must do like this, before they do report I go detailed with them. The next period, report ready, very good they know. Done, finish, then did I confuse them? Done, any questions, no? Then I go on. I never that one leave them alone. That is mastery learning.

(I#4/Catherine)

Based on her explanation, she would check whether she had confused the students and if they did not have any questions about the concept then they had attained mastery leaning. She also said that she often used group work, cooperative learning, presentation, laboratory work, courseware and discussions in her lessons. The choice of a teaching method depended on the students' ability, the prior knowledge of the students and the content. Based on the feedback from Catherine,

I have to see the topic. If the topic require experiment, that I will go the lab, that time I must do my experiment. I decide the activity of the experiment, if the experiment is

short, only one period then another period with power point, and explain that was in the lab.

(I#2/Catherine)

Besides that she also engaged textbook and courseware upon the requirement of the policy. She said,

First priority I have to use the lap top (courseware). This is the requirement so I have to fully utilize them. Then I need to touch the text book also, and the practical book also, actually I don't have much choice, the text book and lap top (courseware) to support to help me to know more and I want to make reference, I use the reference books more for theories.

(I#2/Catherine)

Catherine chose group work and group presentations to overcome her class discipline problems and at the same time to save time for marking. For instance, by doing group presentation, it was observed that all the students paid attention to their friend. From the answers presented by their friends together with the feedback of Catherine, they did the correction on their exercises on the spot. Subsequently, Catherine only needed to tick their exercise and report when they sent in. In brief, Catherine did not have to do the job redundantly as what she did previously was, she marked and corrected students' mistakes and then she returned the exercises to her students, they had to do the correction and sent in again for her to check.

While doing his mental preparation, Dennis often asked himself three questions: "how to teach the topic?" "how to overcome the time constraint?" and "how to tell the story?" He listed group work, cooperative learning, presentation, laboratory work, courseware and discussion as the teaching methods used in his lessons. He mentioned that choice of the teaching methods was based on the schedule in the school. For instance, when he had more time, he would do more laboratory work or gave more elaborations on the topic.

Otherwise, his priority was to cover the syllabus rather than students' understanding. He mentioned:

...more to keep up with the syllabus and time. Students, if we do not touch on the topic, if we don't teach...comes out in exam their excuse is that the teacher did not teach, therefore they failed the exam, they will say the teacher did not teach. If we touch on the topic, even though they don't understand, they had no excuse. It is better we teach according to schedule, following the class time, following the exam time, if want to ensure understanding, slow...
(I#4/Dennis)

He recalled he picked up his pedagogical skills from a few sources such as by observing his teachers' teaching during school time, based on his own creativity and thinking and from reference books.

...ways to teaching? We observed teachers teach... our experience as a student...taught by 6-7 teachers in a year. Different people different styles and ways, we take a bit here and there. Sometimes the ideas came out by itself. Like the analogies, the teachers never taught that kinds of things, we think and figure it out. Sometimes we got it from the book.
(I#4/Dennis)

3.3.2.3 Students

Andy, Bryan and Dennis considered students as another essential component in their teaching but their concerns varied. As mentioned in the earlier section, Andy emphasized on the motivation of his students which consisted of "external" and "internal" motivation. He referred "internal" motivation to the personal goal of individual student such as what they want to do, their goal and their ambition. "External" motivation on the other hand refers to the recognition given/awarded to the students with outstanding performance by the school, banks and also local associations in the form of "prizes" and incentives. He believed that in comparison, the "internal" motivation was a greater driving force to the students than the "external"

motivation. Subsequently, he also mentioned that that both students and teacher needed some driving force in the forms of incentives and self-motivation to attain effective teaching and learning.

According to Andy, for students to learn effectively, they needed to have the right attitude, be self-motivated, mentally-ready, interested, well-prepared, hard-working and receptive to teachers' teaching (Figure 4.1). He added that all teaching would be in vain if the students were not receptive though he also accepted the fact that he could not force students to learn. Andy expressed high expectation of his students. He had a tendency to say students should know this and that. For instance he said,

Students must be able to tell the given substance exists as a molecule or ionic compound so whether they should give RFM or RMM, you see, they need to know that...
(I#3/Andy)

he added,

There are some experiments the students have to do and from the experiment they need to experience, you know, how scientists go through deriving the empirical formula, they have to learn that, you know, taking measurements, you know, and do the calculations and finally deriving the empirical formula and then from the empirical formula how they get the molecular formula, that one is important. I think they need to experience all that then this is meaningful...
(I#3/Andy)

Andy stressed that besides students, he needed motivation too. He would be motivated if the school authority could tell him how to improve his teaching. According to him, the fastest way for a teacher to improve teaching was through the feedback on the classroom observations made by the school authority and the school inspectorate. He looked forwards to the school authority and the inspectorate for conducting more classroom observations on his teaching.

Bryan felt that the type of students determined how a teacher taught. Whether he used a “rough” or “smooth” way depended on the class. A “rough” way (by force) was used to control the class but most of the time he said he used a “smooth” way (through negotiation and a friendly approach). He knew the ability of his students therefore he cracked jokes and used humour to sustain their attention. The atmosphere in his class was lively and friendly to the extent that he even teased the student (Caroline, not her real name):

Bryan : Ok never mind, continue with this...it is already given. So what is your answer Caroline?
Students : NH_4 ah... and...
Bryan : Shhhh... I want to ask Caroline. If you don't know how to write the chemical formulae you just read what I had given. What is your answer Caroline?
Caroline : I don't know teacher.
Bryan : You not only got carried away by the tide, you got carried away by the bus. Izwan? What is your answer?... answer?
Caroline : NH_4Cl ...
Bryan : NH_4Cl . What is the... its name? Its name? I had written it, read only...

(CO#4/Bryan)

When asked to describe his students' abilities, Bryan said, his students were not even average as some of them got grade D for their science in PMR and they were very weak in basic science and maths. As a result he had to teach from the basics and step-by-step without any short-cuts besides cracking jokes once in a while to sustain their attention.

Dennis considered class control and students' interest as the two most important components of his teaching and they were interrelated. He repeatedly stressed that class control was the most basic aspect of teaching as a teacher who could not control the class would not be able to teach properly. He suggested the first thing to do to control the class was to attract the students' attention through various means such as cracking jokes and using interesting set induction:

First thing is discipline control, how are we going to control our class. We want to attract the attention of the students. When entering the class, the students were still no ready, therefore we use induction set, as for me I like to joke...we had attracted their attention only then we go to what we want to teach..."

(I#3/Dennis)

Dennis has a nephew who was around the age of his students, as such he tried to incorporate some of the favourite topics such as electronic games and 'pop' music from his nephew's conversation into his teaching. He claimed that being able to talk and share something in common with his students helped him to attract their attention and interest.

Like now, I have nephew who is more or less of the same age with the students, so what he always mentions could be put into our teaching and learning. If games, what is the latest games? We touch on games, the kids respond quickly, song...what is the recent song? I often make humour because their thoughts are similar, right?

(I#3/Dennis)

And once the students paid attention to him then it would be easier for him to control the class.

4.3.2.4 Conducive environment

Andy and Bryan believed that a conducive environment supported the teaching and learning process. However, they had different definitions of a conducive environment. To Andy, a conducive environment is one where the teachers faced little or no obstacles and problems in their teaching; a place where teachers could focus on their teaching without been burdened by a heavy non-teaching work load. However, he also admitted that it was impossible to attain that ideal situation in reality as teachers have to deal with lots of paper-work nowadays.

Bryan defined a conducive classroom as one equipped with sufficient facilities such as the LCD, science apparatus and equipment. Bryan felt that a well-equipped laboratory ensured smooth teaching without disturbance. School B was well-facilitated with three laboratories including the Chemistry laboratory. Due to the location of this laboratory, it was conducive for learning as there was very few people passing by the laboratory therefore there was very little disturbance during the lessons. Bryan preferred to stay put in the chemistry laboratory whole day regardless whether he had class or not.

4.3.2.5 Government policy and curriculum

Unlike the other three Chemistry teachers, Andy considered government policy and curriculum as essential components of his Chemistry teaching. He said,

...the government policy is also important. Now lately, in the paper it was reported there is a general decline of interest among students in science and math. One of the contentions is that they said that in the civil service, most of the top management posts are occupied by those doing arts not the science students. So that is one area I think where policy can affect the interest and motivation of students doing science... Don't tell me science students cannot be good manager.

(I#1/Andy)

He observed that the top management posts in the government sectors were often held by the non-science graduates. The trend might lead to the general lack of interest among students to enrol in the science stream. Furthermore, he commended that the science subjects Biology, Physics and Chemistry, were often tougher and more congested than the arts subjects. Hence, students encountered more difficulties learning the science subjects than the art subjects.

Andy stated that a teacher's teaching was guided by the National Philosophy of Education (NPE) and Chemistry Curriculum Specifications. He explained that he preferred to refer to the Chemistry Curriculum Specifications rather than the syllabus for content, objectives, learning outcomes, and activities when preparing his lessons as he could find almost everything there.

4.3.2.6 Parents and school authority

Bryan also considered parents and school authority as essential components of his teaching. He anticipated parents could play an important role in motivating their children to learn. He thought that it would be beneficial if the teachers and parents worked together to look into the learning problems of the students and gave necessary help and encouragement. He believed that his students preferred to listen to their parents therefore the school should make use of the situation. He commented students with concerned parents created fewer problems in class.

Similar to Andy, Bryan believed that the school authority should inculcate motivation among the teachers. Bryan proposed that the school authority should have more two-way communication, be more considerate and willing to listen to what the teachers said and how they felt. For instance, the school authority should give comments and suggestions on his lesson plans that he sent in every week so that he could improve himself. He expressed his disappointment as the school authority never gave any comments on his lesson plans.

4.3.2.7 Thinking skills and science process skills

Catherine felt that it was important for a teacher to include thinking skills (critical and creative thinking skills) and science process skills in the lesson plans. To her, the science process skills were closely related to the thinking skills. She admitted that the only way to incorporate the critical and creative thinking skills was through questioning. When asked whether she emphasized the thinking skills, she said, “Thinking skills we always write it down in the lesson plan, KBKK, noble values also, asking questions, make them thinking, no more than that.” (I#5/Catherine).

As for the science process skills, she explained that,

Process skills is during experiment, like doing analysis...related to KBKK, making hypothesis, finding variables, this is applied during the experiment.

(I#5/Catherine)

The science process skills were especially important when doing the experiments for PEKA project. Other than that the science process skills and the thinking skills were more like requirements written in the lesson plan.

4.3.3 The learning difficulties of students

In topic 3, the students had to learn the relationship between the mole concept and the three entities consisted of the molar volume, number of particles (Avogadro's number) and molar mass. In the same topic they had to learn how to calculate the empirical and molecular formula besides synthesizing the chemical formulae, chemical equations and finally solving the stoichiometric problems. As a whole topic 3 consists of a lot of calculations.

None of the four teachers mentioned their student knowledge related to the learning difficulties and misconceptions of students on topic 3 as essential

components of their teaching. However, when asked, they listed some learning difficulties which they anticipated encountered by their students.

Andy noted that his students encountered learning difficulties on four concepts in topic 3: the mole concept, chemical equations, molar volume and calculations involving two or more quantities and stoichiometry. He estimated that about eighty percent of topic 3 was related to calculations thus he expected his students would encounter problems when doing the calculations especially those involved volumes and also two different quantities such as converting from mass to number of particles. He mentioned that most students would face this kind of problem when they needed to involve two different quantities. He showed some uncertainties while listing the learning difficulties of the students,

...I think maybe for this molar volume, as far as...maybe because these molar volume...these molar volume... because we can use 22.4 or 24, right? And some more gas is very...something that you seldom deal with of. Mass and number of particles...number of objects, these types of quantities they are more familiar, you know but volume, I think...er...to them, they don't deal so much with volume, maybe that will be a bit of a problem for them...

(I#5/Andy)

Other than that, the students had difficulties in balancing chemical equations. He also mentioned that,

First...balancing is maybe problematic for some students, second will be the calculations. They cannot balance, you know, even some of them can write the chemical formulas, you know, for each of the products, for each of the reactants and products but they cannot balance...

(I#5/Andy)

Based on his observations, the main reasons why the students encountered learning difficulties were: students did not have strong maths foundation, they could not apply what they had learned and they were lazy.

Bryan perceived his students encountered learning difficulties in five areas of topic 3: mole concept, chemical formula, chemical equation, molar volume and calculations. The mole concept referred to the conversion of three entities, that is volume, number of particles, and mass into “number of moles” and vice versa. Bryan said, “Two molar volumes sometimes make students confused but they cannot do volume maybe because they don’t understand the number of particles and molar mass.” (I#4/Bryan). In addition, he also thought that his students also could not memorise the charges of the ions,

...the problem them not remembering...if for me, it is most important for them to remember the cations and the anions, right? Have to, there is no other way no matter how you need to memorize, that is the only way. If they do not know, it would be difficult for them to say lead (II) which is very common still they didn’t know what is that...

(I#4/Bryan)

Besides that he also realised that the students did not know the chemical formulas and were confused of the ions and their charges, he said that if the students did not know the chemical formula for a substance then they would be able to proceed with the question. He commented the concept was not difficult provided they could memorise the chemicals symbols charges of the ions. Bryan anticipated that his students faced difficulties in doing the calculations and writing the chemical equation because they were poor in basic mathematics and had not learned the periodic table. He believed that I would be better if the students learned about the periodic table before learning topic 3 so that they knew the charges of the cations and anions.

When asked what problems encountered by her students while learning the concept mole, the immediate response given by Catherine was: they were lazy, not paying attention, and they could not memorise the chemical formula.

She perceived her students encountered difficulties in five chemical concepts in topic 3, namely chemical equations, chemical formulae, the mole concept, molar mass and molar volume. She expressed her worries that,

...even they get the number of moles correct some of them don't know to convert to the ratio of mass. Then the next one instead of using the figure Avogadro's constant, they only use N_A , they don't understand the question, instead of that 6.02...two marks gone...

(I#5/Catherine)

In addition, she expressed,

After the students know the relationship between the various entities, they always make mistakes while trying to simplify and solving the problems...

(I#5/Catherine)

On the other hand, she was confident that the students could solve the direct questions but not those problems involved two-step conversion such as converting mass into volume or number of particles. To her, the calculations was simple only if the students could interchange or manipulate the mathematical formulas.

Dennis perceived that his students encountered three difficult concepts: synthesising chemical formulae, balancing chemical equations and solving stoichiometric problems. When asked which concepts the students often encountered problems and difficulties. He said,

I feel that the calculations...not many problems if formula is not given, they can calculate, that is what I often mentioned that those without mathematics problem will be able to understand, those with mathematics problems will have difficulty in understanding. But overall, it is because they don't memorize the formula. Balancing the equation is also a problem...

(I#4/Dennis)

The reason why his students could not synthesize the chemical formulae was that they could not memorise the chemical symbol of anions and

cations and the charge/s. As for the calculations, the students could not memorise the mathematical formulas or the algorithms. Furthermore, they had problem in doing the proportionality calculations. For example, he said,

...if it is like calculations, sometimes they got it interchangeably $x/b=c/d$, sometimes they write b/c . That answer is wrong. They got confused on how to calculate x . Sometimes they interchange $x/b=c/d$.

(I#4/Dennis)

The learning difficulties of the students as perceived by the four teachers are summarised in Table 4.3.

Table 4.3

Students' Learning Difficulties as Anticipated by the Chemistry Teachers

Andy	Bryan	Catherine	Dennis
Chemical equation	Chemical equation	Chemical equation	Chemical equation
Molar volume	Molar volume	Molar volume	Molar volume
Mole concept	Mole concept	Mole concept	
	Chemical formulae	Chemical formulae	Chemical formulae
Stoichiometry	Calculation	Molar mass	Stoichiometry

Based on the students' learning difficulties shown in Table 4.3, it was clear that all the four teachers perceived the writing of a balanced chemical equation, calculations involved molar volumes specifically and calculations involving the mole concept and stoichiometry as learning difficulties commonly encountered by their students. Catherine was quite sure of what caused the problems to the students such as they cannot do the conversions and simplification. The rest of the teachers gave reasons such as students were lazy, they could not memorise the formulas, they don't know the formula, they were very weak in basic maths, one could infer that they did have some ideas of the

problems and learning difficulties encountered by their students, however, they were yet to precisely and specifically point out what was the real problems. For instance, if the students could not balance the chemical equation, was it because they did not know the chemical formula, or they did not understand the meaning of coefficient, the subscripts and the brackets in the chemical formulas.

4.3.4 The representations used by the chemistry teachers

None of the teachers mentioned the transformation of content knowledge using representations as their essential component of teaching chemistry. Based on the field notes taken during the classroom observations and through the oral delivery of the teachers, the representations used by the teachers were identified (Table 3.6, p. 120). Based on the classroom observations, the teachers seemed to engage a wide range of representations in their teaching. The representations were categorised into explanation, question and lab work. Further discussion on the representations used by the teachers will be presented under the section instruction.

Although the teachers claimed that they did not know PCK, they did have conceptions on teaching and the essential components of their teaching which could be inferred as their conceptualization of PCK. In comparison, Andy seemed to display the most number of constructs which influenced and related to his teaching and students' learning suggesting a wider view on teaching. Most of the factors mentioned by the teachers seemed to concur with the knowledge bases of effective teaching proposed by Shulman (1987). Bryan and Dennis incorporated their indicators in assessing successful teaching in their views of teaching. However, there was no evidence of their applications

in teaching topic 3. The four Chemistry teachers displayed some of their views in their teaching. For example, Andy gave incentive to motivate his students to answer the quiz while Catherine engaged group work and group presentations in her class as well as facilitated the presentations by showing the correct answers.

All the four Chemistry teachers considered content knowledge and pedagogy as essential components of their learning and gave their justification why the components were essential in their Chemistry teaching. Besides the two components, they also thought that other components such as students, conducive environment, motivation, government policy, curriculum, school authority, parents, thinking skills and science process skills were also important in their teaching.

None of the Chemistry teachers considered the transformation and representations of the content knowledge and the learning difficulties encountered by their students as the essential components of their teaching. The researcher had to ask them to provide information on the said issues.

There was a great similarity among the learning difficulties encountered by the students as perceived by the four Chemistry teachers suggesting their students encountered the same learning difficulties. They were balancing chemical equations and calculations involving the molar volume. However, the four Chemistry teachers failed to elaborate specifically the learning difficulties of their students.

To sum up, the four Chemistry teachers considered content knowledge and pedagogy as the two most important components in their teaching. Other than that, they also considered students, conducive environment, policy,

curriculum, school authority, thinking skills and science process skills as essential components of their teaching.

4.4 The teaching processes of the chemistry teachers

This section presents the teaching process of the four teachers, how they actually carried out their PCK in their teaching. The teaching process consisted of three phases: the pre-active phase, the interactive phase and post active phase of teaching. It involved what the four teachers did before, during and after delivering their lessons.

4.4.1 The preactive phase

4.4.1.1 Preparation

The preparation done by the four teachers involved writing the yearly scheme of work, daily lesson plans, getting familiar with the content knowledge through reading the textbook and reference books, preparing teaching resources/materials, previewing the courseware, preparing the lab work, and trying out the questions in the exercises.

4.4.1.2 Yearly scheme of work

The four teachers prepared a yearly scheme of work at the beginning of the school year. It was compulsory for all the teachers to write their scheme of work and submit to their superior to be checked one month after the school reopened. Coincidentally, great similarity was noted between the scheme of work of Andy and Dennis (Figure 4.2 & Figure 4.3 respectively) and that of Bryan and Catherine (Figure 4.4 & Figure 4.5 respectively).

Chapter and learning outcomes	Activity/Extra activity	Science process skills/ thinking skills	Scientific attitudes and noble values
Chapter 3 Chemical Formula and Chemical Equation			
3.1 Relative atomic mass and relative molecular mass	Extra activity Calculate the relative molecular mass of substances.	Analysing	Being systematic
3.2 The mole and the number of particles	Extra activity Solve numerical problem to convert the number of moles to the number of particles of a given substance and vice versa	Analysing	Having critical and analytical thinking

Figure 4.2. An excerpt of the yearly scheme of work of Andy

Week /date	Chapter and learning outcomes	Activity/extra activity	Thinking skill	Scientific attitudes and noble values
	Chapter 3 chemical formulae and equations			
	3.1 Relative atomic mass and relative molecular mass	Extra activity Calculate the relative molecular mass of substances	Analysing	Being systematic
	3.2 The mole and the number of particles	Extra activity Solve numerical problem to convert the number of moles to the number of particles of a given substance and vice versa	Analysing	Having critical and analytical thinking

Figure 4.3. An excerpt of the yearly scheme of work of Dennis

Theme : Matter around Us
 Learning area : 3. Chemical Formulae and Equations

Week No.	Learning Objectives	Suggested Learning Activities	Learning Outcomes	Thinking Skills and Scientific Skills	Scientific attitudes and noble values	No. of Periods	*Rks.
6 6/2 – 11/2	3.1 Understanding and applying the concepts of relative atomic mass and relative molecular mass	Collect and interpret data concerning relative atomic mass and relative molecular mass based on carbon-12 scale	A student is able to: <ul style="list-style-type: none"> state the meaning of relative atomic mass based on carbon-12 scale 	Observing Classifying Relating	Having an interest and curiosity, thinking rationally	2	

* Rks. - Remarks

Figure 4.4. An excerpt of the yearly scheme of work of Bryan

Theme : Matter around Us
 Learning Area : 3. Chemical Formulae and Equations

Week No.	Learning objectives	Suggested learning activities	Learning outcomes	Thinking skills and scientific skills	Scientific attitudes and noble values	No. of periods	Remarks
	3.1 understanding and applying the concepts of relative atomic mass and relative molecular mass	Collect and interpret data concerning relative atomic mass and relative molecular mass bases on carbon-12 scale.	<ul style="list-style-type: none"> A student is able to: state the meaning of relative atomic mass based on carbon-12 scale 	Observing classifying Relating	Having an interest and curiosity Thinking rationally	2	

Figure 4.5. An excerpt of the yearly scheme of work of Catherine

The content in the two yearly schemes of work of Andy and Dennis were exactly the same in terms of the content: (i) chapter and learning outcomes; (ii) activity/extra activity; (iii) science process skills and thinking

skills; and (iv) the scientific attitudes and noble values. The activities listed were similar to those suggested in the text book and practical book (Low, Lim, Eng, Lim, Umi Kalthom binti Ahmad, 2005). It was noted that the two yearly schemes of work were actually adopted from the sample scheme of work given in a reference book.

On the other hand, the yearly scheme of Bryan and Catherine were similar except Catherine did not put in the time frame. Initially Bryan prepared his own yearly plan based on the Chemistry Curriculum Specifications and textbook. Later on, he used the yearly scheme obtained from a senior chemistry teacher from the same zone. The yearly scheme of work contained components such as (i) week number (no.); (ii) learning objectives; (iii) suggested learning activities; (iv) learning outcomes; (v) thinking skills and scientific skills; (vi) scientific attitude and noble values; (vii) number of periods; and (viii) remarks.

Catherine said her yearly scheme of work was obtained from a senior chemistry teacher and was prepared based on the Chemistry Curriculum Specifications. The learning objectives, suggested learning activities and learning outcomes were taken from the curriculum specifications. Other information included the number of weeks, thinking skills and scientific skills, scientific attitudes and noble values, number of periods and remarks. She was the only teacher who made use of the scheme of work. She said that during her lesson preparation, the first thing she needed to refer to was the yearly plan as it contained many learning outcomes which was very helpful. Then she chose the learning outcomes which depended on the students. She added further that she followed the yearly plan most of the time so that she did not miss anything.

The four teachers were teaching in different schools and they did not know each other. The similarity in their yearly scheme of work suggested that

they were obtained from the same sources that is, from the senior teachers and from the reference book. It was a common practice in the schools that the experienced teachers shared their yearly scheme of work with the novice teachers. The novice teachers then adopted the yearly scheme of work by making necessary changes. The same yearly scheme of work would be used by the teachers year after year by changing the date and week. Additionally, although the scheme of work of the teachers were obtained from two different sources, they were similar in terms of the sequence of topics, learning objectives, learning outcomes and the learning activities most probably due to the centralised curriculum.

By comparing the content of the yearly scheme of work of the four teachers, the yearly scheme of work of Bryan and Catherine contained more information like date, number of periods and remarks (Table 4.4).

Table 4.4

Content in the Scheme of Work of the Chemistry Teachers

Content in scheme of work	Andy	Bryan	Catherine	Dennis
Date		√	√	√
Week		√	√	√
Chapter	√			√
Learning objective		√	√	
Suggested learning activities/ activity/extra activity	√	√	√	√
Learning outcomes	√	√	√	√
Thinking skills and scientific skills	√	√	√	√
Scientific attitudes and noble values	√	√	√	
No. of periods		√	√	
Remarks		√	√	

A few things were noted in the scheme of work of the teachers:

- (a) none of the four teachers put in their school activities and events such as examination and public holidays into their scheme of work;
- (b) none of the four teachers made any remarks or reflection on the scheme of work after carrying out their lessons; and
- (c) they could not follow exactly all the activities suggested due to time constraints and the availability of the facilities.

To conclude, the writing of the yearly scheme of work by the four teachers was more of a routine requirement of the school authority that they needed to fulfil.

4.4.1.3 Daily lesson plan

Andy regarded preparation as essential before delivering his lessons. His lesson preparation focussed more on the content knowledge, teaching resources, lesson plans, students and the environment. However, he admitted that most of his preparation was done mentally as he spent more time thinking of the new examples and figuring out how to present his lessons. Andy wrote his daily lesson plan in the record book which he sent to his principal to be signed weekly (Figure 4.6).

<i>Rekod Kerja Harian [Daily Work Plan]</i>	
<i>Minggu yang ke- [Week no.]</i>	<i>Hari [Day] : Wednesday</i> <i>Tarikh [Date] : 28/3</i>
<i>Masa/Kelas/Mata pelajaran [Time/Class/Subject]</i>	<i>Tajuk/Objektif/Aktiviti [Topic/Objective/Activity]</i>
Chemistry 4 Sains [Science]	Learning Area (LA): 3 Chemical formulae & Equations 3.6 Chemical Equation Learning Outcomes: 1. Balancing a chemical equation 2. Numerical problems involving stoichiometry Activities: 1. Recalling the steps in writing a balanced chemical equation 2. Discussing steps in stoichiometry (i) Writing a balanced chemical equation (ii) Determining the quantities involved (iii) Comparing the mole ratio (iv) Using appropriate formula 3. Guided problem solving Resources: Hand out: photostated task sheet

Figure 4.6. A sample of the daily lesson plan of Andy

The lesson plan of Andy contained learning area (LA), learning outcomes, activities, and teaching resources. Andy listed two out of the five learning outcomes in the curriculum specifications due to limited space although he planned to cover all the five learning outcomes. It was observed that for that particular lesson, he only managed to achieve the first learning outcome in the said lesson. As a result he had to postpone the second learning outcome: the “Numerical problems involving stoichiometry” to the next lesson. He decided to make such changes because he realised that his students needed more time to learn how to balance the chemical equations. The incident suggested that

Andy taught his lessons with flexibility and he made necessary adjustment on the lesson plan based on the progress of his students.

Bryan said that he often began his preparation by referring to the Chemistry Curriculum Specifications. He did not write his lesson plans in the record book, instead he kept all his lesson plans in the form of soft copies in the computer. The lesson plans were compiled in a file and sent to be checked by the school authority weekly. Bryan commented that by keeping a soft copy of the lesson plans in the computer made it convenient to be retrieved, modified and changed in the future (Figure 4.7).

Basically, the lesson plan of Bryan contained learning objectives, activities, thinking skills, noble values, teaching materials/aids, and reflection. Most of the information was extracted from the Chemistry Curriculum Specifications such as the learning objectives, thinking skills and noble values. Bryan viewed the writing of lesson plans as a routine requirement which he had to hand in to be checked by the school authority. Bryan was disappointed with the school authority as they never put any comments in his lesson plans. Actually, he looked forward to some constructive suggestions from his superior to improve his lesson plan and teaching. Bryan placed a template for reflection at the end of his lesson which he just ticked on the relevant boxes.

Lesson plan																
Date & Day	19 April/Thursday															
Time	0800 – 0920															
Class	4K															
No. Of Students	27															
Subject	Chemistry															
Topic	Chemical Formulae and Equations															
Objectives	The students are able to: <ul style="list-style-type: none"> a. Identify the reactants and products of a chemical equation b. Write and balance chemical equations 															
Activities	a. Activity 3.2 : Chemical equations															
CCTS	<ol style="list-style-type: none"> 1. Relating 2. Making inference 3. Making conclusions 															
Noble Values	<ul style="list-style-type: none"> • Being honest and accurate in recording and validating data • Appreciating and practicing clean and healthy living 															
Teaching Material	Text-book, reference books & worksheet															
Teaching Aid	LCD, power point slides															
Reflection	<table border="1"> <thead> <tr> <th></th> <th>Reflection</th> <th>Yes/No</th> </tr> </thead> <tbody> <tr> <td>(i)</td> <td>Did all students understand the instruction?</td> <td></td> </tr> <tr> <td>(ii)</td> <td>Were the resources appropriate?</td> <td></td> </tr> <tr> <td>(iii)</td> <td>Were the students able to complete the set task?</td> <td></td> </tr> <tr> <td>(iv)</td> <td>Could the lesson be improved?</td> <td></td> </tr> </tbody> </table>		Reflection	Yes/No	(i)	Did all students understand the instruction?		(ii)	Were the resources appropriate?		(iii)	Were the students able to complete the set task?		(iv)	Could the lesson be improved?	
	Reflection	Yes/No														
(i)	Did all students understand the instruction?															
(ii)	Were the resources appropriate?															
(iii)	Were the students able to complete the set task?															
(iv)	Could the lesson be improved?															

Figure 4.7. A sample of the daily lesson plan of Bryan

The lesson plan of Catherine contained the theme, the learning area, learning objectives, learning outcomes, activities, thinking skills and science process skills, scientific attitudes, noble values and reflection (Figure 4.8).

Lesson plan	
Time	Date: 19 April Day: Thursday
8, 9 4C	Subject: Chemistry
	Theme : Matter Around Us
	Learning Area: 3. Chemical Formulae And Equations
	L/Objectives : 3.6 Interpreting chemical equations
	L/Outcomes : Students are able to:- (a) State the meaning of chemical equations (b) Identify the reactants and the products of a chemical equation
	Activities:- T&L using LCD & courseware Act. 3.6 (Experimenting)
	Thinking skills & science skills: Observing, interpreting data
	Science attitude and noble values: Being systematic
Reflection: A few students were restless but overall, good response	

Figure 4.8. A sample of the daily lesson plan of Catherine

It was noted that she followed closely the learning outcomes in the Chemistry Curriculum Specifications. For the said lesson, she listed only two out of the five learning outcomes due to limited space as she needed to write two to three lesson plans every day. As a result, she had to keep the lesson plan brief, as she explained.

Dennis prepared the daily lesson plan which he submitted to the school authority weekly. His daily lesson plans contained learning topic, learning objectives, learning outcomes, and reflection (Figure 4.9).

Lesson plan	
Class	4 Sains1
Subject	Chemistry
Learning topic	Chemical formulae and Equation
Learning objective	Interpret chemical equation
Learning outcome	(i) write chemical equation (✓) (ii) interpret chemical equation quantitatively and qualitatively (✓) (iii) Solve numerical problems using chemical equation (?)
Reflection	Students still 'have problem' in solve numerical problems (<i>sic</i>).

Figure 4.9. A sample of the daily lesson plan of Dennis

At the end of the lesson, he went through his learning outcomes to check whether he had achieved them. In the said sample, he only put a tick beside learning outcomes (i) and (ii) indicating he had achieved them. On the other hand, he put a question mark at learning outcome (iii) indicating he had not achieved it. Subsequently, he wrote “Students still had problems in solving the stoichiometric problem” in his reflection and he decided to re-teach learning outcome (iii) in the following lesson.

All the four teachers wrote their daily lesson plans. Sometimes they wrote their daily lesson plans after they had conducted the lessons due to their busy schedule. The teachers did not write their daily lesson plans in detail due to the fact that they had to write two to three lesson plans a day and also the space was limited. Differences were noted in the content of the lesson plan of the four teachers suggesting that there was no standard format (Table 4.5).

Table 4.5

Content in the Daily Lesson Plan of the Chemistry Teachers

Andy	Bryan	Catherine	Dennis
Date and day	Date and day	Date and day	Date and day
Class	Class	Class	Class
Subject	Time (duration)	Subject	Theme
LO/A	No. of students	Theme	LO/A
Activities	Subject	LO/A	LO
LO	Topic	Activities	Reflection
Teaching resources	LO/A	LO	
Reference	Activities	TS and SS	
Task	TS and SS	SA and NV	
	SA and NV	Task	
	Teaching resources	Reflection	
	Reference		
	Reflection		

* LO/A – Learning objective/Area

LO – Learning outcome/s

TS and SS – Thinking skills and scientific skills

SA and NV – Scientific attitudes and noble values

Comparatively, the daily lesson plan of Bryan was more detailed than the rest of the teachers. This is most probably because he typed his lesson plans using the computer and printed them. Thus he did not encounter the ‘limited space’ problem. Furthermore, he could retrieve and make use of the previously saved lesson plans to prepare his lesson plans by making modification. It saved him a lot of time. On the other hand, Dennis’s lesson plan contained the least number of items and there was no activity. This is most probably because he followed entirely what was in the content of the courseware.

A few things were noted in the lesson plans of the four teachers, namely

- (a) Bryan used learning objectives and learning outcomes interchangeably;

- (b) only Bryan and Catherine wrote thinking skills, science process skills, scientific attitudes and noble values in their daily lesson plan; and
- (c) all the teachers wrote reflection after their lessons except Andy.

It was also noted that the four teachers did not necessarily carry out all the things they wrote in their daily lesson plans. For instance, although they wrote the thinking skills and science process skills, it was noted that they did not emphasize them.

4.4.1.4 Preparation of content knowledge

Although an experienced teacher, Andy still had to read the content before teaching. He said,

...you still have to read through also...have to read because one year ago, you have to think also, sometimes it gets rusty...

(I#4/Andy)

He further remarked that,

Textbook is just to make sure you don't leave out any important concepts...but normally I don't use textbook, just to refer what are the main topics I need to cover.

(I#4/Andy)

Besides that, as mentioned earlier, Andy possessed an in-depth and a wide scope of knowledge of chemistry, he acquired the current knowledge of chemistry through reading the science column in the newspaper and also science magazines. He stated,

I read newspaper, they had some articles on science...like the Borneo Post and Strait Times. You just try to read to get ourselves updated. I also subscribe to this 'TIMES' and National Geographic...

(I#4/Andy)

Bryan put priority on content knowledge in his teaching. He believed in reading a lot of content before going into the class as he said,

If you are not ready and you go to the class...I don't want students to tell me "you are wrong" especially in the town school...

(I#4/Bryan)

Bryan mentioned that he picked up most of his chemistry content knowledge during his degree program. At the same time he also collected a lot of chemistry reference books which he found useful when he started teaching the subject and also using English as the medium of instruction.

For me...that day when they made the change like that (the policy), I feel as if I am back to university time, I learned chemistry in English again because a lot of the reference in the university were in English. As for the chemistry content, I know lots in English, so I am confident in the content...not a problem... The only thing is how to present to the students...do they understand, that cause me a big headache. Another thing, if you don't tell them the right sequence and sometimes your language is not precise, a little misunderstanding might cause them to make mistake in the whole calculation as they don't understand the concept...

(I#3/Bryan)

Comparatively, Bryan needed to do a lot of reading to prepare his lessons in his first year of teaching chemistry and for that purpose he also purchased many reference books. With the changing of the medium of instruction he prefer to prepare new notes rather than translating them,

Previously, a lot of the notes were in BM, so I don't want to translate from that, so I get the new one. Just compare the books. Actually the way they present the ideas, see which one is easy for the students, so that students can easily understand. There are some books they teach a little bit difficult, some books very easy to understand they give very simple examples, very easy understand...

(I#3/Bryan)

Besides referring to the reference books, Bryan also referred to the textbook to make sure what he taught was not out of the syllabus.

However, coming into the third year of teaching the subject, he said, “I can teach Form Four without any reference” (I#4/Bryan). It means he did not need to do reading to prepare the Form Four Chemistry classes because he was confident with the content knowledge. However, he still needed to do so to teach the Form Five Chemistry classes.

As mentioned in the earlier section, Catherine thought it was extremely important for a chemistry teacher to know the content before teaching the lessons. She referred to the Form Four Chemistry Curriculum Specifications and the scheme of work (yearly scheme) to ascertain the content that she had to teach. She explained,

...Before going to class I have to make sure the objectives, I have to do it in detailed this content, I must make sure before I go to class, make sure what I have to tell to them, I just tell them that point only...

(I#4/Bryan)

Catherine mentioned that she read the textbook and reference books on the said content. As she did not have a degree in chemistry and was not trained to teach the subject, she had to read a lot of reference books to master the content knowledge. As a result, she collected a lot of reference books and workbooks. While browsing through the Chemistry Curriculum Specifications, she also studied the learning outcomes which she had to achieve. She explained there were three levels of learning outcomes – Levels I, II and III, which corresponded to the levels of knowledge, comprehension and application respectively in the Bloom Taxonomy. An example of the Level I learning outcome was: “state the meaning of molar mass” and an example of the Level III learning outcome: “calculate the relative molecular mass of substances”

which required the application of the mathematical formulas/algorithms. Catherine stressed that she used the levels of learning outcome to assess her students' understanding and also her teaching. If her teaching achieved Level I learning outcome it meant students also achieved the same level of understanding.

Dennis felt that a teacher must have content knowledge before entering the class. Since he majored in chemistry he admitted he did not spend much time in preparing the content. He did refer to the textbook and reference books when preparing his lessons, he said,

We look at the textbook, look at the title, looking at the title we can imagine what is from the title and objective. The textbook has learning outcomes and learning objectives. Follow what is in the curriculum specifications and that in the textbook.

(I#5/Dennis)

He admitted that he encountered problems understanding content written in English, subsequently, he said,

I predict...predict the meaning. If we understand the concept, we can predict the meaning, which is what I did. We can understand just like we read story...

(I#5/Dennis)

4.4.1.5 Preparation of curriculum materials and teaching resources

Besides preparing the scheme of work, daily lesson plans and content, the teachers also prepared their curriculum materials and teaching resources such as finding/creating new examples, creating analogies, refining the power-point slides, reviewing of courseware, preparing quizzes, notes and hand outs.

Andy mentioned that he spent more time in thinking of new examples and analogies than reading the content at the time when this data was collected.

He would try to think what the easiest way to teach a day or two days when doing his preparation.

He gave an example which stroke his mind when he was drinking water from a bottle the night before his lesson,

...try to sustain students' interest, so that they can see the application of chemistry in the real situation. For example, if you want to teach them about the number of particles. Just have to take the 500 ml of mineral water and ask them 'This is 500ml, can you calculate for me how many moles of water inside? If you can drink water from one bottle of water, how many molecules of water have you taken?

(I#6/Andy)

Andy rationalised that the mineral water in a bottle example is something practical and students could relate to it therefore it was more interesting to them. He explained further,

I think for the students, if you can maintain their interest, it would be very helpful for them, otherwise if they find it very dry, and very distance they will lose their interest quickly.

(I#6/Andy)

He also created an analogy using the foreign currency to present the atom chosen to be the standard atomic scale which will be discussed in the later section. The reason why he chose the foreign currency as his analogy was because his students had some experience on stock market and foreign currency, therefore the said analogy was related to their experience, knowledge, and interest. What was more important was that the example was different from those stereotypical examples found in the textbook.

Although Andy was not in favour of using the courseware provided by the Ministry of Education, he still made use of it based on two reasons: (i) he had to show a good example to his staffs since his school sets a rule that every

teacher must use LCD to teach twice a week; (ii) for the sake of the students.

He said,

...to me the topic is quite dry, you know, can be dry you know, it's all numbers and calculations. I think my purpose of using the CD is just to make it more interesting, to create the induction set, you know.

(I#5/Andy)

Besides the courseware from the Ministry of Education, he also bought his own CDs. Before deciding which courseware to use in his lessons, Andy reviewed his courseware collection to choose the content which was easiest for his students to understand. He sometimes showed more than one courseware on the same content so that his students could understand the chemical concept from various perspectives. Andy was very particular in getting himself familiar with the content in the courseware as he believed that it was better not to use courseware at all if a teacher did not know which content to show to the students.

Bryan used power-point slides to present his content and to facilitate his explanation all the time. The slides were the product of the joint effort of a group of chemistry teachers from Zone A including himself. The slides contained facts, definitions, examples, exercises, diagrams, figures and quizzes, additionally, the slides were colourful and attractive but with no animation, narration and interactive quizzes when compared with the courseware from the Ministry of Education. Bryan gave positive comments on the courseware sent by the Ministry of Education as “absolutely beautiful and complete” but he still preferred to use the power-point slides prepared by the zone. The reason was that,

It is slow, takes time to display...very slow...very slow.
It is absolutely beautiful and complete. If we follow, we have 40 minutes in a period, if you use it, it will not finish

in 40 minutes. It is not that I am not interested, if you have time, you can actually use it. If the students concentrate definitely they can get it.

(I#3/Bryan)

In addition, his students could not understand the narration too thus it was a waste of time.

Furthermore, he said he was more comfortable with the power-point slides which he was involved in preparing. Before every lesson, Bryan reviewed, modified and refined the slides to suit his students as he often felt that there was something missing.

At the time when this study was conducted, Bryan said he did not have to read the textbook or reference books while preparing the Form Four Chemistry lesson, instead his preparation focused more on searching for new examples from the textbook and reference books. However, he admitted that he often encountered difficulties in looking for suitable examples for his students whom he described as 'slow learners' and weak in basic mathematics as most of them scored 'C' in mathematics in the PMR examination.

When come to the preparation of teaching resources, Catherine stressed that,

First priority I have to use the lap top, that's the requirement. I have to fully utilize it. I have to use the textbook and the practical book. The textbook and the lap top to support and help me.

(I#4/Catherine)

Furthermore, she gave positive comments on the courseware as, "...very helpful, I don't have to prepare the figure, it's all there, they help me to talk, good..." (I#4/Catherine). Since she did not have a degree in chemistry and was not trained to teach chemistry, her preparation included trying out all the examples and exercises that she used in the classroom, "I read more and the calculations I have to do more, everything extra-extra..." (I#4/Catherine). She

previewed the courseware before her lesson, “I study the courseware also before I show to them; I have to study first to see the timing” (I#4/Catherine). After reviewing the courseware, she browsed through the textbook, reference books and practical book to choose suitable exercises and activities/tasks for her lessons.

Upon making sure of the content, Dennis would proceed to look at the activities in the textbook and practical book, he claimed that the activities in the textbook was sufficient and he would refer to the reference book if he was not sure of the calculations. It was noted that he created some analogies in his lessons. For instance he used a “football and tennis” analogy to teach the relative atomic mass. Then he created another analogy using the ‘*roti canai*’ (Asian pan-cake) analogy when teaching solving the numerical stoichiometric problems,

I relate it to the making of Indian pancake. We use analogy...which means something simple that students know, easy isn't it? If everyone know the thing (Indian pancake), they will get involved...

(I#7/Dennis)

He claimed that by using something students knew made it easier to get involved. Further discussion on the rori canai analogy is presented in the later section. Dennis mentioned that if he could not understand the calculations, he would refer to the reference books. So far he did not mention anything on reviewing the courseware.

In terms of the questions and exercises used by the teachers, none of the teachers mentioned that they prepared their questions asked in the class before hands. All the teachers gave their students exercises at the end of their lessons. They made use of the exercises in the textbook which consisted of the “Work it out” and “Quick Review” and all of them gave positive comments on the

questions in the two types of exercise. In addition, Andy and Bryan gave extra exercises in the form of 2-in-1 notes and “Test yourself” quiz respectively. More discussion will be presented in the later section of this chapter.

To sum up, all four teachers prepared two types of lesson plan: the yearly scheme of work and the daily lesson plans. It was noted that all the yearly schemes of work of the four teachers did not contain school activities and no remarks were made after completing a particular topic.

Based on the feedback of the teachers, it was obvious that they gave priority to familiarise and master the content knowledge during pre-active phase of teaching through reading the textbook and reference books. However, before they read on the content they normally check on the learning outcomes either in the yearly scheme (Catherine), chemistry curriculum specifications or textbook to ensure the content they have to teach. Based on the learning outcomes and the suggested activities in the yearly scheme or the curriculum specifications, the teachers then decided on the activities, the teaching resources and curriculum materials they would use in their lessons. Subsequently, the teachers focussed on preparing the teaching resources such as reviewing of courseware, power point slides, and giving instruction to the lab assistant to prepare the science apparatus and equipment if there was experiment.

Generally, the main teaching resources used by the Chemistry teachers consisted of courseware (Andy, Catherine and Dennis) and power-point slides (Bryan), written exercises from the textbook, quizzes, science apparatus and equipment, and textbook in their teaching.

The main references used by the four Chemistry teachers were the Form Four Chemistry Curriculum Specifications, Form Four Chemistry

textbook, reference books, Form Four Chemistry practical book and workbooks. Bryan was the only teacher using the practical workbook with the approval of the school authority whereas the rest of the teachers used the Form Four Chemistry practical book provided by the Ministry of Education.

Although there was great similarity in the aspects of preparation and resources used by the four Chemistry teachers, their preparation varied in terms of width and depth. For instance, it was more obvious that Andy and Bryan put more effort in creating new examples and analogies. Teacher Catherine's preparation was more on refreshing the content knowledge and looking for examples. On the other hand, Dennis paid more attention to the content knowledge than the pedagogical strategies. He mentioned nothing on reviewing the courseware before his lessons. As a whole, the using of internet materials was uncommon for all the four Chemistry teachers. The types of preparation and the resources used by the four Chemistry teachers was summarized in Table 4.6.

Table 4.6

Lesson Preparation and Teaching Resources Used by the Chemistry Teachers

Aspect of preparation /Resources used	Andy	Bryan	Catherine	Dennis
<i>Aspect of preparation</i>				
Content	√	√	√	√
Example	√	√	√	√
Exercise	√	√	√	√
Analogy	√	√		√
Reviewing of courseware/power point	√	√	√	
<i>Resources used</i>				
Chemistry curriculum specifications	√	√	√	√
Textbook	√	√	√	√
Reference book	√	√	√	√
Courseware	√		√	
Power point slides		√		
Practical book	√	√*	√	√

*Practical workbook

4.4.2 Student

Andy had 28 students (13 girls and 15 boys) and majority of them were *Bumiputera* made up of Malay, Bidayuh and Iban with a few Chinese. The students sat at the first three rows of benches in the Chemistry laboratory with four to six students sitting at one bench. It was noted that those students sitting in front were attentive and serious as compared to those sitting at the back.

All the students were quiet and attentive during the classes except those boys sitting at the back. They were playful and talkative and Andy had to set an eye on them most of the time. As a whole, the class attendance was good and the students were punctual for their classes although their homeroom was located at quite a distance from the laboratory. The students in Four Science had the best academic performance in the school A and more than half of the class were appointed as the school prefects.

Bryan had 29 students (7 girls and 22 boys) in his class and besides this class he taught chemistry to another Form four classes. Similar to Andy's class, majority of them were *Bumiputera* consisting of Malay, Bidayuh, and Iban while the rest of the students were Chinese. As mentioned earlier that Bryan's students got to apply to enter School B therefore the students came from different parts of Sarawak. In addition, they only registered themselves a few weeks after the school reopened, thus Bryan's lessons were about four weeks behind the rest of the teachers in this study. Comparatively, Bryan's students were mostly average students whom he described as weak in maths and science. Comparatively, they came late for 10 minutes for every lesson and they liked to joke with their teacher.

Catherine had the biggest class among the four teachers. There were 36 students, 16 girls and 20 boys in 4C and all the students were Chinese. Besides

teaching 4C chemistry, Catherine also taught chemistry to 4A and 4B. The placement of students to the three classes was based on streaming whereby students with the best PMR results were placed in 4A, followed by 4B and 4C. It was the first time for Catherine to teach so many classes of Form Four Chemistry and in fact she contracted the whole form four chemistry as previously she was often given just one class of Form Four Chemistry and usually it was the weakest class. The assigning of three Form Four Chemistry classes to Catherine was a new experience and challenge for her.

It was observed that about one-third of the students in 4C were hyper-active (naughty, noisy and talkative) while the rest of the students were quiet and attentive. Some of the students involved themselves actively in school activities therefore they often went in and out of the class during the lessons. The environment in the class was lively and often noisy. The students felt free to talk and they could even talk to each other from opposite corners of the laboratory. One or two of the boys often slept in the class, and one boy in particular liked to disturb his friends such as wetting his seat with distilled water. Catherine often reminded her class to behave themselves and be serious with their study. It was a common scenario that the students kept on talking with their friends after entering the lab and Catherine would remind them to get ready for the class:

...so, are you ready? Is...everyone here? Ok, please get ready. Please get ready. Settle down, silence please. Ok, before we proceed, we start with our presentation first. Ok, I passed this time to Group one...

(CO#1/Catherine)

The students came to the lab late by 10-15 minutes every lesson although their homeroom was only separated from the chemistry lab by the biology lab. However, most of the students did pay attention to Catherine's

teaching and it was noted that all the students were attentive and quiet under three circumstances – when Catherine showed the courseware, during the group presentations and when they had deadlines to meet.

Dennis's class was the smallest in size as compared to others. There were only 18 students, consisting of 10 boys and eight girls. Sixteen of them were *Bumiputera* made up of Malay, Bidayuh and Iban with two Chinese students. Similar to Andy's students, Dennis's students were also the "cream" of the school and most of them were all-rounders and good in both academic and co-curriculum activities. Many of them represented the school in competition in games, sports, debates and quizzes. More than half of the class were appointed as the school prefects. The students were obedient and punctual coming to the laboratory although their homeroom was a distance away. They were very polite and they greeted the researcher even during the first visit.

Since the students were actively participating in inert-school competitions (school representatives) and school activities (school prefects), Dennis encountered a lot of unforeseeable disturbances. In a few occasions, he was left with only 7-13 students in the class resulting in he had to postpone his lessons. He commented on the active participation of the students in all sorts of competitions and school activities, he commended that the school was too active and did not have consideration on the weak students. But as the same situations occurs quite frequently and also due to the time constraint, Dennis carried on with his lessons as usual and no extra input was given to those absent.

4.4.2.1 Ability of students

Andy said it was still too early to comment on his students' abilities until he had marked the first progressive test. He commented,

This is an average one, it's not like if you are teaching in the elite school...you get the best students, you know...you will be quite confident after you had delivered a lesson maybe 70 to 80% of them maybe can master already...

(I#4/Andy)

He added,

...the ability of the students...their range is very different, you know, it's very different, this class is a mixed ability. I think very extreme, you see, the minimum is C, C for mathematics and science, the best is A...

(I#4/Andy)

Andy admitted that having students of diverse abilities made teaching difficult and he had a hard time finding the best way to teach them, in addition they took time to understand,

...many students they will take time, you know, they will need time to digest this whole thing...calculations, you know...it's not possible, no matter how well you teach because this class is average...I think I need to teach a bit today, you know, when you come back the next time I have to teach a bit again, you know...

(I#4/Andy)

To overcome the diverse abilities among the students, Andy proposed streaming, he said,

...the other schools...other schools maybe they have three or four science stream, you know, then the teacher can adjust...you know, for this very good class, you know, maybe this is my approach, for weaker class these are my approach...

(I#6/Andy)

In terms of attitudes, he felt that the present batch of students were less playful and had better attitudes than their seniors. He also compared a girl in

the class with her sister whom he had taught two years ago. He felt that the elder sister was better in her study than the younger sister.

Bryan reserved his comments on the abilities of his students even after giving one test. He only commented that his students were weak in basic mathematics thus he anticipated that they might encounter difficulties in the calculations. However, he was quite pleased with them as they asked questions when they did not understand although often those who asked questions were the good students sitting at the front row. Bryan was worried about the abilities of his students due to their academic entry point that was C in mathematics and science subjects based on their PMR results. Most of his students obtained grade C in their PMR science and only one or two of them scored grade A. He commented,

if possible, block timetable and combine the classes, and then you stream again, the good one go to one class and those slow-slow ones go to one class, there is a lot I want to do but I don't know how to do...

(I#6/Bryan)

Due to the mixed ability of the students, Bryan also suggested streaming, he said,

if possible, block timetable and combine the classes, and then you stream again, the good one go to one class and those slow-slow ones go to one class, there is a lot I want to do but I don't know how to do...

(I#6/Bryan)

Though not all the students had good grades in science and mathematics in PMR, Bryan was still confident that they could make it if they could focus in class,

I think it is 50-50, if they really focus...actually if you can focus on each of them definitely they can but it takes time. So like them, there are many...29 pupils, if you want to focus on each one of them is difficult. If you don't focus when they are not online, definitely they will not understand, although they just see like that...What I

observed those sitting there and trying to listen...at least they can give an answer.

(I#6/Bryan)

Catherine thought 4C was weak in subject content, half of the class was lazy and some did not care at all about their studies nor were aware of the importance of learning. She described the scenario when she played the courseware in the class, "They pay attention but were dreaming, those sitting at the back." In comparison, her 4C class was worse than their seniors who were hard working and did not have any discipline problems. She thought their response could be due to their abilities,

Really we can say ...ability. Normally I don't try to see that way because I always hope that they can overcome that and be better. Provided they change their attitudes. If they are more serious, a little more focus, I think they can, even though...regardless what they get in science. Don't think of it, it's a new subject, they have to...they need to be more mature, they are still playful. They are happy if they can understand...

(I#6/Catherine)

From Catherine's feedback, one could see that although the present class 4C was naughty, she actually did not mind provided they worked hard and did their homework. She explained that,

...sometimes we have to use different methods, sometimes you have to think of new way to control them...get their attention. Very different from the last two batches. So far so good, what I try to limit is try not to pressure them, let them have their own way to learn...

(I#6/Catherine)

In general, she still considered their behaviour as tolerable as compared to those arts classes that she was teaching then. She shared her experience teaching one of the arts class,

If you encounter the worse one 5G, no book, no pencil, sleepy beasts, sleepy beauties, no matter what you write, no action...they are poor, they don't know BM, they

don't know BI, they have no interest to study, what can we do?

(I#6/Catherine)

Dennis described his students' abilities as quite satisfactory as about half of the class scored grade A for Science in their PMR examination. He stressed that PMR and SPM were totally two different examinations as such a teacher should not judge the abilities of his/her students based on their PMR results. This is because the students might be just lucky to obtain good grades due to the multiple choice questions.

He also noticed the differences in the ability of the students and the amount of effort they put in their work. Besides ability, Dennis believed it was students' attitudes that determined their performance. He preferred to take a 'middle path' in his teaching which he regarded as the best way so it was not too easy and too difficult for the students.

Dennis was rather strict with his students and he seldom joked in class. He would give warning immediately if they started to joke and make fun. As a result, the students seldom joked and talked in his class. They were well-behaved, polite, shy and rather passive, however, they became very active and lively when attempting the interactive quizzes in the courseware. They were excited, happy, laughing and swaying their bodies when they heard feedback like "Congratulations" "Good job", and sighed when they heard "Try again". The students were obedient and gave full cooperation to their teacher. It was observed that they were attentive most of the time when Dennis showed the courseware.

Briefly, the composition of the students in Schools A, B and D was similar with the majority of them *Bumiputera* consisting of Malay, Bidayuh

and Iban. These students from School A and D were the high achievers of the school. Besides being good academically, they involved themselves actively in co-curricular activities and also as school prefects which somehow gave rise to disturbances to the daily routine class. The regular absentees from Dennis's class missed their lessons as sometimes he could not wait for them due to time constraints.

All the teachers reserved judgement on their students' abilities even after giving one or two tests. However, they did comment on their attitudes and behaviour by comparing them with their seniors and even siblings. Andy and Catherine were confident that those students who failed their tests could pass the SPM Chemistry examination provided they worked hard. All the teachers felt they could not use the PMR results of their students to verify the abilities of their students as Form Four Chemistry was a totally new subject and the examination format was totally different too.

4.4.3 The interactive phase

This section elaborates on the representations used by the four teachers to deliver their lessons and the specific strategies employed by them to address students' learning difficulties and misconceptions.

4.4.3.1 The routine lesson of the chemistry teachers

All four teachers conducted their lessons in the chemistry laboratory regardless whether they did experiment or not.

Andy often arrived 10-15 minutes earlier than his students in the laboratory either to set up his lap top and LCD, to see if the lab assistant had prepared all the apparatus for his experiment or to write notes on the board so

that he had more time to teach. He often began the lesson by asking questions to help the students recall what they had learned previously. For instance, he helped students to recall,

Two weeks ago we had started on chapter 3, formula and chemical equation, there are some important concepts that I had introduced to you and we had used the LCD to clarify some important concepts. Ok? You still remember what is meant by relative atomic mass of an element?

(CO#2/Andy)

Other times, he would go through the exercises with the students if homework was given to the students,

We have finished molecular formula and empirical formula, right? Ok? And I remember having asked you to do the exercises... Ok, the calculations on page 42 and page 44, have everybody done so?

(CO#6/Andy)

At the beginning of his lesson, he often told students clearly the overview of the lesson and the expected learning outcomes with the help of the courseware. Based on the learning outcomes displayed on the screen he would elaborate further by saying,

...ok, listen, these are four learning outcomes, so after 40 minutes, these are the things you are supposed to be able to do. Ok, you have to know how to define what is the meaning of relative atomic mass, ok? RAM, based on the carbon-12 scale...in fact there are three types of concept that you need to know, first is the relative atomic mass, so it is RAM, another one is the relative molecular mass, RMM for molecule, ok? And then the next one, relative formula mass, RFM, ok? This is for ionic substances, ok? So remember last time when you learned about matter, you already learned that matter can exist either as atoms, molecules or ions...

(CO#1/Andy)

Based on the excerpt shown, one could see that Andy also told the students how the new concept was related to the concepts previously learned.

While introducing a new concept, he often began giving an explanation on the definition in the textbook followed by that in the courseware. After explaining the definitions he then proceeded to the examples, and ending the lesson by giving exercises from the textbook. While the students were doing their work, he walked around to check their work, explaining and showing them how to solve the problems when they asked.

The main teaching aids Andy used in his teaching were the courseware, science apparatus and hand-outs. The courseware was used as teaching aid to enhance his explanation in every lesson, based on the content displayed, he gave a lot of elaboration using “chalk and talk” approach (Appendix H). One thing which was very obvious was that Andy was very particular about two things in the calculations: students must write complete steps and with units. For instance, he wrote:

$$1 \text{ mole} = 6.02 \times 10^{23} \text{ particles (atoms, molecules, ions)}$$

$$1 \text{ mole Cu} = 6.02 \times 10^{23} \text{ atoms}$$

$$1 \text{ mole of CO}_2 = 6.02 \times 10^{23} \text{ molecules}$$

Bryan was often ready waiting for his students in the laboratory as he preferred to sit in the laboratory most of the time instead of the staffroom which was crowded. In fact, he only went to the staffroom to attend the morning briefing. As mentioned earlier that his students were late by 10 minutes for every lesson. After greeting Bryan, the students remained standing for him to check their homework and attire. While going round from one bench to another, Bryan gave warnings to those who did not do or had not finished their homework, he would show them how to solve the problems if they asked. He also often teased and joked with the students.

Using the power-point, Bryan began his lesson by going straight to the concept. For example, for the sub-topic mole and the mass of substances, he showed the three types of relative mass for atom, molecule and formula.

The mole and the mass of substances

A_r – relative atomic mass

M_r – relative molecular mass

F_r – relative formula mass

Then he proceeded to find out the perception of students by asking a few questions:

1. What is molar mass?
2. What is molar volume?
 - a. at STP?
 - b. at room conditions?

The lesson continued with Bryan giving explanation on the definitions, examples, asked students to solve the “Test Yourself” quiz and finally he gave exercise/homework from the textbook to the students at the end of the class.

Besides using the “chalk and talk” approach to explain the examples, most of the explanation and elaboration was done using the power-point slides which served as teaching aid and guideline. A few observations were noted in

Bryan’s lessons:

- (i) The interaction between Bryan and his students was very much like that between “a mathematics teacher and the students” whereby students gave the answers to every step written (Figure 4.10):

Source	Transcript	Remarks
Bryan	...so one mole in your daily life...one dozen, you know what is one dozen?	Bryan tried to introduce mole concept using dozen, something students were familiar with Students confused mole with molecule
Students	Yes...	
Bryan	How many items?	
Students	Twelve...	
Bryan	Twelve...twelve items...we call it one dozen. In Chemistry they not use...they do not use dozen but they use one...one mole. You get it?	
Students	Teacher, molecule	
Bryan	Not molecule, m...o...l...e, so symbol mol. One dozen 12 items and then one mol, how many items?	
Students	6.02×10^{23}	

(CO#2/Bryan)

Figure 4.10. An example of interaction between Bryan and students

- (ii) Bryan had a tendency to provide clues to students and often his questions ended up as “fill-in-the-blanks” for the students (Figure 4.11).

Source	Transcript	Remarks
Students	6.02×10^{23}	Teacher gave clues in the form of filling in the blanks at (1) and (2)
Bryan	6.02×10^{23} , or that number we call it <u>Avogadro... (1)</u>	
Students	Constant	
Bryan	Constant, Avogadro constant and symbol N_A , for A, they write it in subscript...subscript form, you see, at the end of the first sentence...one dozen...one dozen 12 items so if you say one mol... <u>6... (2)</u>	
Students	6.02×10^{23}	

(CO#2/Bryan)

Figure 4.11. An example of Bryan’s questioning technique

- (iii) Bryan had a tendency to code switch from English to *Bahasa Melayu* (BM) and vice versa. As a result, his explanation sometimes remained ‘hanging’ and incomplete:

6...23...items. In our case, we don’t say items, we always say...say particles, but particles can be atoms, can be molecules, can be ions, and are you clear about that? It used that...it used thing like dozens, twelve, right? Not formula...that one is not formula, that one is constant, it does not

change, if you say one mole must be 6×10^{23} times 10^{-23} , it does not change, ok?

(CO#2/Bryan)

It was noted in the excerpt shown, Bryan began his explanation in English, and then he switched to BM, back to English and half way he switched back to BM, English and finally ended in English.

While giving explanation, it was observed that Bryan often said “I don’t know how to teach already...” when he ran out of ideas.

Catherine conducted all her lessons in the chemistry laboratory. The lab was built in the 1970’s, therefore the size was small, the benches were small too and there were only eight benches in the laboratories as compared to the 10 benches in the laboratory of the other teachers. Subsequently, the situation in her laboratory was crowded.

Catherine had to wait for 10-15 minutes at least before all the students came into her class although their homeroom was just separated from the chemistry lab by the biology lab. Catherine began her class either with students’ presentations or by showing the learning outcomes by showing the courseware. Sometimes she called a student to read the definition from the textbook, which she reinforced by explaining the definition again using the courseware (Figure 4.12):

Source	Transcript	Remarks
Catherine	Alright, so I want you get yourself ready, sit up straight, open your textbook to page 30, we go into the mole and the number of particles. I hope you are ready, draw the curtain, the side there...are you ready everyone? Yes or no? Keep your homework first, don't do your homework while listening to this, please be faster...	While giving instruction, Catherine had to discipline the students. She is showing the definition from the courseware at the same time she also asked students to refer to the textbook
CD	(Music and the definition of mole)	
Catherine	Can listen this? I don't want to catch you. I know you do something else. I know you are writing. You need to give 100% attention especially to this chapter and beginning from this and onwards. Ok? I am talking here, I don't want at the end of today you cannot solve any calculations later on. Ok? Don't let me catch u. pay attention and not doing something else or even the chemistry homework now, homework has to be a homework, ok, look in front here, you can refer to your book on page 30 textbook. And today we are going to learn about the concept of mole, the concept of mole, in English M...O...L...E means...if you look at the picture...this animal is also called a mole, alright? How about in this picture? Where is the mole?	

(CO#3/Catherine)

Figure 4.12. A excerpt of Catherine's explanation using courseware

While playing the courseware showing the definition and examples, she would incorporate her explanation in between the narration (Figure 4.13):

Source	Transcript	Remarks
CD	The mole is equivalent to a specific number...	
Catherine	That is the comparison...	
CD	Such as a pair of shoes is equivalent to two shoes. A dozen of eggs is equivalent to 12 eggs. A gross of bottles is equivalent to 144 bottles...	
Catherine	This is the comparison...	
CD	Thus, one mole of sugar is equivalent to 6.02×10^{23} of sugar molecules. One mole of salt equivalent to 6.02×10^{23} salt molecules. One mole of copper equal to 6.02×10^{23} copper atoms.	
Catherine	You understand these examples? Whatever substances it is, whatever substance, ok. When we mention one mole meaning that that substance has 6.02×10^{23} particles in it, alright? Fine with you?	
CD	One mole of diamond....	

(CO#3/Catherine)

Figure 4.13. An excerpt showing how Catherine incorporated her explanation while showing the courseware

Finally she assigned one or two questions in the exercises from the textbook to the groups,

Ok, that is for today. First, to your textbook...textbook, page 32, ok? Are you ready? Group discussion, 1, 2, 3, 4 as usual, 5, 6, 7, 8. You turn to page 32, "Work This Out" 3.1, every student has to bring your calculator. I reminded you already. "Work This Out" 3.1, Group 1, you do question 1, question 1 means a, b, c, d. Group 2, you do question 2 and 3, Group 2, ok? Group 3 question 4, ok? Thank you. Group 4 question 5, thank you. Group 5, give you question 1, group 6 question no. 2 and 3, ok? Group 7 question 4 and Group 8 question 5. I will give you 15 minutes to do so. Divide your work...

(CO#3/Catherine)

After she had assigned the work, a representative from each group went to the front to collect the transparencies and transparency pens from her and they began to discuss their questions. Catherine went around to supervise the students' work and showed them how to answer the questions when asked, as she was going round, she reminded the students,

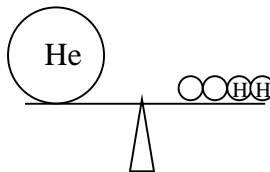
What is your question? You are doing no. 2 and 3. Sample contained molecules of water, how many, this one? How many moles of water are there in the sample? How many moles of water actually is? Wait...how many moles of water molecules is...sample contains molecules of water... oh...how many moles of water meaning that how many... use your formula no. 1, don't worry, write the formula...write the formula there. You do the procedure first, then I teach you how to use the calculator. So you write the formula first, I teach you how to key in. Quickly...

(CO#5/Catherine)

Based on the excerpt, one could see besides teaching the students doing the calculations, she also taught them how to use the calculator. The students were keen to ask questions when Catherine went round the class checking their work.

Dennis used the ready-made transparencies to teach during the first two lessons of topic 3. The transparencies were colorful and attractive (Figure 4.14).

Relative atomic mass
of an element, A_r = Mass of atom/ mass of a hydrogen atom
(based on hydrogen
scale)



Mass of 1 helium atom
= 4 times the mass of a
hydrogen atom



Relative atomic mass of He = 4

Figure 4.14. A Sample of transparency used by Dennis

Upon receiving the courseware, he switched from the transparencies to courseware starting from the third lesson. From then on, he relied almost entirely on it in his teaching. Besides the courseware, he also used the textbook and the practical book in his lessons. Comparatively, the courseware was the main teaching resource used; the use of the textbook was confined to definition of concepts and exercises. The practical book was used when conducting experiments.

Dennis often began his class by showing the learning outcomes in the courseware. Then he proceeded to the chemical concepts. To reinforce the concepts, he normally called a student to stand up to read aloud the definition from the textbook before he explained (Figure 4. 15).

Source	Transcript	Remarks
Dennis	Shall we continue? Today we discuss about...we will learn about the molecular formula. So what is molecular formula? We will continue...	
CD	At the end of this lesson, students should be able to state the meaning of molecular formula, determining molecular formula of substances, compare, and contrast empirical formula with molecular formula. Click on the blinking button to proceed.	
Dennis	Ok, at the end of this lesson, you should be able to state the meaning of empirical formula. What is the molecular formula of substances and then compare and contrast empirical formula with molecular formula.	Dennis repeated the learning outcomes in the courseware.
CD	The molecule of ethene, in one molecule of ethene there are two carbon atoms and 4 atoms of hydrogen atoms. The molecular formula of ethene is C ₂ H ₄ . Let's see another example. What is the molecular formula of benzene? Drag and drop the answer into the correct box provided. You can check your answer by clicking answer button.	
Dennis	Benzene, what is the molecular formula of benzene?	
Students	78...	
Dennis	Can we check? Class, what is the molecular formula? We check the answer.	
CD	Congratulation...	

(CO#6/Dennis)

Figure 4.15. An excerpt of Dennis's explanation using courseware

Next he showed examples on the board followed by asking students to try the interactive quizzes from the courseware. Finally, he asked students to do the exercises in the textbook, for instance,

Ok, so...class, you open your textbook turn to page 44, you try to do exercise 3.8 on page 44. You try question no. 1 to question no. 6. Is it clear? You try to do the exercise any problem we discuss on Friday, ok?

(CO#6/Dennis)

When students were doing their work, he walked around to monitor and help them when they encountered problems. He went through the exercises with the

students in the next lesson and sometimes he called students to show their answers on the board.

During the classroom observations, both Catherine and Dennis ever encountered technical failure once while trying to set up the LCD projector. For Dennis, it happened during his first attempt to use the courseware in his lesson. Both teachers asked help from their colleague to look into the problem. Catherine immediately adjust her plan by asking the students to read the textbook while waiting. As the technicians could not fix the problem, she quickly changed her strategy by discussing the activity 3.1 (experiment) in the activity book instead of teaching the concept. It was noted that no time was wasted during the whole incident. On the other hand, Dennis wasted almost one-and-half periods waiting for his colleague to fix the problem. He even attempted to shift to another lab to try out the courseware but the attempt failed too. Dennis did not instruct his students to do anything while waiting.

Although three of teachers: Andy, Catherine and Dennis used the same courseware as the main teaching aid in their lessons, comparatively, Dennis relied much more on the courseware in his teaching than Andy and Catherine. In fact, it was appropriate to say that he relied almost entirely on the courseware in his teaching as he showed almost everything in the courseware from the learning outcomes, definition, explanations, interactive quizzes and exercises. Subsequently, he gave less elaboration and explanation on the content shown. Andy and Catherine were selective in showing the content in the courseware, at the same time they incorporated a lot of explanations and elaboration while showing the content.

Generally, the lesson procedures of the teachers were very similar in terms of the sequence of their teaching. All of them began their lessons by

showing the learning outcomes (except Bryan who just showed the title), introducing the definition of the new concepts, elaborated with examples followed by giving exercises for the students to do.

4.4.3.2 Instruction (representations)

The main concepts in topic 3 were the three relative masses (atomic, molecular and formula), mole concept (molar mass, molar volumes and number of particles), chemical formula, chemical equations and stoichiometry which were generally abstract, containing a lot of technical terminologies, chemical symbols, units and calculations. All the teachers used numerous representations to transform their content knowledge during instruction. The representations could be grouped under three categories namely explanation, laboratory work (practical) and question (Table 3.6, p/120).

Basically, there was a high similarity in the representations used by the teachers to teach topic 3 due to they using the same curriculum, curriculum materials such as textbook, activity book and courseware.

4.4.3.3 Explanation

Andy showed a rich repertoire of representations in his oral explanation. Basically, he gave long explanations which contained a lot of facts (Appendix I) and the students did not give much response. He presented his explanations from simple to complex, and the explanation was clear, detailed and thorough. At the same time, he highlighted the differences between the new concept and the previously learned concepts followed by the significance (importance) of the concepts.

Andy used courseware and the textbook to explain the definition of the chemical concepts. Usually, he called a student to stand up to read the definition from the textbook before he explained its meaning. He later elaborated further the meaning of the definition using the courseware. For example, when he was introducing the relative atomic mass, he referred to the figure in courseware to explain the definition. He also asked his students to draw the diagram and complete the exercise (Figure 4.16).

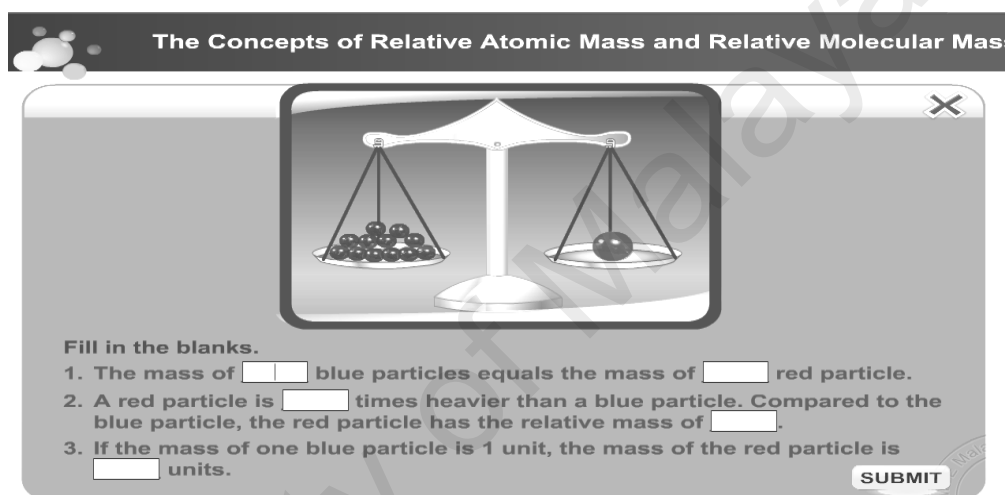


Figure 4.16. Sample of slide in the courseware used by Andy to teach the Relative Atomic Mass

(Source: Ministry of Education)

After introducing the definition, Andy continued to show more slides on relative atomic mass, using the analogy of 10 cents and ringgit to explain the meaning of “relative”. Then he explained the historical development of the atomic scale, how it started with the hydrogen atom as the atomic scale, replaced by oxygen atom and finally by carbon-12 atom. He further explained the relative atomic mass concept with diagrams and mathematical formula in the “2-in-1” notes given to the students. The “2-in-1” notes contained partially work-out examples and more exercises.

He came out with some impressive analogies and examples. For example, he used currency to analogize the standard atom in the atomic scale of relative atomic mass:

when we compare two things there must be a standard that we used, other matters will be compared against one standard atom, so we choose carbon-12, take for example. For example, let's say there are many countries in this world and every country has its own currency, right? In Malaysia, we have the Malaysian ringgit, Indonesia...Rupiah, Thailand is the baht, ok, but there is a standard currency, you know, there is a standard currency that everybody agrees. For example if one country trades with another country, ok, let's say Malaysia and Thailand, ok, Thailand currency is baht, Malaysia currency is ringgit, so it's not very easy to do trading, right? So, they must have a currency ok, so they must have a stable value where both countries can accept, ok, so this standard currency is normally...maybe the US dollar or the British pound or gold. Ok, the standard for currency, of course there are few criteria, right, people don't just choose any currency as a standard, ok? Maybe some of the criteria that they choose maybe the currency must be stable, correct or not? Must be stable, cannot be fluctuating all the time, right? It must be stable, and second it must be widely used and widely acceptable, ok, so the same with our standard for atom, ok, that's the criteria, there are certain criteria which must be met.

(CO#1/Andy)

Based on the description on the foreign currency in his analogy, Andy stressed the criteria used to choose the foreign currency with that used to choose the standard atom used in the atomic scale: it is a standard therefore it had to be stable and valuable besides being widely accepted. The rationale of choosing the currency as an analogy of the standard atom was because Andy anticipated his students had some knowledge on foreign currency, currency exchange and share market thus it should be quite easy for them to understand.

In order to make students understand "mole" as a unit of measurement for quantity of particles, Andy used simple analogy to explain the meaning of mole. One mole of a substance is similar to one pair of shoes and a dozen of

eggs. If one pair equalled to two items and one dozen equalled to 12 items then one mole equalled to 6.02×10^{23} particles which could be atoms, molecules or ions. He tried to make connection between the abstract concepts with things familiar to his students. In addition, he stressed on the point that one mole, one dozen or one pair of anything was the same in terms of quantity regardless of their sizes. For instance, one dozen of chalks had the same number of items with one dozen of drums though their sizes were different.

Andy claimed that he did a lot of mental preparation trying to create new examples. As discussed in the earlier section, he created a problem on water molecules while drinking water from a bottle and thinking of how to teach his lesson on Avogadro Constant the next day. He used the problem as a quiz to challenge his students and he gave some incentive to the first person who got the correct answer:

...do you know the mineral water? The half-litre...it contains 500 cm^3 ... 100 cm^3 is equivalent to 100 g. How many water molecules does it contain?

(CO#2/Andy)

Andy drew diagrams to help the students visualise the example. For instance, when he showed the following example:

A closed glass bottle contains 0.5 moles of oxygen gas, O_2 .

(a) How many oxygen molecules, O_2 are there altogether in the bottle?

(b) How many oxygen atoms are there in the bottle?

[Avogadro constant: $6.02 \times 10^{23} \text{ mol}^{-1}$]

He drew the diagram of a bottle and labelled the gas in the container as " O_2 " to help the students to visualise the information given (Figure 4.17).

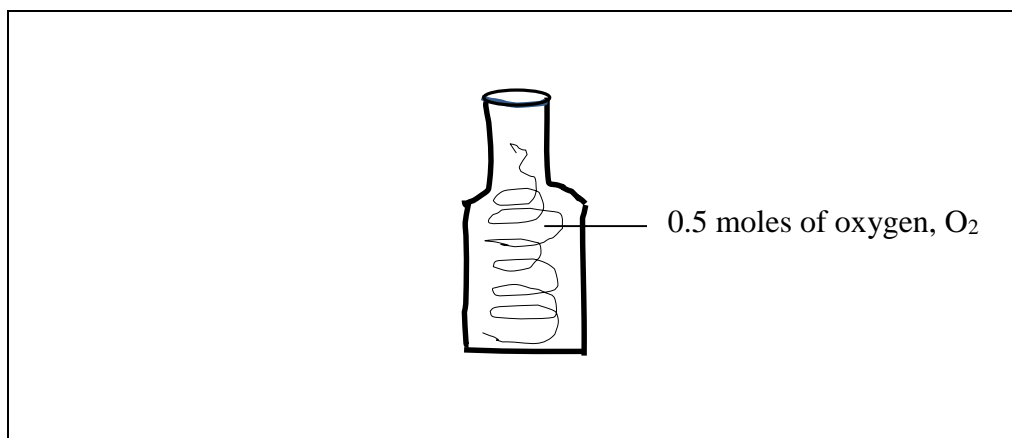


Figure 4.17. Diagram of the glass bottle used by Andy in his explanation

Andy constructed a diagram to explain the meaning of “ $\frac{1}{12}$ x mass of an atom of carbon-12” while teaching the carbon-12 scale

Relative atomic mass of an element,

$$\text{RAM} = \frac{\text{the average mass of one atom of an element}}{\frac{1}{12} \times \text{mass of an atom of carbon-12}} \quad (\text{Figure 4.18}).$$

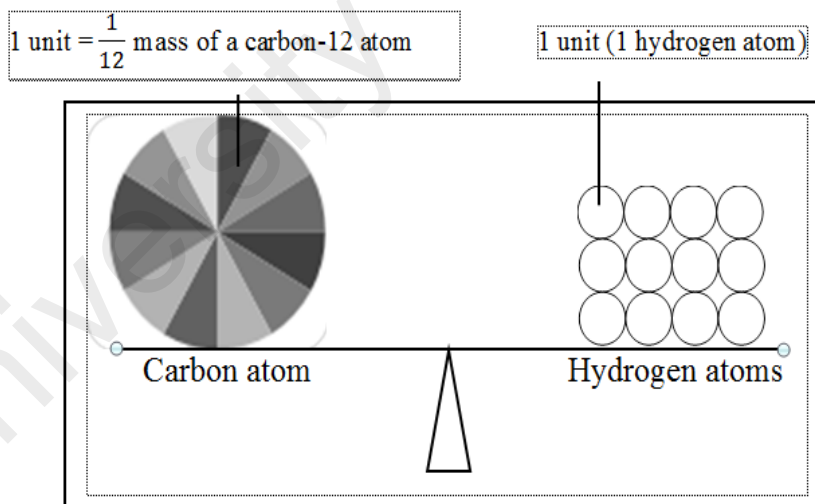


Figure 4.18. Diagram used by Andy to explain “ $\frac{1}{12}$ x mass of an atom of carbon-12”

Andy recalled that the concept “ $\frac{1}{12}$ x mass of an atom of carbon-12” had been bothering him since he taught Chemistry,

I remember when I was a student I had to struggle also. Last time I had 6 months under a temporary teacher, it is really tough. There are many questions that I asked and the teacher could not give me satisfactory answers. When I was young also I had problem in understanding certain concepts that is why I try to make use that experience when I teach the students. So I try to make concrete for student, very cornet why $1/12$? Because there are 12 hydrogen atoms equivalent to one carbon atom. If you can break this C-12 to 12 equal parts means $1/12$ of carbon atom is equivalent to one hydrogen atom. So the scale in your mind is still equivalent to hydrogen atom.

(I#7/Andy)

As a student, Andy could not understand why he had to multiply “mass of an atom of carbon-12” by “ $\frac{1}{12}$ ”. As a teacher, he felt that he had the responsibility to find ways to make his students understand. He divided the carbon-12 atom into twelve equal portions therefore every portion was equivalent to $\frac{1}{12}$ of the mass of a carbon-12 atom that is one atomic mass. The relative atomic mass of a carbon-12 atom was 12 based on the hydrogen scale. It meant an atom of carbon-12 was twelve times heavier than a hydrogen atom. Therefore one had to multiply the “mass of an atom carbon-12” by “ $\frac{1}{12}$ ” to get one atomic mass. With the divided portions, students could visualise clearly that “ $\frac{1}{12}$ x mass of an atom of carbon-12” was actually equalled to the mass of a hydrogen atom.

Besides the new examples he created, Andy also make use of the examples in the textbook and courseware. He described himself as flexible in showing the examples in his lesson. He was able to make adjustment by increasing or reducing the number of examples used in his lessons based on the available time he had.

When explaining the calculations, Andy interacted with his students through asking questions for every steps written and the students responded by giving answers to the steps (Appendix J). Comparatively, as mentioned earlier, the interaction was not frequent when he explained facts.

Andy had mentioned that 80% of topic 3 involved calculations, thus he anticipated his students could easily get confused with the algorithms while doing calculations involving the mole concept and the three entities of molar mass, molar volume and Avogadro's Constant. He revised the mind map "Relationships between the number of mole with mass, number of particles, and volume of gas" in the textbook (Figure 4.19) into the mind map as shown in Figure 4.20.

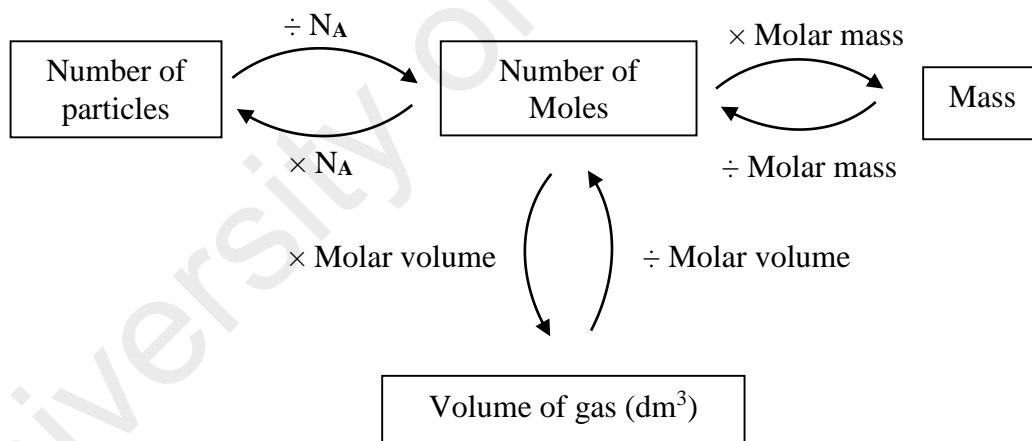


Figure 4.19. Mind map showing the relationships between the numbers of mole with mass, number of particles, and volume of gas

(Source: Low et al, 2005, p 38)

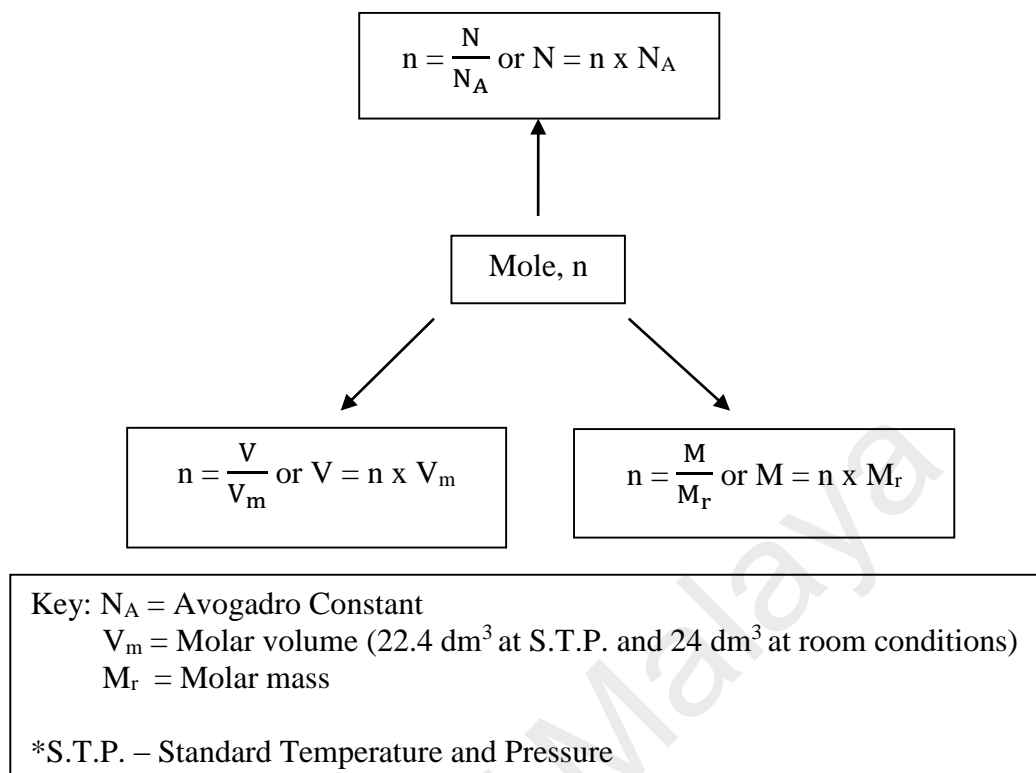


Figure 4.20. The revised mind map of Andy

Andy pointed out two weaknesses of the mind map given in the textbook:

- (a) there were too many arrows to memorise thus students easily got confused with the direction of the arrows;
- (b) the algorithms of the conversions were not shown therefore students did not know where to begin.

He explained the reasons why he refined the mind map,

...not easy for the students to remember these arrows. Now I put in the formulas straight away, so they don't have to memorise arrows pointing down is multiplying or divide, you know. This is just to show them the formulas, and they should know the relationship already...is all here. You have the formula whether you need to divide or when you change the subject of the formulas...

(I#7/Andy)

The revised mind map was easier for the students to see the relationship between the number of moles and the three entities. For instance,

if a student intended to find “the number of particles contained in X g of substance Y”, based on the formulae shown in the revised mind map, students could convert X g of substance Y into the number of particles by following the steps below:

- (a) Convert X g into the “number of moles” by dividing X with the molar mass of Y; and
- (b) Multiply the number of moles obtained from (a) with the Avogadro’s Constant ($6.02 \times 10^{23} \text{ mol}^{-1}$).

In the revised mind map, Andy had transformed the relationship between “the number of mole and the entities” into formulas. Based on the formulas given, the students only needed to substitute the values accordingly and then do the calculations. He further explained that the students could pick up a suitable formula for any calculation. For example, to calculate the number of moles contained in a volume of gas, the students could choose “ $n = \frac{V}{V_m}$ ” where “V” was the given gas volume and “ V_m ” was the molar volume either in room conditions or at S.T.P. Additionally, Andy also commented that the mind map could be used with great flexibility,

...if they use the correct formula, it does not matter which quantity you need to calculate, you can change the subject of the formula...

(CO#4/Andy)

For instance, based on the formula “ $n = \frac{M}{M_r}$ ”, one could derive “ $M = n \times M_r$ ” and “ $M_r = \frac{M}{n}$ ” by changing the subject of the formulae.

Besides examples, analogies, definitions, mind maps, diagrams and questions, Andy also used the sub-microscopic and the symbolic representations to deliver the content. Examples of the sub-microscopic

representation were particles such as atoms, molecules and ions. Topic 3 contained a lot of symbolic representations such as chemical symbols, chemical equations, chemical formulas, mathematical formulae for the calculations, and unit of measurements such as gram, cm^3 , dm^3 .

Andy realised that his students often did not know how to begin when solving the numerical problems involving concept mole, in addition they also could not memorize the algorithms in the calculations. Andy came out with the “2-in-1” notes to assist his students overcoming the said problems. Besides as notes (contained definitions, explanations, mind maps and formulae), it also contained partially solved examples (solutions) and exercises. The “2-in-1” notes served as a guide and reference for the students while solving the numerical problems as Andy listed all the steps in the calculations in his examples except the formula and calculations. He said,

I noticed that many of the students they are not used to writing the statements, you know, they just...they are used...just writing and make short-short calculations without the answers or just the answers. For the weaker students, they did not write anything because they don't know what to write, so that is why I come out with this guided solutions. So that the good students they know if they skip the three steps, they lost three marks, these are the important steps they have to show. And for the weaker students...tell them what steps they must do. If they don't know what to write, then these are the things I tell them you must write, so the guided solutions...it will benefit the two groups of students actually...

(I#7/Andy)

A sample of the guided solution (Figure 4.21).

Question:

Hydrogen peroxide, H_2O_2 , decomposes according to the following chemical equation:

$$H_2O_2 \rightarrow 2H_2O + O_2$$

Calculate the volume of the oxygen gas at STP produced from the decomposition of 34 g of hydrogen peroxide, H_2O_2 .
[R.A.M: H, 1; O, 16; $V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$]

Solution:

Given the chemical equation for the reaction: _____

Relative molecular mass of hydrogen peroxide, $H_2O_2 =$ _____

No. of moles of hydrogen peroxide = _____ mole

From the chemical equation above,

_____ mole of hydrogen peroxide produces _____ mole of oxygen.

Therefore, _____ mole of hydrogen peroxide produces _____ mole of oxygen.

The volume of oxygen at STP = _____

Figure 4.21. An example in the “2-in-1” notes

It was noted that the guided solution contained partially solved solutions. All the necessary steps were provided except the important information and the calculations whereby the students had to fill in themselves. Andy refused to provide all the answers in his guided solutions because he believed that the students had to work out themselves in order to grasp a better understanding of the concept.

While teaching the chemical formula, Andy used the cross-multiplication method to teach students synthesizing the chemical formula (Figure 4.22). Given a cation Ca^{2+} with two positive charges and an anion Cl^- , with one negative charge. Through cross-multiplication, one needs two Cl^- to balance the two positive charges from calcium ion.

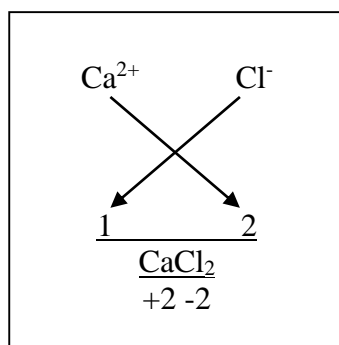


Figure 4.22. Cross-multiplication used by Andy to teach chemical formula

The strategy emphasised on the balancing of the positive and negative charges mathematically. The cross-multiplication method contained representations such as chemical symbols of ions, arrows, numbers and chemical formulae, it was a common strategy used in textbook and it provided an easy way to synthesize the chemical formula without really understanding the concepts behind.

Another problem encountered by Andy's students while solving the stoichiometric problems was writing a balanced chemical equation. To overcome the problem, he taught them to use a template to write the chemical equations (Table 4.7).

Table 4.7

Template Used by Andy to Teach Chemical Equation

Steps	Answer
1. Chemical equation in words	Hydrogen + oxygen \rightarrow Water
2. Unbalanced chemical equation (UBE)	$\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$
3. Balanced chemical equation (BE)	$2\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$

Different from the other teachers, Andy wanted his students to write a chemical word equation before writing the symbolic equation. The second step was to replace all the reactant/s and product/s with chemical formula. The third

step was to rewrite the unbalanced chemical equation (UBE) and then balance it. Andy emphasized the writing of the unbalanced chemical equation. Compare to the other teachers, they only wrote one chemical equation and did the balancing on it.

It was observed that the writing of chemical equations using the template was systematic. In addition, Andy spent a lot of time explaining the steps in writing chemical equations and he asked the students to jot down notes for each step in the template. He admitted that although the writing of chemical equations using the template was systematic, it did not guarantee correct answer for every attempt, according to him practice was still the key factor to ensure success.

Bryan engaged mostly verbal explanation in his class. Most of the representations engaged by him in teaching topic 3 were similar to the rest of the teachers. However, differences were noted in the self-created examples, analogies, slides, the “Test Yourself” quiz, and questions used in his lessons. Additionally, he used something extra such as the atomic structure models, chemical bonding and electron configuration to explain the synthesis of chemical formulae.

Bryan used the slides to explain almost everything he taught which included the definition, explanation, examples and quiz. As mentioned in the earlier section, Bryan preferred to use the power-point slides prepared by the Zone A chemistry teachers and not the courseware provided by the ministry of education (Figure 4.23). The slide shows the definition of relative molecular mass, an example of relative molecular mass and explanation how to find the relative molecular mass.

Relative Atomic Mass and Relative Molecular Mass

5. The relative molecular mass (M_r) of a compound is defined as the number of times one molecule of the compound is heavier than one twelfth of the mass of a carbon-12 atom.

- Relative molecular mass of a compound = $\frac{\text{Mass of one molecule of compound}}{1/12 \times \text{mass of one carbon-12 atom}}$
 - Example: A molecule of water, H_2O , is 18 times heavier than one twelfth of the mass of a carbon-12 atom. Thus, the relative molecular mass of H_2O is 18.
6. Relative molecular mass = sum of relative atomic masses of all the atoms in the molecule

Figure 4.23. A sample of the power-point slide used by Bryan

Though he admitted that the courseware was attractive, interesting, and with animations yet the narration was difficult for his students to understand because they were not proficient in English. Similar to Andy, Bryan also explained the meaning of “mole” by equating it to “a pair” and “a dozen” as they all measured quantities. If a pair of shoes equalled to two shoes, one dozen marbles equalled 12 marbles, similarly one mole of particles equalled to 6.02×10^{23} particles which might be ions, atoms, or molecules.

Bryan presented the examples with increasing difficulty and complexity. He was particular about the units of measurement in the calculations whereby he wrote units for every variable in the calculations. When students failed to understand, he created impromptu examples. While explaining the examples, Bryan continuously interacted with the students to get answers from them to every step he wrote (Appendix K).

Based on the excerpt, one could see that, while introducing the relationship between the concept mole and the Avogadro Constant, Bryan introduced some new concepts that students had not learned such as the

periodic table and chemical bonding (ionic bonding). Due to the fact that when calculating the number of particles in a substance, the particles might be atoms, molecules or ions, and if ions then there was anions and cations. Therefore the students needed to be able to identify the types of particles and how many ions were contained in a substance based on the name and chemical formula given. It was a tough task at this stage as they had not learned topic 4 periodic table and topic 5 chemical bonding. In fact, Bryan recommended students should learn topics 4 and 5 before they learn topic 3.

Upon introducing the mole concept and Avogadro's Constant, Bryan continued to give examples in the "Test Yourself" quiz (Figure 4.24).

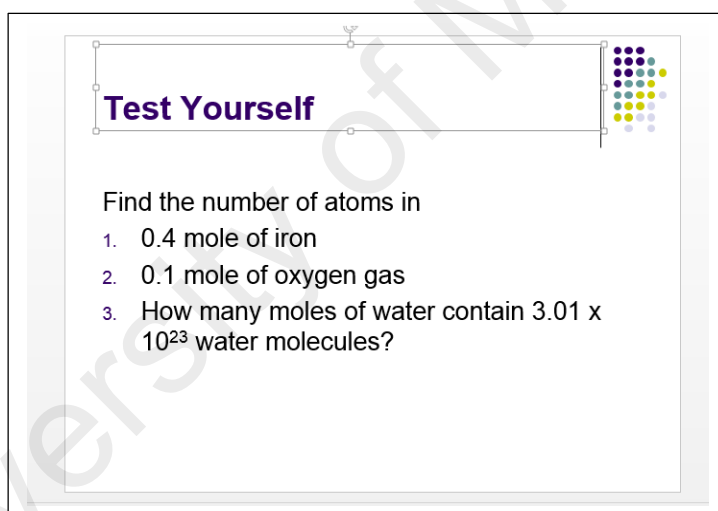


Figure 4.24. A sample of the "Test Yourself" quiz of Bryan

While trying the 0.4 moles of iron example, most of the students did not bring their calculator therefore the lesson was interrupted with most of the students went back to their class to get their calculators. And the rest of the lesson ended up all the students trying the three examples in the "Test Yourself" quiz and Bryan went round to help them and teach them how to use the calculator. And just before the class ended, Bryan assigned some homework: "Work This Out" from the textbook to students.

It was noted that the flow of his explanation was frequently interrupted by either code-switching (between *Bahasa Malayu* and English) or him jumping from one concept to another. As a result his explanation became incomplete and the information received by the students were scattered and not consolidate. The situation also tended to prevent students from understanding the concepts. During the lesson, Bryan also had to teach the students how to use the calculator as most of the students did not know how to key in the exponent. It was something unplanned of.

It was observed that Bryan emphasized the importance of algorithms in the calculation. For instance, a student asked him how to solve the problem:

60 gram of aluminium sulphide contains 38.4 gram of sulphur. Find the empirical formula of aluminium sulphide.

The feedback he gave was:

60 g – 38.4 g, you get mass for aluminium, got it?

He did not explain to the student the rationale for doing “60 g – 38.4g” to reinforce her understanding.

Bryan used diagrams, drawing, figures and tables to present his explanation. For instance, he drew the diagram of a cake to help him explain the simplest ratio and also the difference between “molecular formula” and “empirical formula” (Figure 4.25).

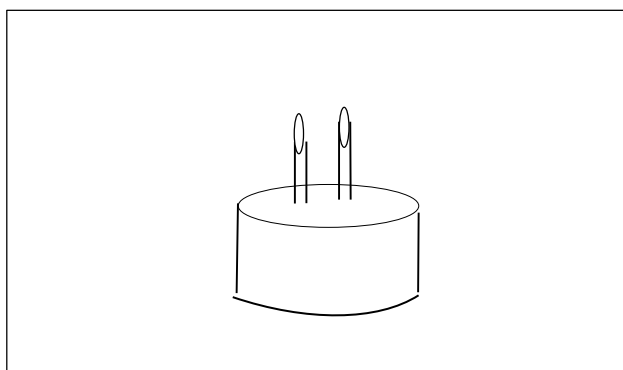


Figure 4.25. Diagram of a cake used by Bryan in his explanation

Bryan told students the cake was made of:

“2 kg of sugar, 4 kg of flour and 4 kg of eggs”

The ratio of “sugar: flour: eggs” therefore was 2: 4: 4

To get the simplest ratio, divide by 2:

$$\frac{2:4:4}{2} = 1: 2: 2$$

He further reinforced the “simplest ratio” concept by giving the following exercise to his students (on a slide) (Figure4.26).

Example

Compound	Molecular formula	Simplest ratio of atoms of elements	Empirical formula
Water	H ₂ O	H:O = 2:1	H ₂ O
Ethene	C ₂ H ₄	C:H = 1:2	CH ₂
Benzene	C ₆ H ₆	C:H = 1:1	CH
Vitamin C	C ₆ H ₈ O ₆	C:H:O = 3:4:3	C ₃ H ₄ O ₃

Figure 4.26. The ratio exercise used by Bryan

He used diagram in the practical workbook to explain the apparatus set up of the burning of magnesium ribbon in the empirical formula experiment. The calculations of the empirical formula was tabulated. Bryan reminded the students to memorise the algorithm of the empirical formula calculations. Bryan was the only teacher who did not use the mind map in the textbook because he felt that it made his students more confused.

Generally, Bryan engaged all the submacro and symbolic type of representations suggested in the textbook. Examples of the submacro representation were particles (atoms, molecules and ions), bonding (covalent and ionic bonding), and atomic structure models. Bryan spent a considerable amount of time explaining the synthesis of chemical formula using atomic structure model, chemical bonding, and electron configuration. However, he could not really make his students understand as the chemical bonding and electron configuration were new concepts to them.

Similarly to the other teachers, Bryan used symbolic representations such as chemical symbols (for elements, molecules and ions), and chemical equations in his lessons. These symbols were the basic representations in chemistry. For instance, he also used the cross-multiplication method to teach the writing of chemical formula though the presentation of the steps were different from that of Andy (Figure 4.27).

Ion	Sodium ion Na^+	Oxygen ion O^{2-}
Charges of ion	+1	-2
No. of ions	2	1
Chemical formula of sodium oxide: Na_2O .		

Figure 4.27. Cross-multiplication used by Bryan to teach chemical formulae

Although most of the representations used by Bryan were similar to those used by the other teachers, differences were noted in his analogies and examples and also the explanations given. In addition, he used a number of new concepts which students have not learned such as periodic table, chemical bonding and electron configuration. The use of the new concepts seemed to complicate his explanations.

The representations used by Catherine were almost similar to that of Teacher Bryan as she also used the atomic structure model and chemical bonding to explain the synthesis of chemical formulae. She used most of the representations in the textbook, practical book and courseware which included the definitions, diagrams, examples, symbols, mind map and exercises. In comparison to the other three teachers, she created the least number of examples and analogies. Most probably because she did not teach many classes of chemistry prior to the data collection and she spent most of her time on group presentations.

Based on the excerpt of teaching, it was noted that besides showing the courseware, Catherine often referred to the textbook while explaining the definition (Appendix L). She read the definition from the textbook. While reading, she paused at certain terminologies to check whether the students

remembered or understood the meaning. If the answer was “no” then she would take the opportunity to revise the concepts with the students. She also gave tips and showed students the technique in answering the questions during examination. Other time she would tell students the importance of that concept in the examination.

Catherine used a lot of examples to explain the calculations (Appendix L). She showed the examples in great detail including writing the units for every single step in the calculations. Additionally, she used representations from other topics such as atomic structure model from topic 2 and diagram of chemical bonding from topic 5 to explain the formation of cations and anions while teaching the chemical formulae. She got the same response of the students as Bryan as the introduction of new concepts such as chemical bonding did not really help the students understand better. She also used the cross-multiplication method to explain the synthesis of chemical formulae and balancing the charges on the cation and anion (Figure 4.28).

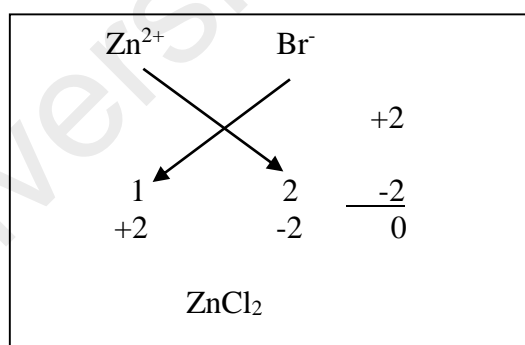


Figure 4.28. Cross-multiplication used by Catherine to teach chemical formulae

There is some differences between the cross-multiplication method with those of Andy and Bryan. She added one more step “+2-2=0” to indicate the overall charge of the chemical formula is zero or neutral.

She was in favour of the content in the courseware as it was colourful, attractive, with animations, interactive, saved her time in preparing the diagrams, and enhanced her explanations. She explained the use of the courseware allowed her to elaborate on the concepts and interact with the students through asking questions. Catherine was selective of the content in the courseware for showing. It was noted that she used the content with great flexibility suggesting that she was familiar with the content in the courseware. Sometimes she gave the explanation before showing the courseware, another time she showed the courseware before giving the explanation. Both her explanation and the courseware complemented each other in reinforcing students' understanding. Catherine also instructed the students to jot down important points from the courseware or underline important points in the textbook to help students recall what they had learned.

Based on the excerpt (Appendix L), one could see that Catherine incorporated her explanation in between showing of courseware smoothly. At the same time she asked students whether they understood once in a while and the students seemed to be able to follow the lesson.

Catherine accepted the fact that it was difficult to make every student in the class understand the concepts in one lesson. However, she could not wait for everybody to understand before she proceeded to a new topic suggesting she might not practice the mastery learning mentioned in her views on teaching. Although the placement in 4A, 4B and 4C classes was by streaming, Catherine taught them the same way in terms of content, teaching approach, exercises and assessment. However, she did apply her experience teaching gained from teaching 4A and 4B into 4C as her time table was arranged in such a way that the sequence of her lessons was she taught 4A first, followed by 4B and finally

4C. She could often anticipate what she would encounter in 4C class based on the responses of the students from 4A and 4B classes. For example, if 4A students encountered problems in their learning, subsequently 4B students would encounter more problems than 4A students and 4C students more problems than 4B students and took much longer time to learn the said concepts.

According to Catherine, in order to make students understand, a teacher needed to “lower” himself/herself to the level of the students and “behaved as if he/she know nothing at all” while explaining a concept. She made her explanation simple by replacing the terminologies with simple words. In her explanation, she often pointed out to the students the differences between the new concept and the concepts previously learned. She also asked them to make comparison when they got confused. She often gave opportunities to her students to explain before she explained. As a whole, her explanation was simple, systematic and clear. Catherine used group presentations and therefore she spent a lot of time facilitating the presentation, checking students’ answers as they presented, she corrected students’ mistakes at the end of each presentation. That probably also explained why she did not create a lot of examples and analogies of her own as most of her explanations were based on what the students presented.

As mentioned in the earlier section, Dennis taught with the commercial transparencies in the first three lessons of topic 3. He created the “football and tennis” analogy to teach the concept “relative” while teaching the “relative atomic mass” (Appendix M) then he used the “*roti canai*” analogy to teach proportionality.

Ok, class, now we will talk about the relative. Ok, let's say, this is a ball that we use to play, ok, the mass of the ball is what...ok...10g, ok? And this is ... consider...ok, you assume as a tennis ball, ok? Let's say we want to compare the mass of the two balls. Ok, so, let's say you compare the size of both balls, ok, how many times...the size?

(CO/#1/Dennis)

As he was introducing the “relative” concept, he drew the diagram of the football and tennis ball (Figure 4.29):

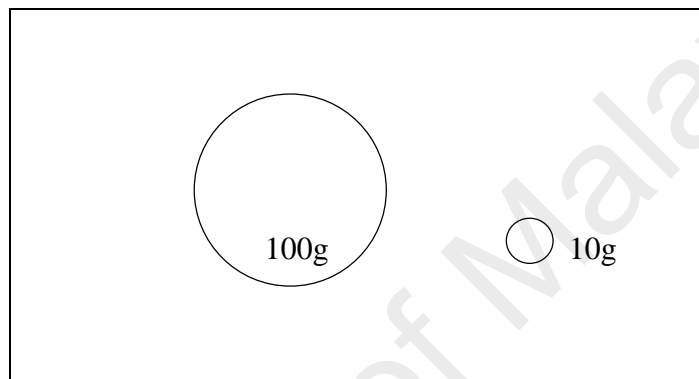


Figure 4.29. The diagram of analogy of football and tennis ball

Immediately he asked students to compare the size of the two balls and he drew another diagram (Figure 4.30):

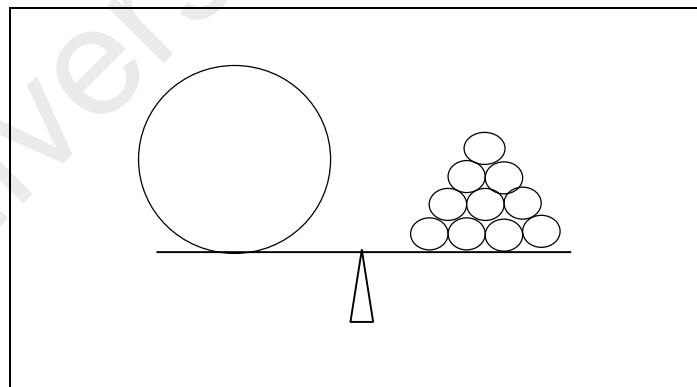


Figure 4.30. The diagram used by Dennis to compare football and tennis ball

As the students could not give the answer about the comparison, Dennis put forward two alternatives for the students to choose: $10-1=9$ or $10/1=10$. Finally he called upon two boys of different heights to the front.

Based on the excerpt, it was noted that Dennis tried to use various examples (prepared and impromptu) to explain the meaning of “relative” (Appendix M). However the response of the students were not encouraging as they kept quiet when he asked whether they understand what he was trying to explain. It was noted that his teaching did not flow smoothly. At the same time, some misconception such as equating “mass” and “weight”, then the ratio was interpreted by students as “divide”, some students thought oxygen as ions and also molecules were noted. Dennis referred to the textbook for the concept definition and he asked student to read to the class. It was noted that the boys in his class were responsive and students did ask Dennis when they don’t know the term A_r . Dennis also introduced the periodic table at the back of the textbook as reference of the RAM of elements.

Another analogy created by Dennis was the making of *roti canai* which he used it to explain the proportionality and the limited factor in stoichiometry. He said, “You are given the information that to make 10 pieces of *roti canai* you need:

500 g flour + 1 egg + 100 ml water + 50 g margarine

He then asked students,

“If you want to make 5 pieces of *roti canai*, how much do you need?”

Answer: 250 g flour + $\frac{1}{2}$ egg + 50 ml water + 5 g margarine

“Now if Ahmad had the following amount of ingredients, how many pieces of *roti canai* can he make?”

1000 g flour + 1 egg + 100 ml water + 50 g margarine

(CO#10/Dennis)

It was noted that he could not tell students what exactly he wanted them to learn and relate the analogy to the said concepts. As a result, the students did not know what he actually wanted to convey. As a whole, Dennis could not use his analogies effectively and his analogies often made students confused.

Dennis code-switched from English to *Bahasa Melayu* and vice versa and gradually he used more *Bahasa Melayu* than English towards the end of the lesson. However, the code-switching of Dennis was not as confusing as that of Bryan because Dennis often code-switched the whole sentence and not partially in the middle of a sentence as in the case of Bryan.

The scenario changed when Dennis used the courseware to teach. Most of the time he played the courseware, showed most of the content in the courseware from the learning outcomes, definition, explanation, examples, to the interactive quizzes. Once in a while, he stopped to elaborate on the content.

Dennis used most of the interactive quizzes in the courseware. His students were excited and they enjoyed the quizzes because the feedback was instant. It was noted that in a few occasions Dennis discarded the quiz/exercise half-way when he realised that the questions were difficult and complicated. This suggested he was not familiar with certain content in the courseware. This interpretation was further supported when he asked the students to try those questions with wrong answers in three occasions. There were some mistakes in the questions such as the questions contained wrong information or the answers provided were wrong. As a result, both teacher and students wasted their time trying over and over again the questions and the correct answers were repeatedly rejected. The students were frustrated.

Towards the end of Form Four, after using the courseware for eight months, Dennis concluded that it was ineffective to teach with the courseware

as it did not give much impact on the learning of the students. He complained that students watched the courseware as if they were watching video or television program. Additionally, the students did not jot down any notes during his lessons. He also realised that although his students enjoyed learning with the courseware, the learning was not sustainable.

Similar to the other teachers, Dennis gave all the exercises in the textbook that is “Work This Out” and “Quick Review” to his students after showing the examples. While the students were doing their work, he went around to monitor their work, showing them how to solve the problems, corrected their mistakes and gave explanations.

4.4.3.4 Laboratory work

All the teachers did the experiment on the determining empirical formula of magnesium oxide. All of them used the Form Four activity book except Bryan who used practical work book bought. Andy and Catherine used the experiment as the PEKA project. The experiment was a guided one as all the procedure and the apparatus setup were provided in the activity book and work book.

Andy did two out of the seven activities suggested in the Form Four Chemistry practical book. They were: “to investigate the concepts of relative atomic mass and relative molecular mass” using analogy (nut and bolt) (Appendix N) and “to determine the empirical formula of magnesium oxide” (Appendix O). Another laboratory work: “To determine the empirical formula of copper (II) oxide” was discussed as a simulation using the courseware.

Andy informed his students one week beforehand to read up for the experiment. The practical was carried out as group work. Before the students

began the experiment, Andy explained the procedure and he reminded the students to do it and not be a passenger in their group. He gave a thorough instruction and explanation of the experiment (Appendix P). At the same time he also mentioned the precaution that students needed to take while doing the experiment such as preventing the white fumes from escaping from the crucible, cleaning of the magnesium ribbon and others.

All the students were very keen on conducting the experiment. They participated actively during the practical. They were proactive, full of curiosity, they asked questions, and consulted the teacher and friends. They asked all sorts of questions and consulted their teachers when encountering problem such as the scale of the electronic balance is in oz. or gram, was is ok if the magnesium ribbon broke into two.

It was noted that most of them were not sure of the procedure of experiment and the calculations of the empirical formula even though Andy had reminded them to read up a week earlier. Andy demonstrated to the students how to heat the magnesium ribbons. In order to cut-short the time on the heating, he asked students to use two Bunsen burners at a time.

Andy did something quite different from the usual practice, for instance, he did not ask the students to repeat the heating, cooling and weighing process until they obtained a constant mass of magnesium oxide. Instead he asked them to repeat the whole experiment using the second piece of magnesium ribbon. He explained that the second trial served as a backup in case the results from the first attempt were unsatisfactory. However, it was noted that the second attempt did not improve students' results. In fact, good results was determined by the complete combustion of magnesium ribbon and not the number of trials. The results showed that only one group successfully obtained the ratio of 1:1

for magnesium and oxygen, the rest of the five groups obtained the ratio such as 2:3, 1:2 and 3:2.

After getting the data, most of the students did not know how to go about with the data obtained. Andy literally had to explain and show all the calculations for the students to jot down. The students did not know how to go about doing the calculations. Since most of the results of the students were different from the theory, Andy told them to adopt the best results from their friends. Andy did not discuss and verify with students the unsatisfactory results.

Bryan was selective on the experiments he gave to his students. He did two experiments in topic 3: “To determine the empirical formula of magnesium oxide” and “To construct balanced chemical equations” (Appendix Q). He said he would like to do more experiments but there was a shortage of apparatus. Bryan and the students referred to the practical workbook when doing the experiment (Appendix R). Bryan was the only teacher who used the commercial practical workbook approved by the school authority.

Bryan used the workbook to explain the procedure of the experiment (Appendix S). His students asked questions while he was explaining. They asked, “What is lid?” “What is crucible?” (CO#5/Bryan). It was noted that Bryan did his explanation without doing any demonstration. It was only when students asked then he asked the boy sitting at the back to hold the crucible and its lid and showed to the class. The procedure and the table of results were given in the workbook. Bryan told the students to write the aim of the experiment, rewrite the procedure in the passive voice, record the observations and results, calculate the empirical formula, answer the discussion questions and write the conclusion in the work book. The lab report had to hand in to Bryan.

Similar to Andy's students, Bryan's students showed great interest and attention while conducting the experiment. They were proactive, excited and were serious about what they were doing, in addition, they proudly showed their friends the outcomes of their experiments such as the yellow precipitation of lead (II) iodide and the lime water that had turned cloudy when they were doing the experiment "to construct the chemical equations".

As Bryan instructed his lab assistant to prepare only two sets of apparatus for the empirical formula experiment. As a result, 13 to 14 students shared one set of apparatus and only a handful of them had the hands-on opportunity. Bryan admitted he had overlooked the size of his class and he would provide more sets of apparatus next time. Similar to the outcomes in Andy's class, the results obtained by Bryan's students were not satisfactory. The poor results was probably because the students were very excited and scared also when they saw the magnesium ribbon started to burn, as a result they did not close and open the crucible lid properly. Bryan also had to discuss and provide all the answers to the students.

Catherine did only one experiment in the practical book that was "To determine the empirical formula of magnesium oxide". She helped students to recall that they had seen magnesium when they were in Form Three. Catherine gave a detail explanation of the procedure of the magnesium oxide experiment. She began by showing a simulation of the experiment in the courseware before the students did the experiment. She explained the procedure in great detailed because she did not want her students to make mistakes and there was no time to repeat the experiment. She also used the empirical formula experiment as the PEKA project (Appendix T).

Catherine told the students that they would heat the magnesium ribbon once only as they had no time to repeat the heating, cooling and weighing process. Therefore she reminded them they must do their best and made no mistake. It was noted that as Catherine was giving the explanation, the students were attentive and they asked questions when in doubts. They also actively consulted their teacher and asked questions while carrying out the experiment. However, they were playful too and were talking while waiting for the crucibles to cool down. As the heating took time therefore there was no time for Catherine to go through the results, however, she explained to students how they could go about with the data collected. It was noted that the results obtained by the students were unsatisfactory too as students were too excited when magnesium started to burn, some of the girls were screaming and they forgot to close the lid. In addition, the heating, cooling and weighing process was not repeated until the combustion complete. All the factors mentioned might have contributed to the unsatisfactory results.

As mentioned in his views of teaching, Dennis was in favour of doing lab work to enhance students' learning. He also gave the same experiment in topic 3 to his students: "To determine the empirical formula of magnesium oxide". Dennis began the lesson by asking the students to read Activity 3.5 in the practical book and they read quietly. This was to ensure the students understand what they were supposed to do. Then he proceeded to explain the procedure in the practical book in great detail,

Step 6, when the magnesium ribbon starts to burn, cover the crucible with its lid. Ok, after the magnesium started to burn, cover...cover the crucible with its lid...cover it. When you see the the bright flame begins...quickly cover the crucible with its lid. Step 7, using a pair of tongs, carefully raise the lid a little, at intervals. Class, do

not open the cover for a long time. If you open widely...the white smoke will come out...

(CO#8/Dennis)

While explaining the procedure, Dennis did not do any demonstration.

A few things were noted during Dennis's class. The students were not sure of what they were doing even though he had told them to read beforehand and also in the class. He was disappointed as the students kept on asking him how to go about with the experiment. He said,

About doing the experiment, one problem, when you give the students the apparatus, they do not know what to do. Give them that, then they do not know what to do. 'Teacher, how teacher?' The books are informed of their eyes, although I inform them next week we have experiment for example 3.2, until that day, the apparatus were put in front of them, they still asked, 'Teacher, how teacher?' Meaning that they did not do preparation. If I explain, it might be a waste of time.

(I#6/Dennis)

However, it was noted that the students were efficient in weighing the magnesium ribbon. While the students were heating the magnesium ribbon, Dennis went round to supervise and gave explanation when necessary. As the heating took a long time, Dennis went back to the teacher's desk to read his reference book. The heating continued and none of the students ask their teacher for how long they had to heat the magnesium.

Similar to the rest of the teachers, the results obtained by the students were not satisfactory. Some of the groups got Mg_2O_3 , only 1 group managed to get MgO. Dennis asked those students who had finished their experiment to start writing their lab report while waiting for the rest of the students to finish their experiment. Dennis expressed that he preferred to do the discussion immediately after the experiment. However, in reality, he said,

If we have time, it is better if we can do discussion on why it is done as such. But the problem is if we have 6 groups, group 1 might begin earlier and have 30 minutes, other just merely have sufficient time, so whether we like it or not, we have to continue it the following week. That means an experiment cannot finish within two periods.

(I#6/Dennis)

Dennis went round to give individual coaching. He reminded the students that, if there was a big difference between the two readings then they needed to repeat the experiment suggesting the results could be accepted if the two readings did not differ much. He did not have time to discuss the results with the class. Before students left the lab, Dennis checked with them by asking them what was the empirical formula of magnesium oxide and all the students said MgO and the lesson ended abruptly.

All the four teachers were in favour of doing experiments. However, they could only carry out one to two experiments due to time constraints. The priority of selecting certain experiments was to enhance the students' understanding, the experiment was a popular topic for exam and as a PEKA project. Dennis also stressed that doing experiment was important for examination only.

Based on the responses of the students during the experiments, it was obvious that they liked and enjoyed doing experiments. It was totally a different scenario during the experiment as compared to the usual classes. They were proactive, serious, asking questions and consulting their teachers and friends when they were in doubts. They showed a sense of ownership when they got good results and they would proudly show their products to their friends. Catherine's students clapped hands when she announced that they were going to do experiment.

However, on the whole, the outcomes of the magnesium oxide experiment were not satisfactory. A few issues were noted: (i) although the students liked to do the experiments, they were uncertain of the procedure of the experiment even though they were asked to read the procedure before the classes; (ii) most of the students did not know how to go about the calculations therefore the teachers had to show every step and provide answers to the calculations and discussions; (iii) only 1-2 groups of the students in each class succeeded in their magnesium oxide experiment. The high rate of failure was most probably because they did not follow the procedures properly especially on the closing and opening of the crucible lid. Due to the time constraints, the heating, cooling and weighing process was not repeated until a constant mass of magnesium oxide was obtained; (iv) the students were asked to adopt the better results of their friends without any justification from the teachers; and (v) the experiment was a fully guided enquiry to confirm the theory.

4.4.3.5 Questions

Another representation widely used by the teachers to deliver their content is question. The questions used by the teachers came in two forms: oral and written. All the teachers admitted that “asking question” was the most common method used by them in the classes to assess their students’ understanding. In this study, most of the oral questions asked by the teachers were impromptu questions created based on students’ response. All the teachers engaged questioning for various purposes such as: i) to help students recall and revise previously learned concept; (ii) to engage students in their learning; (iii) to assess students’ understanding and (iv) to discipline the students(sometimes).

(1) Oral questions

As mentioned in the earlier section, topic 3 consisted a lot of calculations and the teachers used a lot of examples to reinforce the concepts. It was noted that teachers posed questions when they were doing recalling, explaining the examples, doing the quizzes, giving explanation and assessing students' understanding. Most of the oral questions used by the teachers were impromptu questions posed when they explained the examples. As they were interacting with the students, they asked questions to engage students and also get answers for the steps written. In comparison, Andy did not ask a lot of questions because he delivered a lot of facts during his explanation (Appendix U). Andy posed questions mainly to help students recall and revise what they had learned previously, to engage them in the learning and also to assess their understanding.

Based on excerpt, one could see that Andy did not encourage the students reading directly from the notes or textbook when answering his question's because he wanted to assess their understanding. He preferred them to understand what they had learned and then answer with their own words. He was disappointed because it seemed like the students had not grasped the concepts and he commented they were lazy and did not do revision. Some samples of the questions posed by Andy were shown in Table 4.8. Based on the response of the students, one could see that students gave better responses when the teacher explained the examples as compared to when he asked questions related to recalling and explaining the concepts.

Table 4.8

Samples of the questions posed by Andy

Purpose	Question	Response of students
Recalling	You still remember what is meant by Relative Atomic Mass of an element? What it meant by the Relative mass, Relative Atomic Mass of an element?	What teacher?
	The concept of Relative Atomic Mass or Relative Molecular Mass or Relative Formula Mass is the comparing, right, comparing the mass of an atom of an element with...with what?	Carbon
Assess students' Understanding	Why do we use...ah...why do we use the carbon-12 atom, why not any other atom? Why? Why?	Maybe easy
Habitual type	Because carbon-12 is the standard atom chosen, right?	Ya...
Engaging learning and assess students' understanding	You have only 4 eggs, ok? 4 eggs, how many dozens is this? How many dozen is this? 4 eggs is equivalent to how many dozen? Lets' say I have 2 dozens of eggs, how many eggs do I have? Lets' say I have 2 moles of copper, how many copper atoms do I have?	1/3 Twenty-four 2x6.02...

Bryan incorporated questions in his explanations to help students to recall, assess their understanding of his students and engage students in their learning (Appendix K). Based on the excerpt, a few things were noted:

- (a) the questions posed by Bryan were mostly convergent and of low order thinking skills, in fact the questions often gave alternatives for students to choose;
 - (b) the questions asked were often in incomplete sentences thus were rather disorganised and confusing;
 - (c) the code-switching interrupted the flow of the questions and arose confusion (Figure 4.31);
 - (d) although numerous questions were asked at one time, the students only responded to the last question;
 - (e) little wait time was given for the students to think and answer;
- and

- (f) when Bryan had a hard time trying to explain to students, he would said, “I don’t know how to explain to you.”, “I don’t know how to answer your question...” another time he said, “I don’t know how to say...”

Source	Transcript	Remarks
Bryan	...so just now you have learned how to calculate relative molecular mass, relative formula mass, between relative molecular mass and relative formula mass no difference, the way you calculate <i>adalah sama</i> , [the same] ok? Now the mole and the number of particles...number of particles, you look at the second substance...the particles in substances can be atoms, molecules and ions, ok, <u>you know what is substance?</u> In your Periodic Table...in your Periodic Table page 176 in your text book, <i>semua itu ialah atom</i> [all of them are atoms]...elements. So molecule, <u>what is molecule?</u> Combination of two or more atoms...two or more. So for example, <u>two atoms, what is it?</u> Oxygen...oxygen atoms, <u>what is the symbol for oxygen atom?</u>	Code-switching Questions Questions Questions
Bryan	Ionic compound...how to say, because you all never learn about chemical bonding so <u>I don’t know how to explain to you</u> . If you learn chemical bonding... chemical bonding chapter 5 after Periodic Table, and then you know what is an ionic compound, how ion is produced and then how cation is produced, so for this moment we just keep it like that, ionic substances...ionic substances, metal, non-metal. If you look at the chemical formula for the substances, metal always ... <u>they always write metal symbol in front...in front chemical symbol for compounds, correct or not?</u> <i>Biasanya logam ini ditulis di...depan, kalau jumpa sebatian yang mempunyai logam, bukan logam, itulah adalah sebatian ionik. Untuk sementara...</i> [Normally metal is written in front, if you see compound with metal and non-metal, it is an ionic compound. For the mean time]...so when you go to chemical bonding <i>saya akan terangkan semula</i> [I will explain again] <u>what is ionic compound, ok?</u>	Teacher said he did not how to make students understand Assessing understanding (students had not learned ionic compound) Code-switching

(CO#2/Bryan)

Figure 4.31. An excerpt of Bryan’s questioning technique

Some examples of the questions posed by Bryan were shown in Table 4.9.

Table 4.9

Samples of the questions posed by Bryan

Purpose	Question	Response of students
Assessing understanding	If you are given the number of particles, how to calculate the number of moles?	Ah...divide by what...
	You got the mol, so how to find mass? 0.2 mass, what does it mean?	Don't understand, teacher
Recalling questions and assessing	What is mass?	
	What is substance? You know what is substance?	
Assessing students' understanding (provide alternatives)	5.6 g of iron... atom or molecules?	Er...atom
Assessing students' understanding	What is the difference between M_r and F_r ?	The letter, teacher
	How to reverse the equation?	Divide the thing divides by N_A

Catherine grasped every opportunity to assess the understanding of her students. She often paused at the middle of her explanations to ask questions. For instance, she asked students whether they still remembered magnesium when explaining the experiment on the empirical formula of magnesium oxide. She often asked questions after showing the courseware. An excerpt of the transcript when she was teaching the Avogadro's constant (Figure 4.32):

Source	Transcript	Remarks
CD	Two items of the same type can be called a pair, 12 items of the same type can also be called a dozen, and 144 items of the same type can also be called a gross. Pair, dozen and gross are examples of unit that can be used to measure amount of items in our daily lives. Let's see there are 6.02×10^{23} of same particles, how do you represent this number? The value of 6.02×10^{23} is called the Avogadro constant or the Avogadro's numbers. The name of Avogadro is in order of familiar Italian Scientist Amedeo Avogadro who lived from 1776-1886. The symbol of the Avogadro number is N_A . When do we use this number? Italian use this number to define a mole. So what is mole?	
Catherine	Ok, <u>What is the symbol of Avogadro number?</u> <u>What is the Avogadro number?</u>	Teacher asked questions
Students	6.02×10^{23}	
Catherine	6.02×10^{23} , ok. <u>So what is Avogadro number?</u> <u>When do you use this number? And what it is Avogadro number have to do when we are defining the mole? What is mole? What is Avogadro number? This is what we to do the connection later on. Can we proceed? Can you follow up to here? Alright.</u>	Teacher asked more questions
CD	Chemists use the unit mole to measure the amount of substances. <u>How much is one mole?</u> Scientist had determined experimentally that 6.02×10^{23} atoms present in 12 grams of carbon-12. A mole is the amount of substance that contains as many particles as the number of atoms in exactly 12 g of carbon-12.	
Catherine	Ok. Again, carbon-12 is used as a scale, right? Scientist put 12 grams of carbon-12, and <u>they found out that, the number of atom in 12 grams of carbon-12, how many? How many atoms are there or how many particles are there in 12 grams of carbon 12? You have any idea? How many particles are there?</u> There are 12 gram of this carbon 12 here. <u>How many particles are there? Inside there? How many?</u>	Teacher asked questions at the middle of her explanation. She answered the questions herself
Students	One mole	

(CO#5/Catherine)

Figure 4.32. An excerpt of Catherine's explanation while teaching the Avogadro Constant

Some examples of questions posed by Catherine were shown in Table 4.10.

Table 4.10

Samples of the questions posed by Catherine

Purpose	Question	Response of students
Recall and relate	Based on carbon-12 scale...carbon-12 scale. Remember atom carbon? Remember the last lesson you learned about carbon?	Teacher gave no wait time for students to answer
Assessing understanding	What it is Avogadro number have to do when we are defining the mole? So let see here, there have two types of formula, chemical and empirical. How are they different? In one molecule of glucose, how many types of atom is there? Do you see what atoms are there? So we have 1 copper atom. Can you see here the N and O? We have nitrogen and oxygen atom in the blanket here. What does this means? What is it mean by empirical formula? What is the empirical formula? Is the simplest ratio, Ok? (Teacher answered the question) So what is the empirical formula of this compound? The question asking you find out the empirical formula. Ok. What is the solution? Now this question, how many element? 2 isn't it? Can you look? 2 mole of aluminium atom combine with 3 mole of oxygen atom. And therefore the empirical formula of the compound is Al_2O_3 . Any question? Any respond from you all?	Yes Teacher gave no wait time for students to answer Ya Sure, we understand.

Based on the questions shown in Table 4.10, one could see that Catherine asked a lot of questions while giving explanation and she gave no wait time to the students to answer her questions. Students often only responded to the last question she asked. It was noted Catherine sometimes gave answers to her own questions.

Dennis asked questions while giving explanation. Most of the questions asked were impromptu. Dennis posed questions while teaching with the transparencies or with the courseware (Figure 4.33 & Figure 4.34).

Source	Transcript	Remarks
Dennis	OK class, before we talk about the mole, so what actually is mole itself...what is mole?	Question
Students	The amount of substance.	
Dennis	OK, so mole is the amount of substance ok...of that contains as many particles as the number of atoms exactly of 12 gram of carbon-12, ok, ok, that is the meaning of mole] ok, now, ok we will discuss, ok, the relationship between mole and the mass, ok, mass, what is mass?	Question
Students	Mass...	
Dennis	Mass, what is the relation between mol and mass? <u>And how to convert mole to mass?</u> Ok, in our previous lesson, ok, we already discuss about the how to convert mole to number of particles, ok, so now, ok, we discuss further how to convert... ok, class, to convert mole to particle, ok, <u>what you must do?</u>	The question was not answered Question
Students	Times...	Teacher probed
Dennis	<u>Time what?</u>	Question
Students	N_A ...	
Dennis	OK, N_A ... <u>what is N_A?</u>	Question
Students	Avogadro Constant...	

(CO#2/Dennis)

Figure 4.33. An excerpt of Dennis's questioning technique while teaching with transparencies

Source	Transcript	Remarks
Dennis	Ok, volume of gas, ok, if you want to convert...ok, number of moles into the volume of gas, what you need to do is multiplied with molar volume. Molar volume is depended on the condition, whether is at SPT or room conditions. If you want to convert from volume of gas to number of moles, you divide by molar volume, ok, molar volume also depend on the condition whether STP or room condition. That is what you need to do, so the three relationship here you must remember. For example, if you were asked to go from number of particles to volume, you can't go straight, you have to...transit...	
Students	Mole...	
Dennis	For mol, you have to transit, there is no direct flight, whether you want it or not you transit beside if you have a plane of your own. So you have to transit if you want to go to volume of gas, you have or you must to transit at the number of moles first before you reach the <u>volume of gas, do you understand or not this chart?</u>	Question Question
Students	Understand...understand	
Dennis	OK, understand	

(CO#1/Dennis)

Figure 4.34. An excerpt of Dennis' questioning technique while teaching with the courseware

Similarly, Dennis posed questions to assess students' understanding, help students to recall and relate and also engaging students in the learning. Table 4.11 show some examples of the questions posed by Dennis.

Table 4.11

Samples of the questions posed by Dennis

Purpose	Question	Response of students
Recall	What is molecular formula?	Teacher gave no wait time
Assessing students' understanding	You get 26.6...so to get the mass of oxygen reacted with magnesium...what you heat a metal in air what will happen?	Burn...
	Do you know the meaning of fume...you know what is the meaning of fume?	No
	What is fume in <i>Bahasa Melayu</i> ?	Teacher gave no wait time given
	If I said you are tall and he is short, what am I doing?	Comparison
	What do you understand the meaning relative?	Relationship
	How to calculate the mass of an atom? How do we calculate the mass of an atom which is very light? What is the best way?	()

Based on the questions asked in the excerpts shown, one could see that the questions used by Dennis were convergent questions and of low orders of thinking skills.

In brief, all the teachers posed questions while giving explanation and most of the questions posed were impromptu questions. At times, the teachers incorporated too many questions in one slot of their explanation and they did not give any wait time for their students to answer resulting their students did not respond accordingly. Most of the time, they would only respond the last questions asked, as a result the questions seemed to serve little purpose.

(2) Written questions

The teachers made use of all the topic 3 exercises in the textbook. There were two types of exercises given at the end of every sub-topic: "Work

This Out” and “Quick Review” (Appendix V). Both exercises were normally given to the students at the end of every lesson then the teachers would go over the questions with the students at the beginning of the following lesson. All the teachers gave good comments on the exercises in the textbook. Andy commended,

I think the questions are great, it can be used as a measure to see whether your learning outcomes is achieved or not. Let's say after your teaching and then students able do the questions from the textbook then you can said outcomes is achieved. The questions are not too many, it's just enough, you can make a fairly accurate guess whether your learning outcomes is achieved or not.

(I#5/Andy)

However, he cautioned his students not to rely solely on textbook exercises; instead, they must do the textbook exercises first before they tried other exercises given by their teacher and from reference books.

On the contrary, Catherine and Dennis considered the exercises in the textbook as sufficient therefore they did not give extra exercises. Whereas Andy and Bryan gave extra exercises in the form of “2-in-1” notes (Figure 4.21) and “Test Yourself” quiz (Figure 4.35) respectively. As mentioned in the earlier section, the “2-in-1” notes was an effort of Andy to assist his students solving the numerical problems whereby guided solutions were provided in the said notes.

According to Bryan, those exercises in the textbook were specially prepared to assess the understanding of the students on the concept just learned. There were 4-6 questions in each exercise which were arranged with increasing difficulty. Bryan claimed that he could assess the understanding of his students based on the number of questions they could answer. If a student could answer the first three questions in the “Work This Out” and “Quick Review” exercises,

it meant they had attained basic understanding of the chemical concepts. On the other hand, if they could answer all the questions in the exercises, it meant they had thoroughly understood the chemical concepts.

Bryan gave the “Test Yourself” quiz to his students after he explained the concepts. Sometimes the quiz served as examples. The quiz provided an opportunity to apply what they had just learned. The quiz contained short questions thus it did not take a long time to answer. The questions were presented with increasing difficulty and complexity. For example, in the quiz converting mass into number of moles (Figure 4.35):

Test Yourself

Calculate the number of moles of the following:

(i)	12 g of Mg
(ii)	3 g NaCl
(iii)	4 g of CaCO ₃

Figure 4.35. A sample of “Test Yourself” quiz of Bryan

Bryan arranged the questions with increasing difficulty and complexity. He began with a single element substance (12 g of Mg) to a 2-element compound (3 g of NaCl) and 3-element (4 g of CaCO₃). The compounds were presented with no subscript (NaCl) to with subscript (CaCO₃) with increasing complexity.

Catherine used the exercises from the textbook but with a different approach. As mentioned earlier that she assigned one or two questions to each group to work out the answers and presented in the next class. In order to encourage the students to be serious with their homework, she gave 10 bonus marks to those who sent in all the exercises. The marks would be added into their final marks at the end of the semester.

Dennis considered the exercises in the textbook as sufficient and provided opportunities to students to apply what they learned. Besides the “Work It Out” and “Quick Review”, he also let his students try the interactive quizzes in the courseware. However, some flaws were noted in the usage of the interactive quizzes in the courseware. For instance, Dennis wasted his time browsing through the quizzes and was indecisive of which quiz to use. Time was also wasted when the students worked on problems with mistakes.

All the teachers used oral and written questions in their lessons. The oral questions were incorporated into their explanations. The main purposes of asking the questions were to assess students’ understanding, to help students recall and revise what they had learned in the previous classes, to engage students in the learning (sustain their attention) and also to control the class. All the teachers assumed that if the students could answer their questions they had understood what they learned. However when students failed to answer the questions, they thought the students were lazy and did not do revision. None of the teachers related students’ failure in answering the questions to a lack of understanding of the concepts.

Generally, the questions asked by the teachers were mostly impromptu in responding to the reactions of their students. It was a common practice that they often posed questions to the whole class and seldom to individual students. However, when they posed questions to individual students, they had a tendency to call the same and better students as in the case of Andy, Bryan and Dennis. Andy, Bryan and Catherine had a tendency to ask numerous questions at one time and also answer the questions themselves.

As a whole, the questions posed by the teachers were convergent questions and of low-order thinking skills which most probably could not assess the conceptual understanding of the students. They also did not give sufficient wait time for the students to think and answer the questions.

4.5 Classroom management

As a whole the teachers did not encounter much discipline problems except Catherine. The science students were normally the high academic achievers in their respective school therefore majority of them were appointed as the school prefects as in case of Andy, Catherine and Dennis' students.

Andy's students were punctual though their homeroom was far away from the lab. The scenario in his class was basically "teacher talked and students listened". The students were quiet, well disciplined, and attentive most of the time except the few boys sitting at the third row to the right of the teacher. They often talked non-stop while he was teaching. It was observed that they were attentive at the beginning of the lessons but as time went by, they began to talk. They stopped when Andy stared at them. Occasionally, they were so engrossed in their talking that they did not pay any attention at all. Andy had tried various ways to attract their attention, among others, giving warnings, asking questions and calling them to write answers on the board. However, the effect was often short-lived. Andy had a busy schedule. Although he had to attend meetings, entertain parents and visitors, went through letters and made decisions when the principal was away, he did not miss any of his classes. He practiced some strategies to overcome the time constraints such as:

- (a) he arranged himself to sit-in 4 Science class to give test, do test correction so that he had more time for teaching;
- (a) he came 15 minutes before class to copy notes on the white board so that he did waste the teaching time;
- (b) he adjusted the number of examples used in his lessons depending on the time he had.

Bryan, on the other hand, was particular about his students' attire. He checked the attire of his students and their homework first thing in the morning. Holding a *rotan* or a meter rule in his hand, he walked around checking the students from one bench to another. As he walked around, he joked and sometimes teased the students. Bryan rationalised that "students with proper attire are students ready for learning".

Bryan also monitored the cleanliness and breakages in the lab by preparing a sitting plan of his students. Based on the sitting plan, he could keep track of those who left behind rubbish such as sweet wrappers inside the drawer or who had broken the science apparatus. He often reminded his students to clean and clean their places after class.

Bryan described his students as 'slow learners' because they were weak in basic mathematics. Therefore he had to crack jokes in his lessons to sustain their attention. He was humorous, sporting and talked to his students like friends. He teased and laughed at the students when they made mistakes. The students also did the same to him when he made mistakes. Both parties often ended up laughing away. Once in a while, Bryan was sarcastic. The atmosphere in the class was often jovial and lively. Comparatively, his students were most daring in asking questions and also admitting they did not understand what the teacher taught. They also dared to point out Bryan's

mistakes. Although they came to the class 10 minutes late every time, Bryan did not complain about it.

Quite a number of the boys in Catherine's class were talkative and they talked non-stop. As mentioned in the earlier section, they could talk with each other from one corner of the lab to the opposite corner of the laboratory. There was a boy who frequently absented from the class. If he came to school, he would sleep in the class. However, Catherine considered this kind of behaviour as tolerable as the behaviour of those students in the 4F and 4G classes were even worse. In comparison, Catherine's students were fast in grasping the concepts especially the calculations. In order to improve the class control and engaged students in their learning, Catherine tried the following strategies to help her students learn:

4.5.1 Motivation and encouragement

Catherine motivated her students to work hard by challenging them to prove to her that they were as good as their peers in 4A and 4B.

She said,

...4C, you had done your best in PMR and you must prove that you are smart enough to be in 4C, you understand what I mean? I challenge you, prove it to me...ok?

(CO#2/Catherine)

She gave individual comment to every student in the class when giving back the test papers. She gave different comments based on their individual performance. For instance, she praised those who did well by saying "well done" and "keep it up". To those who failed, she said "you

have to work hard next time”. Other comments included, “don’t forget to write the units” and “improve your hand-writing”.

4.5.2 Rotation system

Some of the boys did not pay attention during Catherine’s class. They were either talking or sleeping. Catherine practiced the rotation system in the sitting arrangement in the lab. There were four rows of benches in the lab therefore the rotation system gave every student the opportunity to sit in front once in every 4 lessons or every two weeks. Catherine commented the system helped to wake up the daydreamers sitting at the back. Although she could not solve all the problems in her class, she was glad at least the students paid attention once in every two weeks while sitting in front. She said that at least they were not lost all the time.

4.5.3 Reminder

Catherine reminded her students repeatedly to pay attention, work hard, change their attitudes and behave properly. When they came late, she hurried them, “...quickly settle down, let’s start our lesson” (CO#3/Catherine). She let the students decide how they wanted to be treated, “do you want me to treat you like an adult or a kid?” (CO#4/Catherine). Next, she told them to change their attitudes, “you are in Form Four already; don’t run here and there like a kid” (CO#3/Catherine), “4C, don’t play too much, change your attitude” (CO#5/Catherine). To encourage them, she said, “You have to do extra work, so that you can do well in examination” (CO#4/Catherine). When

they were not paying attention she drew their attention by saying, “Hello, excuse me...” (CO#4/Catherine). When only a few students responded to her question, she demanded, “I want everybody to respond”, “what about the rest?” “What about the other side?” and “please give me a good respond” (CO#3/Catherine).

Other times, she threatened them, “I will retain you until you hand in all your work”, “you will be left behind 4A and 4B classes if you don’t work hard” (CO#5/Catherine), “This is the last warning, I will send you to see the senior assistant if you do that again” (CO#4/Catherine). There were a few occasions where she got so frustrated that she scolded the students,

you are not paying attention at all. I know none of you can understand what I said but none of you are worried about it because your face did not show that you are worried...

(CO#5/Catherine)

Although Catherine’s class was difficult to control, they took her reminders and advices positively.

Dennis put priority in class control and had repeatedly stressed that during interviews. He expressed his dislike when his students talked unnecessary, gave warning immediately and told them to pay attention. His students behaved well and were polite. The disturbance that Dennis often encountered was that his students often involved in the school activities or represented the school in competitions. It was common that he did not have full attendance of his class. At one time, he had only seven students left in his class which interrupted his teaching.

4.6 Assessment

When the teachers were asked to comment how they assessed their students' learning and understanding, they all gave the same answer: asking questions, doing exercises and through test/examination. The questions and exercises were discussed in the earlier section therefore this section will discuss tests and examinations.

4.6.1 Test and examination

The teachers assessed their students on topic 3 with progressive test and semester examination except Bryan and Dennis as it was time for semester examination when they finished topic 3. The progressive test was given within a period of time scheduled whereas the semester examination was given based on an examination time-table.

Although the progressive test was supposed to be a topical test on topic 3, 30% of the questions on topics 1 and 2. Andy explained that he wanted to give a second chance to the students to revise their topic 1 and 2 as they did not do well in their first progressive test. The second progressive test was made up of multiple choice, structure, and essay questions. The essay question was new to the students.

Andy informed the students to prepare for the progressive test one week beforehand. However, he decided to give the test during a sit-in class on the day when there was no chemistry lesson. The students were caught by surprise. There were only two students who scored above 50 marks in the second progressive test with the highest mark of 60. Andy gave three reasons for the poor performance of his students: laziness, insufficient practice solving the numerical problems, and

improper revision. In his opinion, an ideal revision should make up of one hour of reading plus another hour of problem solving, reading alone was not sufficient in Form Four level.

As mentioned in the earlier section, Andy arranged himself a sit-in class to do the test correction so that he did not waste his class time. He went through every questions in great detail, taking the opportunities to teach, explain and give tips on answering the questions. Based on his experience, he was confident that those students scoring above 20 marks should be able to pass in their SPM chemistry paper provided they paid attention in class and did their work. Some examples of the test and exam questions of Andy were shown in Figure 4.36.

Example of MCQ

Which compound has the highest relative molecular mass?
(Relative atomic mass: H=1, C=12, N =14, O=16, Na=23, Cl=35.5)

A water, H₂O B ammonia, NH₃
C carbon dioxide, CO₂ D sodium chloride, NaCl

Example of essay question

(a)(i) What is meant by molar mass? [2]
(ii) Determine the molar mass for carbon dioxide, CO₂. [3]

Figure 4.36. Samples Andy's test questions

Based on the examples of the questions, one could see that Andy provided necessary information such as chemical formulae for his students so that they were penalised for not knowing the chemical formula therefore prevented from answering the questions.

more than 50 marks in their second progressive test. Figure 4.38 shows some example of questions set by Catherine.

Structured questions

Table 1 shows the RAM of four elements, J, Q, R and T.

Element	RAM
J	4
Q	16
R	24
T	32

a) Calculate the ratio of no. of moles in 8g of Q to 4g of T.
b) Calculate the mass of J which contains three times the number of atom in 16 g of R.
c) If Avogadro's Constant is expressed at N_A , calculate the number of atoms in terms of N_A for
(i) 9 g of R, (ii) 0.8 moles of T
d) Calculate the mass of an atom of Q in terms of N_A
e) If a reaction requires 8.8×10^{23} molecules of Q_2 gas, calculate the mass of Q_2 gas that is needed
f) Calculate the number of ions of Q in 0.5 moles of an ionic compound Na_2Q . (RAM: Na=23. $N_A=6.02 \times 10^{23}$)
g) Determine the volume in cm^3 occupied by 0.4 mol of Q_2 gas at STP. (Molar volume = $22.4 \text{ dm}^3 \text{ mol}^{-1}$ at STP)
h) A syringe is filled with 16.0 cm^3 of gas Q_2 at room conditions. How many moles of gas Q_2 is contained in the syringe? (Molar volume = $24 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions)

Figure 4.38. Sample of Catherine's test question

Based on the sample of question of Catherina, even though she only set one question for the progressive test, the question covered all the aspects related to the mole concepts and the three entities: mass, volume and number of particles.

Similar to Bryan, it was time for the semester examination by the time Dennis finished topic 3. The examination also contained two papers: Paper 1 consisted of 50 multiple-choice questions and Paper 2 consisted of structured and essay questions. Apart from topic 3,

questions were also set from topics 1, 2 and 8. Only one student scored 87 marks and the rest of the class scored less than 40 marks. Dennis did not give many comments on his students' performance except that the multiple choice questions could not assess students' understanding as one might get the correct answer by luck. Figure 4.39 shows samples of questions set by Dennis.

Example of MCQ

0.25 mole of T combined with 12g of oxygen to form T oxide, where T is an element. Which of the following is the empirical formula for T oxide?
(RAM: O=16)

A T_3O B T_3O_2 C TO_3 D T_2O_3

Example of structured question

Write the balance equation for the reaction below:

(a) Nitric acid + Zinc oxide \rightarrow Zinc nitrate + water
(b) Zinc + Iron (II) chloride \rightarrow Zinc chloride + Iron (III) chloride
(c) Barium hydroxide + Sulphuric acid \rightarrow Barium sulphate + Water

Figure 4.39. Samples of Dennis's test questions

The tests given by the teachers took the forms of progressive test, topical test, and semester examination. All the test and semester examination were scheduled in the school calendar. It was noted that:

- (a) none of the four teachers prepared test specification tables when setting the questions for tests and examination;
- (b) there was no standard format in the test papers among the teachers;
- (c) Andy's progressive test was challenging as it contained questions from three topics;

- (d) almost all the students did not do well in their test/examination. Only one to four of them passed with more than 50 marks in each class;
- (e) all the teachers claimed that the poor performance of their students was due to their laziness and insufficient revision; and
- (f) Catherine gave individual oral comments and encouragement to every student when she gave back the test papers.

4.6.2 PEKA

PEKA was a school-based assessment of science process skills. It was compulsory for the students to do two PEKA projects in Form Four and the teachers could make their own choice on the experiments. Andy and Catherine chose the same experiment “To determine the empirical formula of magnesium oxide” as their PEKA project. Although the experiment was carried out in groups, students had to write individual reports.

Andy and Catherine managed their PEKA project differently. Andy let his students to write the PEKA report themselves. Whereas Catherine spent two periods “drilling” her students on writing the PEKA report. She discussed all the answers with them therefore everyone had the same answers. The rationale was to reduce their mistakes, ensure a better grade and also less marking time. She recalled initially she allowed them to write their own PEKA report, it ended up that she had to spend a lot time correcting their mistakes, return to them,

after they did the corrections, handed in again and she had to mark it second time, the job was redundant and it wasted a lot of time.

To sum up, all the teachers assessed their students' understanding through questioning, exercises, quizzes and test/examination. However, Dennis admitted that it was difficult for him to keep track of his students' learning as they did not ask questions at all. Thus, there was nothing he could do as they did not tell him what they did not understand.

Generally, none of the teachers could give specific descriptions of the mistakes made by their students in their tests and examination. As a whole, the performance of the students was far from satisfactory as only one to four students in each class passed their test/examination. Besides giving the same reasons for the poor performance of their students: laziness and insufficient revision and practice, the teachers also all suggested the same solution: "do more exercises and practice solving more problems". Although most of the students did not do well, Andy, Catherine and Bryan were positive and confident that their students could pass in their SPM Chemistry examination provided they worked hard.

4.7 Reflection

All the teachers wrote reflection at the end of their lessons except Andy. The teachers had their views on the writing of reflection.

Andy admitted that he did not write reflection in his lesson plan after his lessons. He said,

I don't know, to me, if you find it useful you go ahead write. If you don't find it useful, to me, it should be optional. If you want to write, you write, if you don't write...but if you write maybe it will force you to think back on your lesson but I don't write. I don't write because it will be too much for me if I were to write but sometimes I do...sometimes this reflection may backfire to you. If you write all good, students failed, backfire on you, if you write all bad, the school authority will think you are not a good teacher, you cannot motivate them...I think this thing should be left to the teacher concerned.

(I#7/Andy)

When asked whether he reflected on his lessons he said he only did so when he had to teach the same topic next round which most probably was a year later. He described his reflection as "refreshing" how to teach and thinking of new examples. He further revealed that he did his reflection anytime and anywhere. Sometimes he even came across a new idea on his way going to the class.

Bryan claimed that he did not reflect on his teaching because he did not record his thought although he frequently asked himself two questions, "Is this method suitable or not?" before a lesson and "In this case, what to do next?" after a lesson. He asked himself the two questions because he wanted to improve his teaching and to avoid boredom. He said,

I refer to the textbook in advance...I look for what I want to teach, the important one that I want to stress so that they can do...I always do that. The problem is, it is not recorded. If we make record of the success it can be used for research. This is because if I refer to...planning my lesson plan, I refer to ti. As for my textbook, I made many remarks, recorded of what they students did, if I were to teach this, look here, what is there they don't understand. If they don't understand then I cannot go into it, I need to reteach, I always do that. Similarly while doing the experiment, if they haven't mastered something, I have to teach that first...

(I#6/Bryan)

Based on Bryan’s feedback of it was noted that he did reflect over his lessons whereby he took note of successful teaching, unsuccessful teaching, things that his students had mastered and had not mastered in his textbook. And when he was planning for his lesson, he would go over those things that students hadn’t mastered before he taught the new concepts.

Bryan suggested a teacher should include a few things in his/her reflection such as the extent of the achievement of the students. For example, the teacher could write something such as

10% of the students had mastered the skills, 20% was average and the rest were yet to master the skills
(I#6/Bryan)

Other things included students’ discipline, problems encountered, students’ performance, students’ responses and follow-up actions. He admitted that he lacked follow-up actions on his reflection. But then he did mention that he would prepare some questions to ask the students in the next lesson if he felt that they had not mastered the skills/concepts then.

Bryan wrote his reflection in the form of a template which he obtained from a colleague who got it from attending a course (Figure 4.40).

	Reflection	Yes/No (√)
1.	Did all students understand the instruction?	
2.	Were the resources appropriate?	
3.	Were the students able to complete the set task?	
4.	Could the lesson be improved?	

Figure 4.40. Reflection template used by Bryan

He evaluated his teaching with the template at the end of his lessons. Bryan actually looked forward to his superiors to give some comments on his record book but so far they had not done so.

Catherine wrote reflections at the end of every lesson in her record book. Her reflections was more like a record of the achievement of her learning outcomes, a platform for her to jot down students' responses, behaviour and attitudes. She also recorded the activities carried out in the classroom such as exercises, experiments, and group work. Catherine claimed that the remarks written in the reflections were useful reminders when planning the incoming lessons. The summary of the content in her reflection is shown in Table 4.12.

Table 4.12

Content of Catherine's Reflection

Theme	Example
As a checklist/record of accomplishment of learning outcomes	<ol style="list-style-type: none"> 1. L/O (a) and (b) are not achieved due to the failure of the CD drive. Hence, the students are given exercise in groups. 2. L/O (b) is carried forward.
Students' progress and discipline	<ol style="list-style-type: none"> 1. Students still having a little problem in numerical problem solving. 2. Some students are still not serious in doing the calculation questions. Due to this, a quiz will be given on next class. 3. Good response though they looked tired. 4. A few students were restless but overall good response. Good participation.
Comments on things done and as a reminder for coming lesson	<ol style="list-style-type: none"> 1. Presentation is done well. 2. The experiment was done well. The report will be discussed on Tuesday. 3. Exercise was given out in groups & to be presented on Thursday.

* L/O – learning outcome

Based on content of her reflection, it was noted that Catherine did not write any comments about the content taught and her teaching. When asked whether she reflected on her teaching after class, she admitted she often did but practically she did not emphasize on it and furthermore, "...you won't take action on it." (I#6/Catherine). She said,

Now I emphasize on the activities and exercises. Now I really more detailed on the exercises, check more but you don't have time. Now I know which part to stress on, I know which part to speed, I know which part to tell them this is very important in exam... This one you should stress more, the pattern of it, straight away let them be aware, so that they will realise that this is important as the teacher always say this is important.

(I#6/Catherine)

Based on the excerpt, it was clear that she had become more focus in her teaching and she knew what to focus for examination therefore she told students directly what was important for examination.

Catherine often reflected right after her class especially when thing did not go smoothly. It was noted that she did a lot of reflection during her teaching (reflection in action). For instance, when she saw her students frown she knew they did not understand. She realised that the more she understood the content, the better the flow of her lessons. She also found that her teaching became more detailed each time she retaught the same content. She said teaching the content for the first time was often not in detailed. Teaching for the second time was often more detail and better than the first time. Thus, her teaching improved every year although she stressed that her emphasis was on the activities and exercises.

When asked whether he reflect after his teaching, Dennis said he was instructed to do so as it was a requirement. He also admitted that he would reflect when there was a problem such as how to deliver the content within 20 minutes. Similar to Catherine, Dennis wrote reflections in his record book at the end of every lesson. His purposes of writing reflections were similar to that of Catherine: first as a checklist for the achievement of the learning outcomes. Some examples of his reflection, he wrote "objective achieved" when he felt that he had achieved the objective. Otherwise, he placed a question mark (?) at

the learning outcomes if it was not achieved. He wrote “students still have problem in solving the numerical problems” in his reflections when the students could not solve the stoichiometric problems. He decided to teach again for another two periods. Second, reflection served as a record of events taking place in the classroom. For example, he wrote “the class was postponed as students had to attend a talk given by the officers from the fire brigade.”

So far Dennis did not comment on his teaching and the content taught in his reflections. In fact, he said he would not think of his lessons again if everything went fine. After all, he also did not have the time as he taught many classes. He would rather put his thought on what he was going to teach in the next lesson. While planning for the coming lessons, he tried to make decision of which method to use in his teaching:

I feel I have more choices, I have lots of experience, previously I taught like this, am I going to use the old method, we look at our students, if it is suitable, we can, but if not then we have to find new ways. The important thing is how we teach in class, how to explain what we have understood to the students, that is a challenge.

(I#6/Dennis)

The four teachers had different views on the writing of reflection. Andy saw reflection as the planning of what to do and how to teach before the class. He admitted he did not write reflections in his record book after his lessons. In fact, he was concerned of being backfired by what was written in the reflection. He was worried that if he put bad commends on the students in his reflection, it might imply he was not a good teacher. If he put good commends on his students in his reflection, if they failed in examination then it meant he was not telling the truth.

Bryan, Catherine and Dennis wrote reflections in their record books at the end of their lessons although Bryan used a template. There was a great similarity in the content of the reflection written by Catherine and Dennis which could be roughly categorised as follows:

- (a) commends on the students and lessons;
- (b) record of events happened during lessons; and
- (c) suggestions for further actions to be taken.

The most frequently used statement found in the reflection of Catherine and Dennis was “objective achieved” indicating they assessed the achievement of the learning outcomes of their lessons. Additionally, Catherine described the performance of her students as “good participation” and “students did their experiment well”. Catherine also encountered a dilemma in writing her reflection. Her superior commended on negative comments on her students in her reflections, as a result she decided to avoid writing negative comments on her students.

Dennis spent two extra lessons (four periods) teaching the students solving the stoichiometry numerical problems. The decision was made after realising his students encountering problems in solving the numerical problems. He remarked at the end of his lesson that “students still have problem in solving numerical problem using chemical equations” (*sic*). He decided to re-teach the concept. After the re-teach, he wrote in his reflection “students still unable to solve numerical problems using chemical equations”. He decided to teach the concept again. Finally, he wrote “Half of the students showed improvement in solving numerical problems”. Based on the action taken by Dennis, one could conclude that he made necessary adjustments in his lessons

based on the progress of his students though he ever mentioned that his priority was to finish the syllabus rather than students' understanding. However, although he tried to reteach the stoichiometry concept, the outcomes was unsatisfactory most probably the strategies used to teach the concept failed to make his students understand better. The strategies he used were by asking his students to try the questions from the quizzes (courseware) and the exercises from the textbook, later he called the students to show their work on the board and at the same time explained to their friends. It was noted that the explanation given was merely algorithmic showing the procedures of the calculations. The students were much more passive than usual during the three lessons on stoichiometry. At the last lesson, Dennis seemed to lose his patience and at one point, he repeatedly asked the students whether they understood but the students remained silent. Most probably, the students were scared to admit they did not understand.

A few things were noted in the reflection of the four teachers:

- (a) although Andy, Bryan and Dennis did not put it down on paper, they did think of 'how' to teach the chemical concepts before their lessons indicating they were planning their pedagogical strategies;
- (b) none of the teachers commented on their teaching although Bryan often said "I really don't know how to teach them" and "I don't know how to explain", he did not elaborate on his problem.
- (c) none of the teachers commented on the content taught;

As a whole, all the teachers thought a lot about “what” and “how” to teach the Chemistry content although most of the time they did not record their thoughts. The content of their reflection was mostly about the achievement of the learning outcomes, students’ behaviours and events which happened in the class. There was no much evidence of self-evaluation of their own teaching such as their strength and weaknesses. To conclude, the Chemistry teachers lacked reflection and evaluation of their pedagogical skills which was essential for the development and growth of their PCK.

4.8 Summary of the chapter

This chapter reported the findings on the four teachers based on the three aspects in the research questions. The aspects were the teachers’ views on teaching, the essential components of teaching and their teaching process. The findings of the four teachers were compared and reported. In Chapter Five, the discussion and conclusions of the finding will be presented.

Chapter 5

Discussion and Conclusion

5.1 Introduction

This study was set out to investigate the conceptualization of PCK of four chemistry teachers while teaching the topic 3 “Chemical formulae and equations”. The teachers were asked to give their views on the teaching of chemistry and the essential components of teaching chemistry based on the argument that PCK is a distinctive body of knowledge of teaching (Shulman, 1987; Park & Oliver, 2008) as well as the application of knowledge to teaching (Gess-Newsome, 2015). This study also investigated how the teachers actually carried out their lessons or teaching processes based on their PCK conceptualization. According to Gess-Newsome (2015), classroom practice is the location of PCK as “what a teacher does in the classroom was based on their PCK” (p 36). The teaching processes refer to the steps carried out by the teachers while teaching a concept which encompasses what the teachers did at the pre-active, interactive and post-active phases of teaching.

This chapter summarizes the major findings of the study and discusses their implications for the teaching of chemistry. Overall, this chapter is divided into the following sub-sections: (1) summary and discussions of findings; (2) implications and recommendations of findings; (3) recommendations for further research and (4) summary.

5.2 Summary and discussion of findings

The major findings in this study are discussed under the two areas of research: the conceptualization of PCK and the teaching processes of the chemistry teachers while teaching the topic “Chemical formulae and equations”.

5.2.1 Conceptualization of PCK of the chemistry teachers

Basically the teachers shared the views that “teacher is a knowledge dispenser” whereby the teachers gave input to students (Table 5.1). The knowledge dispenser view was consistent with the conventional view of teaching where teachers is supposed to generate and disseminate knowledge and to have their students to gain the knowledge (Holly, 1989; Nichols, 2010).

Due to the congested curriculum and reduced time allocation of chemistry (from five to four periods in a week), all the teachers encountered time constraints. As a result, finishing the syllabus became the main objective in their teaching. Because of “no time”, Catherine admitted her teaching became exam oriented which mainly emphasized on important content in exam whereas Dennis also claimed putting priority in finishing the syllabus rather than teaching for understanding as he would not want to be blamed by the students and their parents for not covering the syllabus.

The teachers’ perceptions that “teacher is a knowledge dispenser” was reflected in their lesson preparation and also in their teaching. Even though Catherine expressed a different view on teaching that teacher is a facilitator, the classroom observations show that she was the one who gave the input. Overall, the teaching of the teachers was teacher-oriented and the scenario in their classroom was mostly “teacher talked and students listen”. All the teachers seemed to have the same belief that they had to be “well-versed” in the content knowledge before entering the classes. They gave priority to getting themselves familiar with the content knowledge during lesson preparations. The priority was especially obvious at the first few rounds of teaching topic 3.

Table 5.1

The Chemistry Teachers' Views of Teaching and the Essential Components of Teaching Chemistry

Items	Andy	Bryan	Catherine	Dennis
Views on teaching	Teacher = Knowledge dispenser	Teacher = Knowledge dispenser	Teacher = Knowledge dispenser	Teacher = Knowledge dispenser
Teaching process	T ↔ SS (2-way) Dynamic	T → SS (1 way)	Teacher = facilitator (1-way)	T → SS (1 way)
Overall view	Holistic – focus on role of teacher and factors influencing teaching and learning process	Focus on the role of teacher	Focus on the role of teacher	Practical reinforce learning
			Focus on the role of teacher	Focus on the role of teacher
Indicator of successful teaching		Successful teaching = students' application		Successful teaching = students' application
Views on essential components of teaching	Content knowledge Pedagogy Student Environment Policy Curriculum	Content knowledge Pedagogy Student Environment Parents School authority	Content knowledge Pedagogy Student Thinking skills Science process skills	Content knowledge Pedagogy Students' interest Class control

T – Teacher
SS – Students

It was noted that the said priority gradually reduced as the number of rounds the teachers taught the same content increased. In other words, as they got more familiar and confident with the content, their reading of content lessened. Though the teachers emphasized in preparing their content, differences were noted in the “depth” of the content knowledge they delivered. In comparison,

Andy portrayed an in-depth content knowledge in his teaching which most probably related to his teaching experience (Gess-Newsome, 2015) and also continual updating himself with the latest development in science and technology by reading science magazines and the science columns in the newspapers. Whereas the rest of the teachers' reading confined to textbook, practical book and reference books.

Andy viewed teaching as a two-way dynamic process whereby besides giving input, the teacher also received feedback and learned from the students too. His views concurred with the dynamic perspective of the teaching-learning process of Shulman (1986b) and Holly (1989). However, the findings of this study show that his teaching was one-way process most of the time as his students did not give much feedback which most probably due to his lengthy explanations and little time was given to the students to give response. In fact, the students were silent and passive and Andy's lengthy input seemed to overload most of them (Johnstone, 2000).

In comparison, Andy's views on chemistry teaching were more holistic than the rest of the teachers. His views covered a wide range from teacher's role, educational policy, curriculum, content, pedagogy, assessment, incentive, environment to maturity and intelligence of students which concurred with most of the attributes of PCK forwarded by Veal and MaKinster (1999), namely content knowledge, student knowledge, assessment, pedagogy, curriculum, classroom management, environment and context. However, his student knowledge was confined to their abilities, motivation, interest, language and attitudes and did not include learning difficulties and misconceptions of the students. The holistic views were likely due to his longer teaching experience

and various working experience as an academic officer in the state education department and as a school senior assistant at the time of the study.

The teachers incorporated some of their views of teaching in their teaching. For instance, Andy used “incentives” to motivate his students answering quizzes. He created a conducive learning environment for his students by making sure everyone in the class could see the courseware clearly. He optimized his teaching time by going earlier to the class to write notes on the board and used the sit-in classes for test correction. Catherine practiced her role as “facilitator” during the group presentations although her main intention was to overcome the discipline problems, sustain their attention and engage them in learning. There was no evidence of Bryan or Dennis applying their indicator of successful teaching that “successful teaching meant students’ capability in explaining the surrounding phenomena with the chemical concepts learned” while teaching topic 3. On the other hand, Andy was able to create an application question for his students by asking them to calculate the number of molecules of water they drank from a bottle of 500ml mineral water. Dennis placed a great emphasis on class control as he repeatedly mentioned it during the interviews. In actual class situation, Dennis immediately gave warning if students talked therefore his students were well behaved.

Each of the teachers listed 4-6 essential components of teaching. Collectively, the components included content knowledge, pedagogy, student, environment, policy, curriculum, parents, school authority, thinking skills, science process skills, students’ interest, and class control (Table 5.1). It was noted that three of the essential components listed by the teachers were the same: content knowledge, pedagogy and students.

The essential components of chemistry teaching of the teachers concur with the constructs of PCK of Shulman (1986b) that is pedagogy and student knowledge though Shulman considered the content knowledge as a prerequisite requirement. In fact, the content knowledge, pedagogy and students were also the main constructs in the definitions of PCK of many scholars such as Smith & Neale (1989), Grossman (1990), Cochran et al. (1993), Veal and MaKinster (1999), Marks (1990) and Barnett & Hodson (2001). Besides that, the essential components of the teachers also concurred with the knowledge bases proposed by Shulman for effective teaching such as content knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners and their characteristics, knowledge of educational contexts.

As mentioned earlier, the importance of the content knowledge was clearly evidenced from the priority given by the teachers in getting themselves familiar with the content knowledge during their lesson preparation. They reported spending a lot of their time reading the textbook and reference books especially at the first few rounds of teaching topic 3. They all shared a similar view that it was important to master the content knowledge before going into their classes regardless of their academic backgrounds and the training programs they underwent. The findings of this study show that all the teachers were satisfied and confident in their content knowledge regardless of their teaching experience. Dennis being the least experienced and had a basic degree in chemistry, said he did not worry about the content knowledge and he could somehow guess the meaning of the content by looking at the title though he might not understand all the English words.

It was noted that all the teachers considered pedagogy as an essential component of their teaching. Based on the findings of this study, upon going through the learning outcomes and the suggested activities in the textbook and chemistry curriculum specifications, the teachers decided their pedagogical strategies. It was observed that the teaching of the teachers often began with introducing and explaining on the definition followed by enhancing the concept with examples and later with exercises using the teaching resources such as courseware, textbook, power point slides and practical book.

Based on Shulman's definition of PCK (1986b), the pedagogical strategies of teaching also involved the transformation of what the teachers had comprehended into a form that were more accessible to students. Altogether thirty two types of representations were identified which were further grouped into three main categories consisted of explanation, experiment and questioning (Table 3.5, p.120). It was noted that majority of the representations used by the teachers were similar as they were using the centralized teaching materials and resources such as the curriculum specifications, textbook, practical book and courseware. The teachers in fact made use of most of the representations given in the textbook, courseware, activity book and power point slides (for Bryan) as most of the representations were fundamental symbols in chemistry. Differences were noted in terms of the self-created analogies, examples and effectiveness in using the same representations. Further discussion will be given in the instruction section.

Although all the teachers considered students as an essential component of their teaching, what they perceived as student knowledge did not totally concur with the description prescribed by scholars such as Shulman (1986), Smith and Neale (1989) and Grossman (1990). The teachers' student

knowledge was confined mostly to their abilities, attitudes, and behaviors. None of them included students' learning difficulties or misconception. On the whole, they were very reserved in giving comments about their students' abilities either before or after giving tests or examination. However, based on the test score, Andy and Catherine were confident that those students who scored over 20 marks most probably could pass the SPM chemistry examination provided they change their attitudes.

When the teachers were asked to elaborate on the difficult concepts, learning difficulties and misconceptions encountered by their students in topic 3, they listed problem solving, calculations involving volume, writing chemical formulae and chemical equations (Table 4.3, p.154). It was noted that, none of them mentioned about the misconceptions of their students and give specific examples of the learning difficulties besides knowing that the students had problems. For example, most of the students faced problems in balancing the chemical equations. The teachers could not specifically point out what actually was preventing the students from balancing the chemical equations. At another instance, students encountering more problems with the molar volume as compared to molar mass and number of particles. The existence of the two molar volumes and the conversion of units most probably had complicated the problem. Some of the teachers did not explain the existence of the two different molar volumes at different temperatures (at room conditions and 273 Kelvin) while teaching the topic. It was noted that the algorithmic teaching of the teachers did not bring about conceptual understanding of the students. The lack of student knowledge among the teachers in relation to students' misconception and learning difficulties had prevented them from planning suitable

pedagogical strategies to overcome students' misconceptions and learning difficulties.

All the teachers perceived content knowledge, pedagogy and student as essential components of their teaching which concurred with the definition of PCK of Shulman (1986b) and other scholars such as Grossman (1990), Smith and Neale (1989), MacKinster (1999), implying that the teachers were aware of the basic components of teaching: content knowledge, pedagogy and student which was the main constructs of the PCK definition of most scholars including that of Shulman.

Besides that some of the teachers included environment of learning as their essential component of teaching as in the case of Andy and Bryan. Bryan personally hoped his students' parents could play a bigger role in motivating their children in their learning, Andy cautioned about the impact of policy of recruitment in the government sector might affect the enrolment of the science students and their motivation in learning science, and Catherine's science process skills, all these essential components of teaching concurred partially with the constructs of the PCK definition as in Table 2.1 (p. 57) implying that the teachers considered context, parents, policy and nature of science as relevant to their teaching.

To sum up, all four teachers viewed themselves as a knowledge dispenser which was reflected in their lesson preparation and teaching. They perceived that they must be well-versed of the content knowledge before going to the class. As a result, they put more emphasis in reading their content initially while preparing their lessons and their teaching were teacher-oriented. Their pedagogical strategies were very much guided by the curriculum resources

such as curriculum specifications, textbook and courseware. They also possessed student knowledge in terms of their background, behaviors, abilities and learning difficulties, what was noted lacking was the misconceptions and learning difficulties of students. The lack of student knowledge on misconceptions most probably had prevented the teachers from adapting and tailoring their teaching to overcome students' misconceptions and learning difficulties as well.

5.2.2 The teaching processes of the chemistry teachers

5.2.2.1 Preactive phase

Basically, lesson preparation was one of the main tasks of the teachers at the pre-active phase of their teaching. Besides preparing the lesson plans, the teachers prepared also the scheme of work (yearly plan), content knowledge, creating examples, analogies, quizzes, notes, reviewing the teaching materials such as teaching courseware and the power-point slides. Besides reading, Catherine also worked out beforehand all the examples and exercises that she planned to use in her lessons when she first started to teach topic 3. The extra preparation was to ensure that she could work out the answers when students asked and she would feel more confident as she neither had a degree in chemistry nor she was trained to teach chemistry.

The teachers prepared two types of lesson plans – the yearly scheme of work and daily lesson plans. The findings of this study showed that the writing of the scheme of work and the daily lesson plans was more of a routine requirement of the schools. In fact, the teachers' scheme of work were either adopted from the senior teachers or the

reference books. It was noted that the teachers did not made full use of their scheme of work as most of them did not refer to it while preparing their lessons except Catherine. Furthermore, besides the basic information such as the learning objectives, learning outcomes, suggested activities and notes/vocabulary, the teachers did not put in their school activities or remarks after their lessons. Although the daily lesson plans of the four teachers were brief and of different formats, they contained basic information such as theme, learning outcomes and activities. All the teachers wrote reflection except Andy.

During the lesson preparation, the first thing the teachers did was to browse through the learning outcomes. By browsing through the learning outcomes in the curriculum specifications or textbook, they determined the content (more specifically the amount of content) and also the pedagogical strategies they were going to use to teach the particular content. Based on the suggested activities they decided whether to carry out experiment or just the usual input using examples followed by exercises. The findings of this study show that none of the teachers referred to the syllabus and some had not seen one. That could be one of the reasons why the teachers were not aware of the aim of the curriculum such as thoughtful learning and producing students as active learners.

Based on the content delivered and the explanations given, it appeared that Andy possessed an in-depth and a broad knowledge of chemistry. For instance, he told students about the macro, sub-micro and symbolic levels of chemistry and statistics to enhance his explanation. The said content was not found in the curriculum. His in-depth

knowledge was most probably due to his long teaching experience (Gess-Newsome, 2015) and his extra reading on science magazines and science columns in the newspapers. By comparison, the scope of reading of the other three teachers was confined to the textbook and reference books.

The findings of this study show that as the number of rounds teaching topic 3 increased, the amount of time the teachers spent in reading the content during lesson preparation gradually reduced to an extent that they just had to glance through the curriculum specifications, textbook and scheme of work to verify what they had to teach. Andy admitted that although he had taught the content many times, he still needed to refresh his memory by browsing through the content and learning outcomes. In fact, the main purpose for the teachers to glance through the learning outcomes was to ensure they did not miss any content.

A shift was noted in the focus of the lesson preparation in Andy and Bryan. As the number of rounds teaching topic 3 increased, they became more confident with the content and they shifted their focus from reading the content to creating new examples and analogies during lesson preparation. Comparatively, Andy had created the most number of examples and analogies, most probably due to his long teaching experience and his personal concerns, it concurred with what Gess-Newsome (2015) said that teacher's PCK and skills could be strengthened by teachers' experience though it might not necessary increased it. Catherine showed very few personal examples and even less analogies. It could be because she had not been teaching many classes of chemistry all these while and she was teaching science of other classes,

and according to Gess-Newsome (2015) the number of preparations assigned to a teacher plus limited preparation time could affect the growth and development of PCK and skills of a teacher. The same argument went to Dennis who created a few analogies such as the “football and tennis ball” and “roti *canai*”, the outcome of using the analogies was not satisfactory as he could not effectively relate the analogies to the concepts.

The chemistry curriculum is a centralized curriculum predetermined by the Ministry of Education Malaysia (Figure 1.1). The content in topic 3 was structured in such a way that the teacher taught one chemical concept in one lesson (double periods). In this study, all the teachers followed the organization of the concepts in topic 3. Though Bryan mentioned that he preferred his students to learn the periodic table (topic 4) and the chemical bonding (topic 5) before learning topic 3 but he did not put his thought into action.

5.2.2.2 Interactive phase

This section presents discussion on instruction, classroom management and evaluation carried out by the teachers. The findings of this study show that the four teachers placed great emphasis on the learning outcomes of each chemical concept. For those teaching with the courseware, they usually began their routine class by introducing the learning outcomes before proceeding to the concept definition. At the end of the lesson, they also used the learning outcomes to assess the attainment of their learning outcomes as in the case of Dennis and Catherine.

Since topic 3 contained a lot of calculations, therefore the teachers normally explained and elaborated the concepts algorithmically using examples and analogies. The examples were obtained from the textbook, reference books or self-created by the teachers. In addition, Bryan gave “Test Yourself” quiz which allowed the students to apply what they had just learned. All the teachers assigned “Work This Out” and “Quick Review” exercises in the textbook as homework to the students followed by going round monitoring and checking students’ work until the lessons ended. In the case when homework was given, the teachers would go through the exercises with the students first thing in the next lesson before they proceeded to the new concept.

All the teachers delivered their lessons systematically. They possessed general pedagogical knowledge as evidenced from their routine practices which concurs with what was defined by Baxter and Lederman (1999). A few observations were noted from the classroom observations:

- (a) the teachers often posed questions to help students revise what they had learned previously at the beginning of his lessons;
- (b) while giving explanation, Catherine grasped every opportunity to revise and relate the new concept to students’ prior knowledge to make sure they understood all the terminologies in the definitions;
- (c) All the teachers took the opportunities to re-teach and explain the concepts while going through the homework and test correction with the students.

As a whole, the teachers were aware of the importance of refreshing what students had learned previously and also relating them to the new concept. However, Andy and Catherine could do the linking more effectively as compared to Bryan and Dennis which most probably because both were proficient in English.

The findings of this study show that the representations used by the teachers to teach “Chemical Formulae and Equations” were almost similar to each other. This is because the teachers were using the centralized education curriculum materials such as curriculum specifications, courseware and textbook in their teaching. As a result, they used the same symbols, chemical formulas, experiments, examples, definitions and exercises to teach topic 3. Basically, the representations used by the four teachers to deliver their lessons could be categorized into explanation, laboratory work and question (Table 3.6, p. 120).

Although the teachers might use the same representations, differences were noted in their explanations, questions posed, self-created examples and analogies. They also showed different capabilities and effectiveness in using the representations. The findings concurred with what was reported by Barnett and Hodson (2001) that some teachers were successful and some teachers were less successful in engaging similar strategies in their classroom for the same curriculum. In comparison, Andy possessed a rich repertoire of examples and analogies which often matched well with the content taught suggesting he had a better pedagogical skills. This is most probably due to his teaching experience thus it concurs with the findings that PCK grows with

experience (Cochran & et al., 1993). Besides having longer teaching experience, the driving force that motivated Andy to create analogies and examples was his concerns for the learners (Loughran, 1994). Since taking up teaching as a career, he had tried to find ways and means to make students understand what he once could not understand as a student. For instance, he could not understand why he had to multiply " $\frac{1}{12}$ " in the definition of the C-12 standard atomic scale. Therefore, he presumed that that most probably his students also encountered the same problem while learning the atomic scale. In other words, he tried to use his personal experience as a student to infer the learning difficulties of his students. This driving force had motivated him to create analogies and examples besides making his explanation as clear as possible. Some of the successful examples and analogies he created will be discussed in the later part of this chapter.

The mole concept and stoichiometry in topic 3 involved a lot of calculations. As a result, a large portion of the teachers' explanations consisted of examples aided with diagrams and analogies. The examples were taken either from the textbook, teaching courseware, or self-created. As most of the examples contained calculations, the teachers' teaching was algorithmic and similar to that of a mathematics lesson whereby the teachers showed the calculations step by step and at the same time posed questions to the students to get them provided answers to the steps. According to Okanlawon (2012), students learned more effectively if they were involved in the question-and-answer sessions. It was because they were more attentive as compared to listening passively to teachers' explanation. However, the findings of this study show that their learning

was restricted by the algorithmic, convergent and low-order thinking questions posed by the teachers which did not bring about conceptual understanding of the underlying chemical principles (Okanlawon, 2010). At times, the fill-in-blank types of clues and limited wait-time did not promote thoughtful learning as intended by the curriculum (*Kementerian Pendidikan Malaysia, 2006*). Based on the interaction between the teachers and the students, it was noted that Andy often delivered a large amount of information and little time was given to his students to give response and comprehend the information. Bryan's explanation was often interfered by his code-switching thus making students' understanding delayed. Catherine seemed to be able to give simple and clear explanation and she checked students' understanding regularly. Dennis seemed to encounter more obstacles in his teaching than the rest of the teachers for two reasons: he lacked proficiency in English though his code-switching was less serious and he did not have a rich repertoire of strategies for his disposal as a result, he had to rely almost entirely on the courseware in his teaching.

The findings of this study show that all the students loved and enjoyed doing experiments as the scenario in the lab was very different from when they were learning the theories. During experiment, all the students were excited, proactive, enthusiastic and full of curiosity. They discussed with their group members, consulted their teacher and friends whenever in doubt. Additionally, they proudly showed the products obtained from the experiments to their friends indicating a sense of ownership. Their responses suggested their fondness of doing the experiments and also their capabilities as active learners which was the

main aim of the Chemistry curriculum (*Kementerian Pendidikan Malaysia*, 2006). However, when it came to the theory lessons, the scenario was a passive one, the teachers talked and students “listen” passively and asked few questions.

Although the students were fond of doing experiments, their teachers were disappointed with them for not doing sufficient preparation, that is reading and understanding the experiments before coming to the class. Based on the classroom observations, it was obvious that the students were uncertain of the procedure of the experiments and they did not know how to process the data and doing the calculations. As a result, the teachers had to literally explain the procedure, show all the steps in the calculations and provide answers to the discussions. It was also noted that the students lacked manipulative skills while conducting the experiments suggesting they lacked practice. Although most of the empirical formula of magnesium oxide (Mg_2O_3 , Mg_3O_2 , Mg_2O , MgO_2) obtained by the students differed from the theory (MgO), none of the teachers gave justifications for the discrepancy. Instead, the students were told to adopt the better data from their peers. Such practice most probably denied the students from inquiring the cause of the discrepancy and to think critically. The said practice did not support the thoughtful learning as intended in the curriculum (*Kementerian Pendidikan Malaysia*, 2006).

The teachers were in favour of doing experiments and they also knew that their students loved to do experiments and most likely could learn better by doing experiment. However, they could not afford to do so due to time constraints caused by the congested curriculum. As a result,

they were selective in doing the experiments, priority was given to those experiments that were popular examination questions and as a PEKA project. Due to time constraints, the teachers had to cut short the heating, cooling and weighing procedure of the magnesium oxide experiment before a constant mass was obtained. The short-cut most probably explained the divergence of the empirical formula from the theory. During the discussion, it was noted that the teachers provided almost all the answers to the students suggesting the experiment might not help to reinforce the conceptual understanding of the students.

The teachers used a lot of oral and written questions (quizzes, exercises/homework) in their lessons. They posed questions to stimulate curiosity, arouse students' interest, encourage students' active participation, revise previously learned content, and to assess students' understanding which concurred with most of the objectives of posing questions (Okanlawon, 2012). However, most of the questions posed by the teachers were algorithmic, convergent and of low-order thinking, such questions therefore restricted them from assessing the conceptual understanding of their students.

All the teachers gave students two types of exercises in the textbook that is the "Work This Out" and "Quick Review" (Appendix V) at the end of their lesson. The questions in these exercise were specially designed to assess students' understanding of the chemical concept. According to the teachers, the exercises were sufficient and good enough for their students. To Bryan, the number of questions that students could answer in fact indicated their level of understanding. For instance, he equaled those students capable of answering the first three questions as

already attaining basic understanding of the concept, and those who could answer all the five questions as fully understanding the concept. On the other hand, Andy also said the capability of students answering the questions in the two exercises indicated his attainment of the learning outcomes.

Besides the exercises in the textbook, Andy gave the “2-in-1” notes to help students learn the algorithm in solving the numerical problems. Bryan gave a “Test Yourself” quiz to assess his students’ abilities in applying the concepts learned. The findings of this study show that Andy and Bryan utilized their extra exercises effectively. As the “Test Yourself” was done in the class, therefore the feedback on the capabilities of students in solving the quiz was immediate. The “2-in-1” notes of Andy acted as a self-learning module in solving the numerical problems. Further discussion on the “2-in-1” notes will be presented in the later section of this chapter.

The teachers also used the interactive quizzes in the courseware/power point slides as oral exercises. In comparison, Dennis used a lot of the interactive quizzes in the courseware as oral exercise, however, the outcomes of using the interactive quizzes was not satisfactory. It was observed that he sometimes showed the interactive quizzes aimlessly, indecisively and uncertainly. He browsed from one question to another, discarded a question after solving it halfway, suggesting he might not plan well beforehand.

The implementation of the PPSMI changed the medium of instruction from *Bahasa Melayu* to English. Andy and Catherine seemed to be able to explain well with their high proficiency in English. Andy’s

explanations were clear, factual and in-depth but lengthy while those of Catherine were simple and clear. She often rephrased her explanation with alternative words to reinforce students' understanding. The change of medium of instruction seemed to bring a significant impact on the teaching of Bryan and Dennis. Both of whom did not have high proficiency in English. As a result, they applied bilingualism to overcome their deficiency (Kanaratnam, 2004). Bryan engaged code-switching throughout his lesson inserting *Bahasa Melayu* within his explanation which often resulted in "hanging" sentences. On the other hand, the code-switching of Dennis was different from that of Bryan as he often began his lessons in English and gradually switched to *Bahasa Melayu* completely towards the end of his lessons.

The use of dual languages by both teachers seemed to cause confusion among their students due to inappropriate choice of words. For instance, Dennis interchangeably used terms of different meanings which were incompatible to each other such as "mass" and "weight", "ratio" and "proportionality" in his explanations. The findings were consistent with the studies reported by Goh and Chia (1993), de Jong (2000) and Johnstone and Selepeng (2001). Additionally, Dennis often accepted the translated version of terms (English to *Bahasa Melayu* and vice versa) without further verification whether the students truly understood the meaning. For example, when he asked students, "what is mass?" the students answered, "*jisim*" which was a direct translation of mass in *Bahasa Melayu*. He did not probe further whether the students understand the meaning of mass.

Besides disrupting the smooth flow of the teaching, the code-switching of Bryan and Dennis seemed to reveal their misconceptions and preconceptions. Some preconceptions were also noted when Andy and Catherine taught the magnesium oxide experiment. For instance, Andy asked his students to repeat the whole experiment with another piece of magnesium ribbon instead of repeating the heating, cooling and weighing procedure until a constant mass was obtained. He explained that the second set of results served as a backup in case the first results was unsatisfactory. It was noted that by repeating the experiment did not improve the results because the results depended on the complete combustion and not the number of trials.

Another preconception was noted when Catherine taught her students to write the PEKA report. Figure 5.1 shows a portion of the PEKA report:

Hypothesis: The empirical formula of magnesium oxide is MgO
Variables:
(a) Manipulated variable: the mass of the magnesium ribbon
(b) Responding variable : the mass of the magnesium oxide
(c) Constant variable : the excess oxygen gas

Figure 5.1. A portion of the PEKA report of Catherine's students

Classroom observation showed that the mass of the magnesium ribbon was not manipulated as the students only carried out one trial. In fact, the MgO experiment was not suitable as a PEKA project because it was not practical to manipulate the mass of magnesium ribbon.

In another occasion, she wrote the formula:

$$\text{Number of moles} = \frac{\text{mass (g)}}{\text{RAM/RMM}}$$

The statement was inappropriate whereby the RAM or RMM should be replaced with “atomic mass” or “molar mass”. From the findings of this study, the teachers seemed to disseminate their misconceptions to their students which concurred with what Taber (1997) stated that teachers become the source of students’ misconceptions due to inappropriate teaching procedures, sequences and use of terminologies.

The implementation of PPSMI also brought along the use of courseware as a teaching resource. All the teachers gave positive comments to the courseware provided by the Ministry of Education of Malaysia including Bryan who did not use it. They described the courseware as useful, interactive, colorful, interesting, attractive and most important of all, it had animation which motivated learning among the students besides enhancing their understanding. The findings of this study show that the students were attentive, interested and motivated to learn when their teachers played the courseware and the power point slides by Bryan. Besides as teaching resource, the use of courseware also served to fulfil the requirement of the Ministry of Education of Malaysia as in School A and C.

Andy actually preferred not to use the courseware to teach as he was confident that he could teach as well if not better without it. For Catherine, the use of the teaching courseware helped to discipline and sustain the attention of her hyperactive students besides saving her time drawing the diagrams. Dennis relied almost entirely on the teaching courseware in his teaching and he admitted that it relieved his lesson preparation and language problem.

The findings of this study show that Andy and Catherine previewed and took notes of the mistakes in the courseware before showing to their students. Catherine also took notes of the time duration needed to show the courseware for better time-management. Besides previewing the teaching courseware provided by the Ministry, Andy also previewed all the courseware in his collection in order to choose what he considered as the most relevant and easiest content for his students to understand. Basically, the content in the teaching courseware shown by Andy and Catherine included the learning outcomes, definitions, explanations, examples and interactive quizzes. While showing the courseware, they incorporated their own explanation and elaboration, highlighted important points and also asked students to jot down notes. It was noted that the extra explanation and the note-taking strengthened the impact of using courseware on students' learning. Both teachers were flexible, selective and effective in using the teaching courseware in their lessons.

On the other hand, Dennis relied almost entirely on the teaching courseware to the extent that the teaching courseware became the main agent delivering the lessons. It was in-lined with what was cautioned by Cheah (2005) that a teacher who is not proficient in English might try to minimize speaking in English by playing the teaching courseware. Comparatively, Dennis did not give much explanation and elaboration while playing the courseware though, he was capable of giving good explanations once in a while. Dennis confessed that, given a choice, he preferred to teach with the language that his students were familiar with that is *Bahasa Melayu*. He rationalized the advantage of learning

chemistry with a familiar language as the medium of instruction, if chemistry was taught in *Bahasa Melayu*, when students could not understand, he was quite sure that it was due to the content. However, if it was taught in English, when the students could not understand, it could be due to the language or content or both. He concluded that using a language that students were not proficient slowed down their learning. This point concurs with what was reported by Johnstone and Selepeng (2001) that “pupils, struggling to learn science in a second language, lose at least 20% of their capacity to reason and understand in the process” (p. 19). It was because the students had to understand the language first before they could understand the content. Dennis admitted he felt “weird” to hear students greeted him “good morning teacher” which normally only happened in an English lesson. After teaching with the teaching courseware for eight months, Dennis came out with three conclusions on the use of teaching courseware:

- (a) it was ineffective;
- (b) it had little impact on his students’ learning; and
- (c) students could not sustain their learning.

He was disappointed with his students as they looked at the courseware like watching television show and did not have the initiative to take down any notes. Based on his argument, it seemed like his students were responsible for the unsatisfactory outcomes of his teaching. In fact, his English language proficiency and inadequate preparation were probably the main obstacles that prevented him from teaching effectively with the courseware. His low proficiency of English prevented him from

elaborating effectively the content and his code-switching made his students confused. His inadequate preparation was proven by his ignorance of the mistakes in the courseware, his uncertainty and unfamiliarity with the content shown. This finding concurs again with what was indicated by Barnett and Hodson (2001) that some teachers were successful and some teachers were less successful in engaging similar strategies in their classroom for the same curriculum.

Andy was enthusiastic in his teaching and had created many analogies and examples to help his students overcome their learning difficulties. He had an in-depth content knowledge and delivered a lot of facts during the lessons. However, based on the response of his students and their performance in the progressive test and semester examination, his teaching seemed to benefit those students who were better academically. His lengthy explanation most probably had overloaded most of his students with facts and information. In fact, only students of a certain age could understand representations at the symbolic levels such as models and analogies (Gabel, 1999). Students' understanding was further slowed down by the use of English as the medium of instruction as not all of them were proficient in English, in addition, Andy talked very fast. He admitted that he talked very fast, however, he felt that the students should try to adapt to his style of teaching. He also perceived that his students should not have any problem with English since they were exposed to the teaching of science and mathematics in English three years ago. In fact, Andy's teaching would be more beneficial to his students if he could break down the lengthy explanation

into a few shorter portion and gave more time for his students to process the information and better understanding.

Andy had created a few analogies and instructional strategies which fitted well with the content and enhanced students' understanding. The topic specific PCK could be compiled and used as training materials for the professional training of in-service and pre-service chemistry teachers. Altogether five topic specific PCK strategies were identified:

- (a) Using the US currency to analogize the carbon-12 atom in the standard atomic scale (p.196). He told the students the reasons why chemists chose carbon-12 atom as the standard atomic scale were because it was stable, valuable and abundant. Likewise, the US currency was also stable, valuable and widely accepted internationally. He explained he chose the US currency after taking into consideration his students' prior knowledge. His students had some knowledge on foreign currency thus it was easier for them to understand. Using the US currency to denote the carbon-12 atom was suitable and relevant in the sense that it helped to transform the submicroscopic representation (atomic scale, carbon-12 atom) into the macroscopic representation (currency) and the criteria use to choose the C-12 atom and the US currency were also compatible;
- (b) Using mind map with mathematical formulas to show the relationship between mass, number of particles, volume of gas and the number of moles (Figure 4.20, p.201). Andy refined the mind map in the textbook (Figure 4.19, p.200) to overcome some shortcomings in the original mind map. The original mind map

contained six arrows with three of them pointing toward and another three arrows pointing away from the number of moles. There was no mathematical formula or statement. Based on the reasons that students easily got confused with the direction of arrows and they often did not know where to begin, Andy converted the relationship between the entities into mathematical formulas and by so doing, he resolved the problems of the arrows. Although the simplified mind map was still algorithmic and did not guaranteed conceptual understanding, it did help to overcome students' problems in solving the numerical problems. Additionally, the mathematical formulas could be used with flexibility as by manipulating the subject of the statement, students could derived other mathematical statements for related calculations;

- (c) Using diagram to explain the meaning of " $\frac{1}{12}$ " in the statement " $\frac{1}{12}$ x mass of an atom of C-12" in the carbon-12 scale. Relative atomic mass of an element was defined as:

$$\text{RAM} = \frac{\text{the average mass of one atom of an element}}{\frac{1}{12} \times \text{mass of an atom of carbon-12}}$$

When compared with the definition using hydrogen atom as the standard atom,

$$\text{RAM} = \frac{\text{the average mass of one atom of an element}}{\text{mass of an atom of hydrogen}},$$

students often wondered why they needed to multiply the "mass of an atom of carbon-12" with " $\frac{1}{12}$ ". Andy used a diagram to

explain the meaning of " $\frac{1}{12}$ " (Figure 4.18, p.198). By so doing, he transformed the symbolic representation into macroscopic representation, through the diagram, students could see clearly that every divided portion of carbon-12 atom represented " $\frac{1}{12}$ of the atomic mass of a carbon-12 atom" which was equivalent to the mass of one hydrogen atom. Andy had made the abstract concept of " $\frac{1}{12}$ " visible and easily understood by students;

- (d) The "2-in-1" notes of Andy served a few purposes: notes, exercise and self-learning module in solving the stoichiometric problems (Figure 4.21, p. 204). He was aware that his students often did not know "where" and "how" to begin when solving a problem, so he prepared some sample solutions containing partially completed steps minus the mathematical formulae and answers to guide the students. The students had to work out the formulas and answers themselves. The partially completed examples served as a guide for the students to imitate when they did the calculations and worked out the answers themselves. Andy hoped that with the guided steps and additional exercises in the "2-in-1" notes, the students could master the calculations better and learned independently;
- (e) When introducing the mole concept, Andy told students that it was similar to measurement unit such as "one pair" and "one dozen". One pair of shoes equalled two shoes and one dozen of eggs equalled to 12 eggs, then one mole contained 6.02×10^{23} particles. He then varied his examples with quantities greater than

one mole such as 3 moles, 3.5 moles and then to examples with quantities less than one mole such as 0.1 moles and 0.25 moles. He also stressed on the point that the quantity of the items was regardless of its size. For example, one dozen of eggs and one dozen drums contained the same number of items.

Bryan was the most sporting among the four teachers. He treated his students like friends and they could joke and tease each other. At the third round of teaching topic 3, Bryan shifted his focus from reading the content to create analogies and examples as he said he did not need to read the content for Form 4 chemistry already though he still needed to do so for Form 5 chemistry. However, due to his moderate proficiency in English, he was unable to explain his analogies and examples well. He often got stuck and became “speechless” therefore he often said “I don’t know how to explain anymore...” during the interviews. So far, the examples he created were suitable and relevant but there was still plenty of rooms for improvement on his analogies. His teaching could be better if there was a better flow of his explanation and focus more on conceptual explanation.

Catherine gave good explanations by keeping her explanations simple. What was unique in her explanations was that she grasped every opportunity to highlight the similarities and differences between the new concept and the previously learned concepts. She also helped students recall and revise the concepts previously learned. For example, she asked students, “Do you still remember the atomic structure that you learned in topic 2?” She had not created many examples and analogies although she had taught chemistry for five years. This is most probably because she

did not teach many classes of chemistry prior to that, her explanations focused mainly on correcting and clarifying students' answers after their presentations.

Dennis had a basic degree in chemistry and was very confident with his content knowledge as he said he did not worry about his content. He also stressed that he could "imagine" (visualize) the meaning of the things he read even though he might not understand every English word he read in the textbook and reference books. He had created a few analogies and examples, unfortunately, it was found that his analogies and examples were inappropriate and likely to bring about misconceptions among his students. It concurred with what was indicated by Orgill and Bodner (2004) that "not all analogies are good and that not all good analogies are useful to all students" (p 15). There was still plenty of rooms for improvement in his pedagogical strategies and explanation.

As a whole, the teachers said that they took "the middle path" in their teaching so that it benefited students of mixed abilities. There was no special adaptation and tailoring of their teaching to suit the student characteristics as proposed by Shulman (1986b) in his PRA Model. For example, Catherine taught three classes of Chemistry: 4A, 4B and 4C with the high achievers placed in 4A, followed by 4B and 4C. The findings of this study show that she taught the same way to the three classes in terms of content, pedagogical strategies and assessment. However, based on the responses of the students in 4A, she could anticipate what she would encounter in 4B and 4C. For example, if 4A and 4B encountered problems in learning certain concepts, subsequently,

she anticipated 4C class would encounter even more problems and more time would be needed to teach the same thing.

The four teachers did not encounter many disciplinary problems except Catherine. She implemented the rotation system and group presentations to overcome the discipline problems, sustain students' attention and engaged them in learning. On the other hand, Bryan checked students' attires at the beginning of his class to settle them down and get ready for the learning, he used humor to sustain their attention and taught from the basic to make learning simple.

All the teachers encountered time constraints due to the congested curriculum. The number of periods of chemistry had reduced from five periods to four periods a week since the implementation of the integrated curriculum. There was so much content to teach in a lesson of double periods (Appendix A). All the teachers had their own strategies to overcome the time constraint. Andy often arranged himself to sit-in the class to do test corrections and came 15 minutes earlier to the lab to copy notes on the board so that he had more time to teach.

Bryan knew that he would not be able to finish the Form 4 syllabus due to the late enrolment of his students therefore he gave away topic 8 as an assignment. The students had to learn on their own by making notes and later send in to be checked by Bryan. Catherine saved time by giving the test correction in the form of a handout. Every student had to do the test correction by referring to the handout and later send in to be checked by Catherine. As for Dennis, he admitted he put priority in finishing the syllabus and not students' understanding due to time constraint. He felt that it was important to cover the whole syllabus to

avoid being blamed when the students failed in the SPM Chemistry examination.

All the teachers claimed that they assessed their students' understanding through posing questions and also through test (formative assessment) and semester examination (summative assessment). It was noted that they asked more algorithmic questions than conceptual questions during lessons. The conceptual questions were often asked during the set induction where the students were asked to explain the definition. It was observed that the teachers often asked students to explain the definition of the chemical concept during the set induction as a revision for the previously learned concept and also for elicitation of the prior knowledge of the students on the new concept. The responses given by the students was generally unsatisfactory as most of the time they could not explain with their own words.

Comparatively, based on the findings of this study, most of the questions posed by the teachers were algorithmic and were used to engage the students while explaining the examples and calculations. The said questions could not assess the conceptual understanding of the students and also did not provide many opportunities for the students to think as most of them were convergent and of low-order thinking. A few things were noted while the teachers were asking questions: they had a tendency to provide clues and answer their own questions. The teachers seldom posed questions to individual students, and when they did, they coincidentally asked the same students who were better academically as in the case of Andy, Bryan and Dennis. As a whole, the students seldom

asked questions during the theory classes except when the teachers went round the class. A few students preferred to stay back after class to ask questions.

In general, all the teachers were confident and satisfied with their teaching as they hardly mentioned about their weaknesses in their teaching. That most probably explains why they were disappointed with the performance of their students in the progressive test, topical test and semester examination where only 1-3 students in the class passed with more than 50 marks. Coincidentally, they gave the same reasons for their students' poor performance: laziness and insufficient practice on problem solving. None of them related their students' poor performance to their teaching or lack of conceptual understanding. This observation was consistent with the findings of Clement (2004) and Johnstone (1999) that "teachers taught but students might not learn". The teachers might have overestimated the amount of learning students gained from their teaching. Besides giving similar reasons for students' poor results, the teachers also suggested similar solution to remedy the poor performance of their students by giving more exercises.

The finding of this study suggested that the teachers equated the students' capability in giving responses to the algorithmic questions posed while solving the problems to "conceptual understanding". In reality, the students might only possess shallow and algorithmic understanding of the chemical concepts even if they performed well in examination (Fensham, 2002).

5.2.2.3 Post active phase

The writing of reflection was supposed to be a routine job at the end of a lesson. All the teachers wrote their reflection except Andy. He was aware of the importance of writing the reflection, however, he felt he should be given an option in writing reflection. He chose not to write reflection because he was worried what he had written might backfire on him. He said, if he wrote positive comments about his students and his teaching and at the end of the day the students failed it meant he was a hypocrite. On the other hand if he wrote negative comments on his students and his teaching then it implied that he was a lousy teacher who did not know how to teach.

In fact, all the teachers often asked themselves what and how to teach the concepts and the students while planning their lessons. However, most of them did not document and take action on their thoughts. For instance, Bryan did not consider himself making reflection as he said “I don’t consider myself doing reflection because there is no black and white”. Andy said he would reflect about the teaching of a topic the next round he taught it which was often a year away. The reflections of Catherine and Dennis served as checklist of the achievement of their learning outcomes, events happened in the classroom, students’ behavior and responses. The finding of this study shows that none of the teachers commented on their teaching, their new comprehension or insights on the content, students, and self. The lack of evaluation on their teaching probably explained why they did not relate the students’ performance to their teaching which might lead to their failure in adapting their teaching to cater for students’ misconceptions, learning difficulties, diverse abilities and background.

Based on the findings of this study, the four teachers possessed their own unique PCK. For instance, Andy had a strong content knowledge and repertoire of pedagogical strategies. Bryan was closed with his students and taught by making funs, Catherine gave clear and short explanation, giving encouragement to her students based on individual performance and Dennis was very particular about class control and did mental preparation by imagination.

Though the teachers had different teaching experience, different academic background and underwent different training program, they did show some similarities in their PCK:

- (i) They put priority in preparing the content knowledge and pedagogical strategies besides preparing teaching resources and assessment;
- (ii) The content knowledge of the teachers grew and developed faster than their pedagogy and student knowledge;
- (iii) When they were browsing through the learning outcomes, they also figuring out the amount of content they were to teach and the pedagogical strategies they were going to use;
- (iv) They seemed to possess similar educational ends and purpose: to make students understand their teaching and pass the SPM examination;
- (v) They knew their students' background, characteristics and abilities but lacked student knowledge on preconception, misconception and learning difficulties;
- (vi) They lacked assessment on students' conceptual understanding and also on their teaching; and
- (vi) They did a lot of reflections mentally on their teaching without taking actions.

On the other hand, the teachers showed differences in the amount of content knowledge they possessed, the capabilities in carrying out their pedagogical strategies,

and creating representations such as analogies and examples. The differences seemed to be influenced by the teaching experience and personal concerns of the teachers which concurred with the findings of Gess-Newsome (2015). For example, Andy was driven by his personal concerns to create pedagogical strategies for his teaching.

Based on the findings of this study, it was found that the teachers constructed their PCK on site by interacting with their students, content and environment as mentioned in the theoretical framework (Cooper & Loughran, 2015; Magnusson, Krajcik & Borko, 1999; Van Driel et al., 2001). It was also noted that the interaction between the PCK constructs of the teachers with the processes in the PRA model that they carried out had enhanced the development and growth of the teachers' PCK. For instance, the teachers did a lot of reading to comprehend the content during their lesson preparation which resulted in their content knowledge developed faster than their pedagogies and student knowledge. On the other hand, the lack of self-assessment on their teaching most probably had prevented them from assessing their weaknesses in their teaching, and indirectly delayed them from creating better pedagogical strategies to overcome their students' learning difficulties.

Besides the three PCK constructs, the teachers also perceived other constructs of PCK which was reported lacking in the Shulman's original definition such as environment, parents, authority, curriculum, policy, and motivation. Shulman (2015) admitted that his definition was devoid of emotion, affect, feelings, and motivation. In addition, it also did not take into consideration the social and cultural context such as language, and cultural setting where teaching and learning took place. Another aspect that was lacking was the student learning outcomes. It was noted that the context where a teacher teaches

It was observed that the context and the environment where the teaching of a teacher took place influenced how he/she was going to teach. For instance, the level of

English proficiency of the students most probably had resulted in Bryan and Dennis turned to bilingual as compared to if they had a class with high level of English proficiency. Besides that the school features, time constraints, congested curriculum, assigned responsibilities were also noted to influenced teachers' decision and the types of instruction they were going to deliver. For example, the teachers did very few experiments due to time constraints.

As for the teaching processes of the teachers, what they chose to do and not to do seemed to influence the growth and development of their PCK. It concurred to what Gess-Newsome (2015) described as teachers amplified or filtered their beliefs, orientations, prior knowledge and context in the model of teacher professional knowledge and skill (Gess-Newsome, 2015, pp. 31). For instance, it seemed like the teachers had amplified the importance of content knowledge due to their beliefs that teachers had to be well-verse in content knowledge. On the other hand, they might filter off the responsibility for students' unsatisfactory performance by not relating the performance to their teaching.

The framework of the findings of this study are summarized in Figure 5.2.

Chemistry teachers need to have good PCK in order to teach effectively (Shulman, 1986b) and attain optimum learning among their students. Based on the students' performance in the topical test, progressive test and semester examination, one might infer that most of the students had not mastered the concepts and attained conceptual understanding in topic 3. It might have some implication on the trend of performance trend in the SPM Chemistry whereby almost half of the candidates obtained a minimum pass of grade D and E (Table 1.3, p. 10).

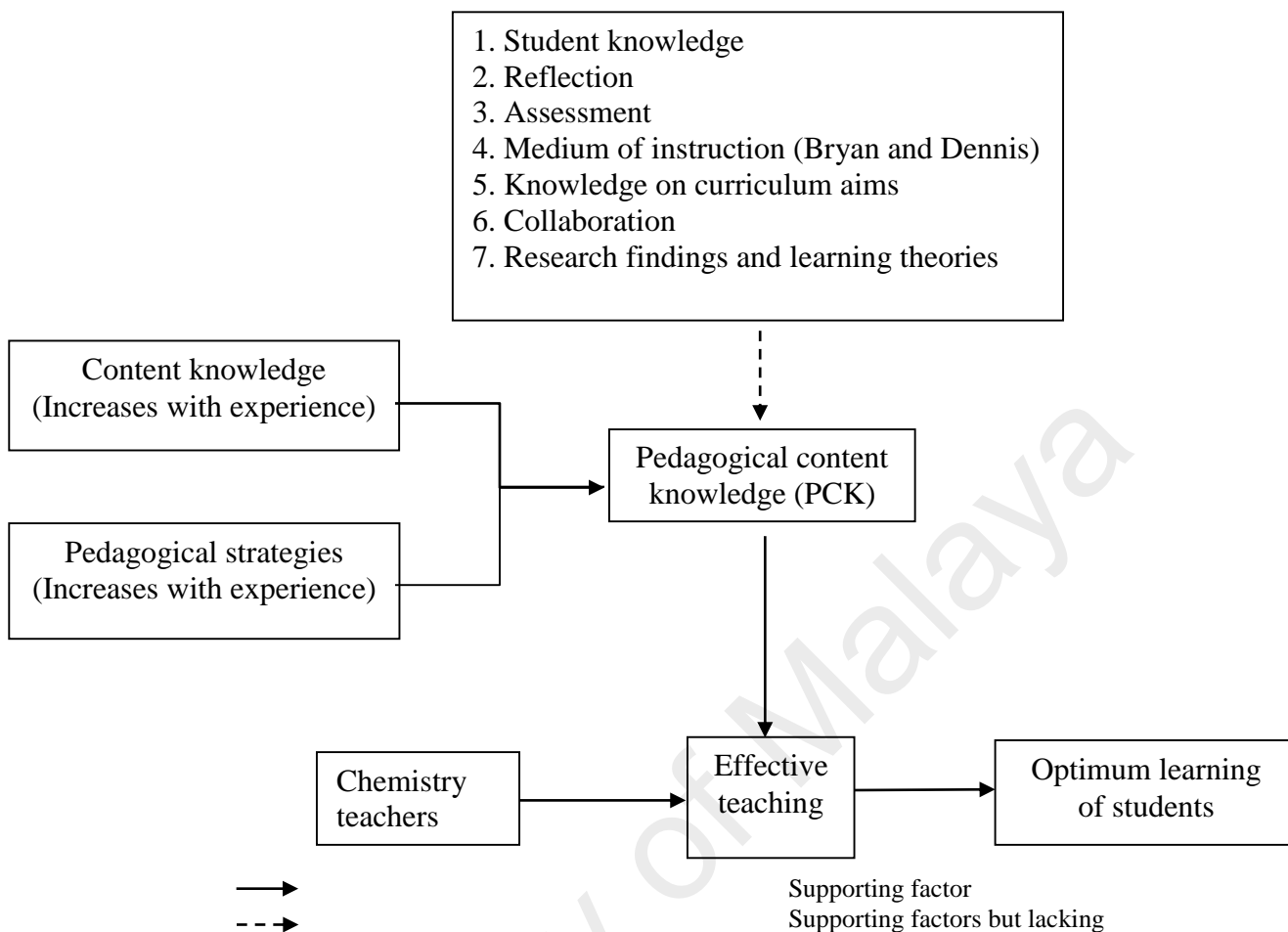


Figure 5.2 The framework of the findings of this study

The findings of this study show that the PCK of the teachers developed and grew with their teaching experience. However, the development and growth of the various PCK attributes did not happen equally and holistically. The attributes such as content knowledge and pedagogical skills were more dominant and displayed clearly by the teachers in their teaching. All the chemistry teachers believed that they had to be well-versed in the content knowledge before going to the class. As a result, they spent a considerable amount of their lesson preparation time in reading the textbook and reference books. The findings from this study show that the teachers seemed to have different focus in their lesson preparation at different stage of teaching. Reading of the content seemed to be dominant in their lesson preparation at the first few rounds they taught topic 3. After they had taught the same topic for a few rounds, a gradual shift

from reading the content to creating analogies and examples was noted. Based on the findings of this study, the shifting seems to be influenced by factors such as academic background and teaching load of the teachers. For instance, although Bryan taught topic 3 for the third rounds, he forwent the reading of content and concentrated on creating examples and analogies. In comparison, Catherine had created very few analogies even though she had taught the same content for the fifth time. The faster shift from reading of content knowledge to creating analogies and examples in Bryan was most likely due to his heavy teaching load in chemistry (3 classes of Form Four Chemistry a year) as compared to Catherine who taught more KBSM science as compared to chemistry and he had an academic degree in chemistry. These influences were categorised as context factors as mentioned by Gess-Newsome (2015). According to Gess-Newsome, these contextual features sometimes were beyond the control of the teachers and they influenced the teaching decisions of the teachers.

Compare to the content knowledge and pedagogical skills, the development and growth of other attributes of PCK such as student knowledge, curricular knowledge and assessment were less significant among the teachers. The lack of the said attributes was most obvious in Dennis and least obvious in Andy. Thus it is possible to infer that PCK attributes such as student knowledge, curricular knowledge and assessment also developed and grew with teaching experience although at a much slower rate than their content knowledge and pedagogical skills. The slow growing of some of PCK attributes was most probably due to lack of reflection and evaluation on own teaching among the teachers.

The findings of this study show that the teachers seldom collaborated with other people such as teachers from the same school or other schools, the school authority and lecturers from the universities and teacher education institutes. It concurred with findings of Brandt (1992), Maguire and Dillon (2001), Holly (1989), Schon (1983), and

Shulman (1986b) that teachers work in isolation. The teachers were seldom exposed to research findings on teaching. Generally, the dissemination of research findings was not common in the Malaysian schools. None of the teachers mentioned reading research findings and articles except Andy. Besides the research findings, the teachers needed to revisit the learning theories such as the information processing theory. The incorporation of the learning theories into the teaching of the teachers would help students learn better.

The changing of the medium of instruction from *Bahasa Melayu* to English seemed to make an impact on those teachers who were not proficient in English as in the case of Bryan and Dennis. By resolving to dual languages and code-switching, the flow of their explanation was often interrupted resulting in ambiguity and confusion among their students. It was reported that students lose at least 20% of their capacity to reason and understand while struggling to learn science in a second language (Johnstone & Selepeng, 2001). The capability loss of the students might be even higher if their teachers were not proficient with the second language too. The lack of knowledge of curriculum aims among the chemistry teachers explained their diversion of teaching from thoughtful learning as intended by the curriculum. Their teacher-oriented teaching accompanied by the huge amount of facts inputted in the lessons encouraged rote learning among the students.

Based on the findings of this study, it was essential for the teachers to possess PCK in order to teach effectively. In order to achieve good PCK, it was essential for the teachers to assess their own teaching and know their students' learning difficulties and misconceptions (student knowledge). From there, they planned their pedagogical instruction according to the characteristics and needs of their students. At the same time, the assessment and evaluation of the learning outcomes of the students were designed in line with the curricular aims. The delivery of the pedagogical instruction was further

enhanced with the incorporation of the content knowledge, language proficiency, curricular knowledge and learning theories of the teacher. As a result of the amalgamation of all the attributes, it helps to strengthen the PCK of the teachers. Shulman claimed that teachers needed strong PCK to be the best possible teacher (Berry, Loughran & van Driel, 2008).

5.3 Implications for the theory and practice

The findings of this study show that the development and growth of the attributes of PCK of the four teachers were not equivalent and not in a holistic manner. The content knowledge and instructional strategies of the four teachers developed and grew much faster than their student knowledge, curricular knowledge, and assessment on conceptual understanding of the students. In order to develop the PCK in a more holistic manner, collaboration with other parties seemed to be a productive path. Additionally, science educators had identified that PCK could be acquired largely through classroom teaching experience, discussion with more experienced colleagues, imitation, reflection, attending professional conferences and reading teachers' journals (Barnett & Hodson, 2001; Van Driel, De Jong & Verloop, 2002). In order to achieve a holistic and faster development and growth of the PCK of the teachers, the state education could set up collaborations between the teachers and other parties through various methods such as mentoring, sharing, discussions, classroom observations, and training programs. The other parties here could be the inspectorates and lecturers from the teacher institutes and universities. Through classroom observations, the school authority, the inspectorate, lecturers, the expert teachers and peers could provide constructive suggestions to improve the teaching of the teachers observed. By exposing the teachers to the latest research findings on learning theories, classroom practices and students' misconceptions, the teachers could create more instructional strategies to help their

students. Additionally, the Education Department could organise more professional development programs such as short-term skills-oriented workshop using the topic specific PCK compiled from various studies on chemistry teaching for the in-service chemistry teachers to reinforce their instructional strategies and develop their PCK (Clermont, Krajcik & Borko, 1993). The Education Department could organise more sharing sessions among the chemistry teachers from the same zone where they could share their successful classroom practices, exchange ideas to promote better comprehension of the content knowledge and organisation of the curriculum.

Besides content knowledge and pedagogical strategies, the pre-service training program in the universities and teacher education institutes should consider to add on “topic specific PCK”, students’ learning difficulties and students’ misconceptions in their course. Having knowledge on the topic specific PCK or the successful classroom practices in chemistry provided a good foundation for the pre-service teachers to overcome their students’ learning difficulties and misconceptions.

Besides collaborating with other parties, it is necessary for the teachers to reflect on and evaluate their own teaching. The writing of reflection at the end of a lesson should extend to include comments on the strengths and weaknesses of own teaching, insights and new comprehension on the content, students, self and the follow-up actions.

Although the PPSMI policy had been abolished, it is worthwhile to mention that the language proficiency in the medium of instruction of the teachers played an important role in the implementation of the lessons. It was necessary to impose close monitoring on the implementation of a policy besides providing teaching materials and in-house training. Mistakes should be avoided in the teaching resources provided by the ministry of education, and errata should be provided to inform the teachers if there was any mistakes. In order to achieve optimum outcomes and smooth teaching, it was

necessary for the teachers to preview the teaching courseware to select suitable content, detect mistakes, and estimate the time duration needed before the lessons.

The congested syllabus had resulted in the teachers rushing through the syllabus and delivering a lot of factual information in a lesson. As a result, the students had to learn and understand a lot of information at a single input. The Malaysian Ministry of Education might consider to increase the duration of teaching and learning time (currently 160 minutes) (Borneo Post Online, 22 December 2012) or reduce the content in the curriculum. This is to promote learning took place and students had a stronger foundation to further their studies in the STEM related areas.

There is a need for the teachers to shift their teaching from teacher-oriented teaching (rote learning) to student-oriented teaching. Hands-on and minds-on activities could be incorporated to produce active learners with a strong foundation in chemistry. These students will continue to study in the STEM related fields at the tertiary level in order to achieve the 60-40 ratio.

5.4 Recommendations for further research

The study on PCK is still not extensive in Malaysia, therefore the study of this field can be extended to other aspects such as:

- (i) to replicate the study to other chemical concepts such as redox reaction, electrolysis and concentration as studies showed that those chemical concepts were difficult concepts encountered by students;
- (ii) to replicate the scope of study to teachers from other states in Malaysia;
- (iii) to extend the scope of study to include other methods of data collection such as using template, mind map and video recording; and

- (iv) to extend in the scope to other areas of study such as physics and biology and also to other levels of Chemistry such as Form 5, Form 6, matriculation and tertiary level.

5.6 Summary of the chapter

This chapter began by giving a brief introduction followed by the discussion on the findings of the study. The section then continued with summary and discussions on the findings and the implications of the study and suggestions. The conclusion which can be derived from the study is that: the teachers perceived themselves as knowledge dispensers and considered content knowledge, pedagogy and students as their essential components of teaching; they carried out most of the processes in the PRA model proposed by Shulman such as comprehension, transformation (preparation, selection, adaptation and tailoring to students characteristics), instruction, evaluation, reflection and new comprehension.

The essential components of teaching of the teachers concurred with the PCK constructs proposed by Shulman (1986b) and also PCK constructs of many scholars. Besides that the teachers also listed other essential components such as environment, parents, policy, curriculum, science process skills and school authority as their essential components of teaching which concurred partially with the PCK constructs of Veal and MacKinster (1999). The concurrence implied the teachers were aware of the importance of these constructs in their teaching. However, in the aspect of student knowledge the teachers still lacked the knowledge of students' misconceptions and specific learning difficulties which seemed to have some implications of the capability of the teachers in adapting and tailoring their teaching to help students' learning.

As for the teaching process of the teachers, the teachers carried out most of the processes in the PRA model proposed by Shulman (1986b). There were a few aspects

that the teachers lacked: (i) adaptation and tailoring to student characteristics especially their misconceptions and learning difficulties; (ii) assessing conceptual understanding; and (iii) reflection on own teaching; and (iv) new comprehension on content, self and students.

Besides that the finding of this study also captured that the attributes of PCK of the teachers grew and developed at different rates. The content knowledge of the teachers grew and developed fast at the first few rounds of teaching a particular topic regardless of the teachers' academic background and types of training. It was because the teachers focused on reading the content during their lesson preparation. The teachers gradually shifted their focus from reading the content to creating examples and analogies for their pedagogical strategies.

It is insufficient for a teacher to possess the content knowledge and pedagogical skills alone, the teacher's student knowledge, reflection, evaluating students' conceptual understanding, knowledge on curriculum aims and language proficiency of the medium of instruction were essential for teachers to achieve effective teaching and optimize students' learning. The lack of knowledge among the teachers in curriculum aims and research findings had resulted the teachers' teaching diverted from the curriculum aims such as producing active learners and thoughtful learning. The teacher-oriented teaching most probably impeded effective teaching that probably explained the high percentage of the students scoring minimal pass at the SPM examination (Table 1.2, p.3). At the same time; it delayed thoughtful learning and optimum learning among students and also the attainment of the 60-40 Ratio Policy.

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