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CONCEPTUAL UNDERSTANDINGS
AND THEIR APPLICATION
TO A PROBLEM ASSESSMENT TASK:
IMPLIEDATIONS FOR NURSING CURRICULUM DESIGN
(Volume One)

By

WONG WAI LIN, MARIAN

A thesis submitted to The Hong Kong Polytechnic
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ABSTRACT

This phenomenographic study explores and understands the qualitative differences among second-year, baccalaureate, nursing students' conceptualization of relevant knowledge to successful problem-solving tasks in a respiratory nursing context. The study includes two phases. In the pilot study phase, the immediate experiences of the participants are tapped, allowing for the construction of the interview tasks and guides. In the main study phase, two consecutive interview tasks with embedded problem situations are used for the twelve participating nursing students to interact voluntarily. These tasks also act as triggers for initiating the actual problem-solving processes, upon which interview data are collected.

The interview data are managed through three levels of data transformation until a framework of "categories of description" is achieved. The resulting "categories of description" framework includes the participants' knowledge conceptualization and problem-solving processes, embracing the knowledge components and its structures, and the conceptual operational behaviors for understanding the embedded problem situations and the nature of the tasks.

The results reveal that nursing students adopt various knowledge base and problem-solving approaches when embarking on a nursing situation that occurs in real-life settings. Students utilize different conceptualizations and problem-solving approaches when they perceive their different roles in patient care service. The data also shows that problem-solving processes used by the students are neither consistent across two interview tasks nor necessarily matching their knowledge conceptualization processes. There is an implication that problem solving skill development for novices should focus on the presentation of real patient problem, especially when individuals embark on a
situation in which new knowledge is developed or the knowledge content being learned is applied during the process of solving a problem.

Four categories of conceptualization are identified, namely, complete integrative approach, partial integrative approach, non-integrative approach and forced-fitting approach. In addition, five categories of problem-solving approaches are also revealed. They are the complete reiterative loop-hypothesis formulation-validation approach, partial reiterative loop-hypothesis formulation-validation approach, incomplete reiterative loop-hypothesis formulation-validation approach, disjointed reiterative loop-hypothesis formulation-validation approach, and forced-fitting reiterative loop-hypothesis formulation-validation approach.

Discussions of the findings focus not only on the roles of students and faculty in the nursing education practice and the Chinese cultural values of interpersonal relationship, but also on the characteristics of conceptual learning experience in relation to collaborative inquiry. The study proposes that facilitation of collaborative inquiry and problem-based learning can offer insights to novices on how to understand the problem-solving situations, what to do and how to proceed in solving them. The thesis concludes with recommendations suggestive of a curriculum design for a university-based nursing program, future directions for research in students learning to solve clinical problems and potential practical implications.
DECLARATION

I declare that this thesis represents my own work except where due acknowledgement is made, and that all material in this thesis has not been previously included in a thesis, dissertation or report for which a degree has been conferred.

Signed: ____________________________

Date: 25 April 2001
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There are a number of people to whom the author owes a debt of gratitude for helping achieve the objectives of completing this research.

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Chapter 1

INTRODUCTION

1.1 Introduction

Nursing discipline, a practice-based profession with a service-oriented nature, is now facing new challenges in a rapidly changing health care environment. In view of the expanded and extended nursing role, nurses are not only required to solve problems of health care services at large, they are also expected to deal with nursing concerns in their daily practice. Not only are nurses obliged to make decisions upon the demands of meeting patients’ needs in a variety of clinical situations, they are also required to respond to the challenges arising from the various disease developments. Moreover, with the emergence of the non-professional helpers and the changing relationship with the medical counterparts, accountability and autonomy of nurses are greatly enhanced (Wong 1998). Nurses are now expected to fulfil and function as ‘thinking’ nurses of a professional standard.

Nurse education has a mission of preparing graduates with new perspectives and abilities so that they can function well within different health care settings. In order to meet the demands of professional competence (Schön 1990, 1991), the teaching outcomes in professional education must be aligned. An understanding on how students gain clinical problem-solving abilities and on
how nurse teachers provide better facilitation to students' learning and application is essential. Problem-solving skills are considered central to daily nursing practices (Terry and Higgs 1993).

However in recent years, the teaching of problem solving for nursing students has come under question. Although problem solving has been defined as one of the critical elements for nurse education, there is an unresolved question whether problem-solving ability is natural or inherently related to the skills and dispositions of problem solving. And to what extent problem solving can be taught to the nursing students if this ability can be learned is still unclear. Empirical evidence (Glen 1995; Valiga et al. 1995) supports speculations that the failure of nursing students in clinical problem-solving is dependent upon the instruction used for the related skill development. This poses a challenge to both nurse education and nursing practice in providing opportunities and resources for practicing problem solving. Nurse education, on the other hand, is confronted with the challenge of determining the content, curricular strategies and opportunities that describe, explore and develop problem-solving abilities.

1.2 Setting the Scene

There is a notion that individuals are regarded as effective problem solvers if they pass the written examination purposely designed to assess the essential knowledge that are related to problem-solving context. However,
only little evidence is available to support that students can transfer their knowledge and adopt specific cognitive strategies in understanding the situation while trying to solve the problem. In fact, most nurse teachers believed that students need to be facilitated in understanding the variety of differing dimensions or perspectives, particularly with the relationship of the problem situation and the dilemma with which they are faced.

Most efforts in promoting nurses' problem-solving skills are based on one assumption that problem-solving skills are largely dependent on a set of generalized processes. Nurse faculty has referred to theories and models which illustrate the general properties of problem solving, as well as the processes in teaching nursing students. However, problem solving in itself involves complex processes, and skills are not easily determined by this direct, step-wise protocol. As a result, two lines of examining the nature of problem solving prevail.

The first method focuses on the product analysis of problem-solving behaviors (van Someran, Barnard and Sandberg 1994). Using retrospective study, it was believed that problem solvers are free from the inference to the actual problem-solving process itself, and that the solution to a problem reflects their problem-solving behaviors. However, this does not mean that every event or sub-process in explaining the behaviours being demonstrated concurrently while problem solving is taking place can be taken into account.
A study (Groen and Patel 1985a) on the problem-solving activities of students from a knowledge-driven approach found that the use of domain-specific knowledge base was the key distinction between successful and unsuccessful diagnosticians. They reported that the problem-solving approaches of students are closely related to their integrated medical knowledge base rather than their specific content knowledge of a medical subject - a relatively new line of inquiry for the skills required in clinical problem-solving. Their results, however, were inconsistent to those reported in most human problem-solving and medical problem-solving literature. One possible explanation for this observation was that only a minor trend of nursing researchers were adopting information-processing theory in examining clinical problem-solving, thus generalizations were quite difficult to achieve. It was further believed that, in exploring the theoretical underpinnings of problem solving studies in nursing, nurse researchers did not take into consideration the role(s) of domain-specific knowledge in all aspects of student learning.

Contemporary researchers were dissatisfied with the representation of hypothetico-deductive reasoning and heuristics in explaining the nurses' clinical decision making. In view of the assumption that most nurse educators hold, the variables most commonly associated with the hypothetico-deductive model did not prove adequate in differentiating strong from weak problem solvers (Bordage and Lemieux 1991). Instead, credence was given to
information-processing approach, with a presumption that it is generalizable to solve all problems across nursing field provided the practitioners employ each proposed strategy or process in dealing with any clinical problem.

Cholowski and Chan (1995) refuted the idea that teaching problem-solving processes alone is sufficient in explaining competent problem solving. Since previous studies interpreted problem-solving process as the information-processing approach, they argued that the problem-solving process (the process) may be used in different ways, and that it may yield different solutions (the outcome) to the clinical situations. They further stressed the urge to formulate more qualitative and holistic research approach for predicting problem-solving approaches and its underpinnings. This paved way to a new line of examining the nature of problem solving, which will be the basis of the research for this study.

1.3 Significance and Scope of the Study

Studies have been conducted to investigate how nurses use knowledge to make a particular clinical decision (Narayan and Corcoran-Perry 1997; Corcoran-Perry, Narayan and Cochrane 1999). Both the knowledge and cognitive processes required to explore the solutions in a nursing situation were determined. The finding showed that these nurses were able to acquire domain-specific concepts and knowledge that integrated well with the cognitive processes
required, which were subsequently contributed to the solution of a clinical nursing context.

Critique of the approaches in teaching clinical problem-solving found that the information-processing approach stresses the sequential cycles along a progressive path of data collection to resolution, but gives very little credit to the relevant knowledge which is necessarily in place in the linear steps involved in each problem-solving reasoning cycle. On the contrary, the knowledge-driven approach values the application of relevant knowledge of each component carried along in clinical reasoning processes. In the latter, the identification and availability of relevant knowledge has a place in evolving and/or dominating each step of the problem solving. A table summarizing the problem-solving processes and outcomes in nursing based on different problem-solving approaches is constructed (Table 1.1).

Table 1.1 Problem Solving in Nursing: Relationships Between Problem-Solving Approach and the Involving Processes and Outcomes

<table>
<thead>
<tr>
<th>Problem-Solving Approaches</th>
<th>Problem-Solving Processes</th>
<th>Problem-Solving Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information-Processing Approach</td>
<td>Hypothetico-deductive Method</td>
<td>Different outcomes (Solutions)</td>
</tr>
<tr>
<td>Heuristic Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge-Driven Approach</td>
<td>Knowledge-triggered Process</td>
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</tbody>
</table>
The lack of understanding to the learning of problem-solving process among nurses led to a growing interest among researchers in exploring representations of knowledge and processes separately. What are the processes involved? Do nurses examine the construction process while making clinical decisions? What are the relevant knowledge contents used to organize the information about the problem context? Answers of these questions may give hints to the different types of discourses used for problem solving by health care practitioners (Bordage and Lemieux 1991).

Previous research studies in nursing discipline failed to understand the entire problem-solving process within which what' components or rules interplay in learning problem solving. An explanation of how students arrive at competent problem solving in their practice was also limited. As a result, there is a paradigm shift towards exploring student approaches in learning the subject content in relation to the ability of problem solving (Ramsden 1988). For instance, the study on students' conceptual learning and understanding to science subject content led to an awareness of the construction of innovative representation of a text explanation in science teaching (Eizenberg 1988). Helpful insights were drawn from these findings to re-direct the faculty in seeking for a better way to teach problem-solving skills to their pre-clinical students.
With the increasing trend in the understanding of students' learning of problem solving, the approach of phenomenography (Marton 1981, 1986) is introduced as an appropriate line of enquiry in nursing education research. Phenomenographic study in student learning mainly focuses on two streams, the conceptual learning and the problem solving of different disciplines (Ramsden 1988). This kind of study represents an underlying interest in extending the knowledge of problem solving, skill development among novices. Through phenomenography, findings confirming that problem-solving ability is closely related to the knowledge base embraced by the individual problem solver are made available. This model also proves that students react with different conceptualizations to specific clinical phenomena. In short, individual students behave differently in approaching clinical problem tasks.

Implications drawn from such complementary views of problem-solving researches provided plenty of scope for understanding the course of action in nurses' problem solving. It is anticipated that future studies should draw on previous works that reveal the specific elements of problem-solving processes adopted by clinical nurses. In addition, more in-depth investigations should focus on how problem solvers use their knowledge to interact with the problem tasks in order that they arrive at an understanding of the problem situation.

In this study, the researcher explored how novice nurses use qualitatively different approaches in their problem-solving process when encountering
clinical problem-solving tasks. Although the framework of reference used for this study only dealt with applying the findings of novices' problem-solving approaches to the teaching of clinical problem solving for new cohorts of nurse learners, the principles behind the application are still of educational significance. There are strong and valid reasons for the researcher to believe that they are equally applicable to continuous development of many other levels of nurses with different expertise and years of experience.

1.4 Research Objectives

The present study aimed at understanding the experience of second-year, baccalaureate nursing students in conceptualizing the biological science knowledge and their approach to solving the problem in patient care tasks. Through the exploration and examination of the phenomenon of the knowledge conceptualization and conceptual application during problem solving in a respiratory nursing context, the domain-specific knowledge content and cognitive strategies of the students were examined. It is anticipated that insights to the curriculum design with regard to the development and implementation of teaching strategies for improving student learning can be generated.
The three main research objectives for this study were listed as follows:

1. To study the qualitatively different ways in which the second year undergraduate nursing students conceptualize the concept of the respiratory regulation of acid-base balance;

2. To study the qualitatively different ways in which the second year undergraduate nursing students approach real-life problems involving the concept of the respiratory regulation of acid-base balance;

3. To understand the relationship between the different ways how the concept of the respiratory regulation of acid-base balance is being conceptualized by the second year undergraduate nursing students with their problem-solving approaches.

Pertinent to these objectives, three research questions were then designed and developed:

1. What are the qualitatively different ways in which undergraduate nursing students conceptualize the regulation of acid-base balance in normal respiratory physiology?

2. What are the qualitatively different ways in which undergraduate nursing students approach nursing problem-solving?
3. Is there any relationship between the students' approaches to problem solving and their conceptualization of respiratory regulation of acid-base balance?

1.4.1 Glossary of Terms

This research addressed the experience of nursing students in conceptualizing the knowledge content and in their approach to problem solving in a simulated nursing context. For the purpose of this study, the following operational definitions were drawn.

- Problem-solving approach is conceptualized as a "cognitive task" (Narayan and Corcoran-Perry 1991).

- Problem-solving behaviour is characterized as a "person-task" interaction between an individual and the problem-solving task (Ericsson and Simon 1993; Newell and Simon 1972; Simon 1979).

- In phenomenography, individuals are the persons who bear different "ways of experiencing" a phenomenon (Marton 1986). "Experience" in this study focuses on the relationship or interaction between the 'problem-solver' and the 'problem'.

- The terms "conceptualization" is used interchangeably to mean "ways of experiencing". The ways of experiencing are interpreted in an experiential level depicting how the phenomenon appears to the person, and include a description of "variation" as well as a description on the collective level (Marton and Booth 1997).
• The cognitive thinking underpinning each student nurse in approaching problem solving refers to the "Ways of conceptualizations" and the "Ways of understanding clinical phenomenon". These are the main objects of the study.

• "Conceptualization" refers to the "categories of descriptions" of the conceptual understanding to facts or issues embedded in the presented phenomenon.

• "Problem-Solving Approach" is an orientation to guiding the problem-solver to go through in understanding the problem before arriving at a solution.

• "Successful Problem-Solving" is defined as an individual who is able to demonstrate all the pathways necessary to arrive at a problem-specific solution.

• "Phenomenography" directs the researcher to adopt an empirical approach and understand other's experience (Marton 1999, pg. 116): Phenomenographer aims to study individual's experience to uncovering the variations among their experiences and focuses on the individual's "ways of experiencing" different phenomenon. "Phenomenography" is different from "Phenomenology" where the researcher focuses on the 'shared experience' and tends to add meanings and interpretations to the original descriptions of the participant's.
1.4.2 Assumptions for the Study

A phenomenographic approach embracing a "second-order" perspective (Marton 1981) was adopted for this study. The experiences of the subjects who participated in this study were not described "as they are". Rather, their experiences were taken as things that specifically appeared to them (referring to the subjects). Descriptions of their perception and experience were made in terms of what they exactly described.

As "phenomenography provides descriptions that are relational, experiential, content-oriented, and qualitative" (Marton 1986, p. 33), the following assumptions formed the basis of this study:

1. Every student who embarks on the problem-solving tasks has a unique perception and experience, and is able to verbalize his / her own views to others.

2. There is a close relationship between the knowledge content and the problem-solving approaches being used in the identified problem-solving tasks.

3. The conceptualization and problem-solving approaches are uncovered and delineated using the research method in this study.

4. The characteristics and patterns of students' conceptualization and problem-solving approaches elicited are only true for this study. No
claims are made on the applicability of the conceptualization and problem-solving approaches involved to another nursing context.

1.4.3 Organization of the Thesis

The thesis is organized as follows. The first chapter sets the scene by introducing the research objectives, the significance and the scope of the study as well as the definitions of terms and assumptions made. Chapter two is an updated literature review of the features and general characteristics of problem solving among professionals in medicine and nursing. The current practice in problem solving and related skill development, the impact of new educational philosophy to nurse education, the learning outcomes of nursing students in higher education, and the pursuits of curriculum evaluation leading to a curriculum reform are also covered.

The next chapter discusses the common presentations and approaches used to teach biological sciences in pre-registration nursing curricula. Chapter three describes the biological science knowledge content which informs the possible conceptualization of the subjects used in the problem-solving tasks. The abstraction and ambiguity of the knowledge content, if presented, as a matter of facts, are explained. The learning difficulties second year nursing students encountered in learning this content are also discussed.
Chapter four focuses on the methodology model used for this study. This chapter also describes the two-phased, phenomenographic research approach being used. The first phase explains the process of constructing and developing the interview tasks, the interview protocol and the prompts for the "think-aloud" interviews. A clear delineation of the pilot study implementation stage provides some implications to the main study. Discussion also revolves on the data collection and analyses procedures. Concerns of validity and reliability, and the ethical issues involved concludes the chapter.

In Chapter five, a detailed presentation and interpretation of the findings according to the three research questions, namely the understanding of the conceptualization of the domain-specific knowledge content, the problem-solving approach, and the relationship between the conceptual understanding and the problem-solving approach are presented. Chapter six is a discussion chapter of the major findings and conclusions of the study. Implications and recommendations for future research on understanding students’ experience in domain-specific learning closes the chapter. The last chapter, chapter seven is a listing of the references, bibliography and appendices for the study.
Chapter 2

LITERATURE REVIEW

2.1 Introduction

In contemporary nursing, nurses are required, under the tremendous health care demands, to utilize their knowledge in meeting patients’ needs in a flexible and creative manner. They also engage in higher-order thinking while handling complex clinical situations in professional practice. Problem-solving is one example of these required clinical thinking abilities, especially when they have to face the ever-changing health care environments and handle different patient phenomena arising from different disease conditions (Roberts et al. 1993). With problem-solving skills considered fundamental for nurses to possess, problem-solving has been constantly referred to in nursing literature as the hallmark for professional competence.

If clinical competence in serving the clients is warranted in practice, then nurse educators have to justify the competencies of their graduates in meeting stakeholders’ expectations. The design of the professional nursing programs and curriculum must ensure that problem-solving abilities of nursing students are developed and promoted. A model of problem-solving curriculum that includes the practical knowledge and skill in nursing problem-
solving should be the framework used for the skill development of the novices. More studies should be conducted to explore successful problem-solving behaviors embedded in clinical practice (Urden 1989; Davis 1993). The measurement of problem-solving skills among practicing nurses should also attract more attention.

All these demands require the professional nursing educators to constantly ask the following provoking questions. "What is required from a professional nurse to meet the clients' demands?" "How does a professional nurse think about complex clinical problems?" "How do nurse educators best facilitate the competence of problem-solving of the nursing students?" In this chapter, selected literature on problem-solving in nursing will be reviewed. The importance of problem-solving in nursing will also be examined, while another section will discuss the different problem-solving models used in nursing practice and education. Further discussion on how problem-solving skills are acquired, and what could be done to improve students' learning in this aspect will also be covered.

2.2 Problem-Solving in Nursing

Problem-solving is an increasingly prominent, frequently used but inadequately defined concept in nursing practice and education. Very limited explanation has emerged in nursing literature to define and explain what goes on when nursing students embark on a problem-solving process in nursing
practice. In fact, the principal way in which physicians and medical students have addressed this problem in recent years was through researching the nature of problem-solving and seeking a testable problem-solving model to delineate the differences in clinical competence between the experienced and inexperienced health care professionals (Elstein, Schulman and Sprafka 1978). Nurse researchers also have to make extra efforts to uncover the knowledge base that underlies everyday problem-solving practice before directions can be given for the development of appropriate educational strategies in nurse education (Urden 1989; Corcoran et al. 1999).

Recent research findings support the belief that the knowledge and cognitive processes required to solve clinical problems are specific to the tasks and the domain of practice (Corcoran-Perry 1986; Elstein et al. 1990; Westfall et al. 1986; Hassebrock and Prietula 1992). In the following subsections, the definition and the components of problem-solving are identified. The patterns of knowledge and strategies of the problem-solving process used by different levels of nurses are also described. And in order to develop strategies to teach nursing students about problem-solving in special nursing care settings, the nature of problem-solving in a specific nursing area is also explored. Such understanding can help nurse faculty develop better strategies in developing clinical thinking skills, something that is so vital to professional practice. Findings from such studies can also provide a basis for recognizing the knowledge base and the problem-solving techniques that will enhance
beginning nurses' problem-solving abilities. An investigation and understanding of the features and properties of the problem-solving process is also useful for nurse educators to actually characterize and define the knowledge acquisition and skill development required to improve problem-solving abilities among nurses, in particular the novices (Roberts et al. 1993).

2.2.1 Definition of Problem-solving

Problem-solving behavior is based on the interaction between a problem and a problem task (Newell and Simon 1972, Simon 1979). According to Thorndike (1911), a problem only exists 'when the goal that is sought is not directly attainable by performing simple acts available in the personal repertory', and 'the solution calls for either a novel action or a new integration of available action' (cited in Ridderikhoff 1991, p. 197). Using Thorndike's theory, Ridderikhoff (1991) studied the reasoning processes of doctors in solving patients' problems, and he defined problem-solving as 'a serial continuity of operations which transforms the original problem towards a pre-destined goal or solution' (ibid, p. 197). Further clarification on the definition of problem-solving in nursing was provided by Hurst (1985, p. 56), wherein 'problem solving in nursing is a form of higher-order thinking where problem solutions develop from the complex cognitive processes of recalling, evaluating recalled knowledge, decision-making and verifying outcomes'.
Although the methods used in these problem-solving studies were different, problem-solving was always related to the knowledge base of the health care professionals, and was thought to be a powerful means of meeting patients' needs (Greon and Patel 1985a, Balla et al. 1990, Elstein et al. 1990). In many findings of empirical investigations reported, problem-solving in nursing was always considered as clinical reasoning ability that nurses exhibited in practical settings. This point of view was taken into consideration by the author when analyzing the data and writing this thesis. Generally, nurses associate clinical thinking skills to 'nursing process', 'nursing assessment', 'nursing diagnosis', 'clinical decisions and judgment', 'clinical reasoning' and 'nursing problem-solving'. They tend to think these concepts are used interchangeably.

2.2.2 Development of Problem-solving in Nursing

The idea of searching for appropriate approaches and methods to teach problem-solving in nurse education has raised considerable debates on the genesis of problem-solving. One of the main assumptions of problem-solving development in most nursing literature was that the concepts of nursing process and nursing diagnosis are always referred to as the cognitive process of problem-solving (Hurst 1985; Field 1987). In the late 60s, professional nurses started studying problem-solving skills of nursing students in relation to the evaluation and development of teaching methods or strategies (de Tornyay 1968a; 1968b). Investigations shifted to information processing during the 1970s to mid 80s, when nurse researchers increasingly examined the nature of
problem-solving behaviors from different perspectives. Several studies tested the effectiveness of teaching strategies on improving the problem-solving performance of baccalaureate nursing students (Mitchell and Atwood 1975; Yeaw 1979; Jenkins 1985). Others focused on identifying practicing nurses' skills in dealing with patient care problems (Hamdi and Hutelmyer 1970; Sherman, Miller, Ferrand and Holzemer 1979).

Even though the paradigms used across many problem-solving researches were inconsistent, most nursing studies conducted after 1980s centered much on two things:

1) the delineation of diagnostic reasoning and thinking processes on patient care (Gordon 1980; Tanner 1982; Putzier et al. 1985; Westfall, Tanner, Putzier, and Padrick 1986; Tanner et al. 1987; Benner and Tanner 1987; Plunkett and Olivieri 1989; Taylor 1997); or

2) the mental processes of clinical reasoning or clinical judgment (Jones 1989; Brykczynski 1989; Grobe, Drew and Fonteyn 1991; Roberts et al. 1993; Gordon, Murphy, Candee and Hiltunen 1994).

There was also a growing interest in examining the differences of clinical reasoning or problem-solving among experienced and inexperienced nurses, or even among successful and unsuccessful nurse problem solvers (Corcoran-Perry 1986, Brykczynski 1989; Hurst et al. 1991). Similar studies
(Corcoran-Perry 1986, Brycznski 1989; Hurst et al. 1991). Similar studies were carried out until early 90s when professional nurses and nurse researchers placed tremendous efforts to uncover the nature and characteristics of effective problem-solving or reasoning required in clinical practice. This led to the development of a problem-solving approach ('Nursing Process'), which was based on the 'stages model theory' (Hurst et al. 1991; Roberts et al. 1993).

2.2.3 Importance of Problem-Solving in Nursing

The conceptualization of 'problem-solving' in nursing education is not unproblematic. Although a number of descriptions and definitions of 'models of problem-solving' relevant to nursing are proposed by empirical studies, there is no single definition or explanation that reflects the real problem-solving process occurring when nurses manage complexity in health-related problems. There is no particular model that captures the nature and uniqueness of problem-solving processes occurring in professional nursing practice. As a result, most findings of problem-solving in nursing empirical studies are only compared to and drawn heavily from recent problem-solving studies done in practice and education contexts of other discipline, mostly medicine.

A key to understanding effective problem-solving in nursing is to develop studies with systematic evaluations of the performances of nurses
who actually embark to problem-solving tasks until a clearly defined and
described model of problem-solving proven to guide the real nursing practice
is established. If the cognitive process or strategy informing the real problem-
solving performances of nurses is understood then measures meaningful to
clinicians and nurse educators could be identified to improve such skills in
practice. A computerized knowledge based system could also be structured
and adopted as a means of enhancing clinical reasoning (Corcoran-Perry et al.
1999).

2.2.4 Problem-solving and Nursing Competence

Assessment of clinical competence in nursing has received
considerable attention in the past decade. In fact, there is a strong emphasis
that problem-solving skills in nursing should be integrated as part of the
student evaluation in nursing curriculum. There is also no doubt that the
mainstream education has an influence on nurse education - that 'doing' must
be accompanied by 'thinking' (Boud, Keogh, and Walker 1985; Schön 1990,
1991; Wallace 1996; Baker 1996; Schumacher and Severson 1996). However,
nursing faculty are still faced with problems of how best to inculcate these
ideas into the thinking of practicing nurses and nursing students (McCarthy

In contemporary nursing, majority of the problem-solving of patients'
situations arises out of complex mental processes. These processes are central

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to the delivery of safe and effective nursing care: the main essence is that nurses are expected to have the abilities to make relevant observations, to recognize the health problems, and to develop appropriate nursing care plan to address these patient problems (Tanner et al. 1987). Most importantly, it is the presence of this higher-level thinking and the ability to apply problem-solving skills that differentiate the status of the professional nurses from the ancillary staff (Hughes and Young 1990).

2.3 Contemporary Models of Problem-solving in Nursing

Problem-solving is a kind of higher-order thinking that involves recall, evaluation of the possessed knowledge, decision making and the evaluation of the outcomes (Hurst 1985). It is interesting to note that, until recently, only limited literature addresses the knowledge that underlies problem-solving in real nursing practice. A review of the literature on clinical problem-solving in nursing reveals a common assumption about the nature of nursing problem-solving - that problem-solving skills are dependent on a set of generalizable processes or strategies but largely independent of relevant content knowledge (Cholowski and Chan 1995). This assumption led them to conclude that differences in problem-solving performance are due to a lack of understanding of the rules underlying the problem-solving processes, not of knowledge base.
However, this assumption of generalized problem-solving processes was placed under scrutiny in recent years (Carnevali 1984; Cholowski and Chan 1995; Greon and Patel 1988; Pardue 1987). No matter which paradigm the studies of nursing problem-solving embraced, nurse scholars and researchers began to acknowledge and emphasize the role of knowledge base in explaining the problem-solving performances of nurses at different levels. Some studies explored areas such as the knowledge nurses use to make particular clinical reasoning (Corcoran-Perry 1986; de Tornyay 1968a and 1968b; Thompson, Ryan and Kitzman 1990), while others looked at the cognitive processes nurses employ during problem-solving (Jones 1989; Hurst et al. 1991; Tanner et al. 1987). Others even studied both the knowledge and cognitive processes used when embarking on a problem-solving task (Clarke 1988; Corcoran-Perry and Narayan 1991; Corcoran-Perry et al. 1999).

As previously mentioned, most of the available studies on problem-solving were from the field of medicine (Elstein et al. 1990, Groen and Patel 1985a and 1985b, Patel and Greon 1986, Ramsden, Whelan and Cooper 1989, Ridderikhoff 1991, Hassebrock and Prietula 1992). These studies focused mainly on cognitive psychology (Thomson 1959, Newell and Simon 1972, Yura and Walsh 1978). By using this as the basis, nurse educators tried to formulate theories and models to explain and predict the features and characteristics of actual problem-solving tasks in nursing, and subsequently transform this into useful instructional materials methods for developing problems-solving skills.
and abilities in practice. So far, two cognitive psychology theories emerged: the stages model theory (Hill 1979) and the human information processing model (Newell and Simon 1972).

2.3.1 The Stages Model Theory

2.3.1.1 Nursing Process

Nursing process is often seen as a framework for nurses to organize care and problem solve (Little and Carnevali 1976; Hunt and Marks-Maran 1981). It is recommended to student nurses as an effective problem-solving approach in clinical practice (Hollingworth 1986; Chalmers 1989; Koldjeski 1993; Oreo 1994). It is also clearly associated with clinical problem-solving, particularly on improving the quality of nursing care (Wong 1986). However, there are always comments that the complex and ever-changing nature of clinical environments makes it difficult for nurses to transform theories into effective practice. Despite claims that problem-solving is central to nursing practice, the teaching and widespread use of nursing process is still contingent on the thinking processes demanded by most clinical nursing tasks in everyday practice.

Based on the ‘stages model theory’, which provides no detailed guiding pattern of problem-solving in nursing (Roberts et al. 1993), nurses are expected to be ‘creative’ in using their knowledge of nursing process to the real setting. But what is ‘creative use’? What kind of skills and techniques are
McCarthy explained the nature and function of the nursing process. According to McCarthy (1981), the nursing process framework is a problem-solving technique in nursing practice and education where judgments and solutions are made. It is a problem-solving model used for organizing nursing practice by means of a written nursing care plan. It tends to encompass the nature of clinical problem-solving discerned by medical researchers (Elstein et al. 1978), and extends beyond the information processing stage to the patient-centered care planning (McCarthy 1981).

*Stages of Nursing Process*

McCarthy (1981) reported that the role of a nurse in the problem-solving process is different from a doctor because the process of understanding and managing patient care is not similar. A doctor focuses on the diagnosis and appropriate treatment, while a nurse solves problems to assist the client in reaching optimal health potential. She quoted the explanation given by Kelly (1966), that ‘the nurse is primarily concerned with the etiology and alleviation of a symptom, whereas the physician is concerned with the etiology and alleviation of a disease’. She also elaborated the problem-solving mode of the nursing process, and acknowledged that it consists of four main stages, namely assessment, planning, implementation and evaluation (McCarthy 1981; Yura and Walsh 1978). Each stage is discussed separately in subsequent sections.
The stage of assessment is the time when the nurse generates a series of hypotheses according to the patient problem presentation, and focuses on exploring the responses associated with the diagnosis, treatment, complications, prognosis and all aspects of the illness. The health problem of the patient is perceived as the human responses elicited from the disease process of a patient. However, there were some flaws causing a lot of concern in this stage. Leifer (1996) commented that the nurses' diagnostic reasoning processes are closer to a dictionary definition of assessment than of diagnosis, further confirming the idea that nurses are only concerned with the management of health problems rather than diagnosis in nursing. In short, they perceived 'diagnosis' to be equivalent with 'nursing assessment'. There were also remarks that the nursing process does not specify the way information should be processed, and that no clear approach of information processing was prescribed.

Planning is the stage where nurses engage in translating the hypothesis and formulating the plan of action (McCarthy 1981). This stage is similar to the cue interpretation, cue acceptance, cue acquisition, hypothesis generation and evaluation part of the medical problem-solving process (Elstein et al. 1987). This stage is strongly related with the implementation stage of the nursing process. Because of the continuous feedback elicited by these two stages, there is a cycle of hypotheses generation, hypotheses acceptance or rejection going on (McCarthy 1981). This creates the problem of expanded number of
hypotheses being generated, which may cause overloading of information. The overwhelming amount of data could make validation more difficult, therefore yielding mistakes and biases during the information processing.

The identification of the problem situations, the recognition of the interrelationships between different aspects of the problems, and the generation of solutions in light of immediate and long term nursing objectives lead to the next stage of the nursing process, the implementation stage (McCarthy 1981). Again, the nursing actions proposed at this stage stem from the plan that was developed from the hypothesis (McCarthy 1981).

It is clear that the first three stages of actions in the nursing process are products of cue recognition and hypothesis generation. However, there is still no apparent proposition as to how the thinking among nurses evolves and as to how they come to a decision. In the stage of evaluation, the nurse ensures the validity of the original hypothesis by evaluating the effectiveness of the action that was implemented to the patient. This stage is vital because it allows the hypothesis to be verified, and the success or failure of the hypothesis could lead to either confirmation or rejection of the action deemed appropriate for the patient (McCarthy 1981). Once the nurse proves that the actions could solve the patient's problem, then the formulated hypotheses are verified. However, there is an argument that the verification tested upon the effectiveness of nursing intervention at this stage is
problematic. For instance, nursing professionals could not afford to make inappropriate nursing actions, so substantiation is highly unlikely to maintain the patient's best interest even if there is a follow-through system that enables hypothesis checking. Usually the verification at this stage does not go beyond re-considering the changing needs of the patient. Likewise, it is also too late or too risky to note that the hypotheses made are inaccurate for the client, especially at the final stage of the nursing process.

*Implications of the Nursing Process*

The development of problem-solving skill was laid down as an essential component of foundation nursing curriculum in many places worldwide (King's Fund Centre 1990, Australian Nursing Federation 1989, Bramwell 1992, International Council of Nurses 1989, Royal College of Nursing 1990, Registered Nurses Association of British Columbia 1992). To follow its international counterparts, nurse education curriculum in Hong Kong is also starting to inculcate among nursing students problem-solving abilities in serving their clients' health needs (Hospital Authority 1995). In fact, with the Nurse Education in Hong Kong completely entering tertiary level by 2002, it is anticipated that the new generation of nurses will be equipped with independent problem-solving and decision making skills in managing the changing needs of the healthcare (Hospital Authority 1995).
In the stages model theory, learning of problem-solving is not equivalent to the teaching of nursing process. Instead, nursing process is being seen as the mantra of modern scientific mode of thinking required in many professional disciplines (King 1997). It has been described as a definition of nursing rather than providing a theory base underlying the problem-solving process in the profession. In achieving effective problem-solving, nurse educators find it more crucial to think about ‘what to teach’ and ‘how to teach’ problem-solving.

Henderson (1982) argued that there is a danger of seeing the nursing process as the only approach to problem-solving in nursing. She pointed out that the nursing process is only one of the alternatives of problem-solving because it gives no credit to the thought derived from knowledge embedded in clinical experience. Koch (1997) also strongly alluded that strict adherence to the nursing process stifles the creativity of the nursing professions and perpetuates the belief that clinical problems can be solved by just putting them to some kind of logical mode of thinking. He believed that nurses should critically think upon the data obtained from the patient rather than just following stepwise sequences and coming to one single conclusion. Hurst (1985) also described the same reflection, stressing that ‘effective problem solving is more likely to happen when the individual nurse is knowledgeable, intelligent, well motivated and emotionally stable’. For Hurst, motivation of the individual was also one factor that could direct effective problem-solving
process. The value system and the intention of the nurses were also some of the considerations reported by another study (Field 1986).

The method of "nursing process" was taught to novices in many local nursing curricula. In fact, a model of nursing process is being practiced in some regional hospitals in Hong Kong since mid-80's (Wong 1986). The teaching of this framework aims to develop specific skills for students to handle daily nursing tasks during their clinical placement. It is also assumed that inexperienced nurses will learn to adopt the steps of nursing process to patient care simulation in classroom learning. In this way, young nurses will know how to deal with real patient's problem when they go out in the clinical placement. However, it became apparent that students do not understand the concepts or cannot use specific skills in understanding and solving patients' problems. Clinical nurses have expressed concerns over the apparent inability of junior students in applying the knowledge that they have learned to the patient care situations, which has further perpetuated the theory-practice gap currently existing in nursing professionals (Wong 1979; Upton 1999).

In Hong Kong, student nurses undertake public written examination set by the Hong Kong Nursing Board for the purpose of territorial nursing registration. Once registered, they are able to practice as qualified nurses in local communities. The written examination consists of hypothetical patient situation that requires students to develop individual care plans appropriate
for the clients. Students are also expected to demonstrate their competence in assessing patients' problem by means of a care plan writing in several isolated incidents. With this practice, students are required to have some basic understanding of the underlying activities of the patient's illnesses before a care plan can be developed. However, nurse faculty put across concerns over students' difficulty to responses that require them to apply subject content to the problem-solving context embedded in hypothetical clinical situations on examination papers (Hurst 1985). Students also commented that the features and characteristics of typical patient situations appearing in examination papers are largely unreal and, to some extent, somewhat detached from the real nursing situation. In fact, students commonly reported 'decontextualized' materials with disjointed information in the teaching content and examination papers. Thus, the time has now come to challenge the thought that teaching nursing process could lead to effective problem-solving.

2.3.1.2 Nursing Diagnosis

Nursing diagnosis is the end result of data gathering and data analysis within the nursing process (Field 1987). Its main purpose is to allow nurses to combine, classify and label the groups of signs and symptoms causing nursing concern. It is the stage where cues are determined, clustered into patterns, labeled and used in drawing conclusions about the unhealthy responses and etiology of a patient (Ziegler et al. 1986). At this stage, the nurse tends to make judgments about the relationships of the data by comparing it to norms
and standards suggested by theory and research findings before arriving at a conclusion.

One difficulty with this commonly used taxonomy (North American Nursing Diagnosis Association Taxonomy) (NANDA 1991), and this may be vested in the nomenclature of 'diagnosis', is that it directs no focus towards the individual’s strengths or the factors that might mitigate the severity of the diagnosis (Field 1987). While nurse-patient collaboration is highly encouraged in contemporary nursing and patient-centered care highly required across many nursing settings, this taxonomy becomes a problem in nursing practice because there is no consideration of the ‘individuality’ of the client in interpreting the problem.

2.3.1.3 The Role of Nursing Process and Nursing Diagnosis in Nursing

Quite a number of nursing textbooks identified the interface of nursing process and nursing diagnosis in nursing intervention (Field 1987). Field (1987) found that the process of arriving to a nursing diagnosis involves the considerations of metaparadigm, the theories or models of nursing, the nursing process framework, and a systematic problem-solving. Fawcett (1984) also stressed the significance of metaparadigm to the use of nursing process and nursing diagnosis. In the assessment stage, the person, the environment and the health status of the clients are all considered. The nursing actions are
thus the result of the assessment, diagnosis, plan of action, intervention and evaluation of the care provided.

However, the notion of problem-solving in a form of either the nursing process or the nursing diagnosis is problematic. Henderson (1982) and Benner (1984) questioned the belief that all nursing practices can be reduced to an analytic problem-solving (like nursing process and nursing diagnosis). They argued that there is actually no problem-solving strategy or process that could be generalized across all nursing situations. Although there is a logical progression towards establishing a framework for nursing process and nursing diagnosis using outcome effectiveness, how an individual adopts the problem-solving mode to go along the framework of nursing process and nursing diagnosis is still unspecified. Tanner and her team (1987) also added by saying that there is ‘increasing evidence that different processes are used depending on the level of expertise and the nature of the patient situation’ (p. 169). There is also a need to identify what theory controls the development of the framework, and the intervention that results from such thinking processes, especially when nursing diagnosis statements derived from different nursing models have its distinct focus and priorities (Field 1987).

2.3.2 The Information Processing Model

The information processing models are similar to the cognitive processing system because they involve the sorting of incoming information,
sifting the imposing orders upon the items before producing an output (Nisbett and Wilson 1977). In a problem-solving approach, the hypotheses during the phase of information processing are generated at one point in time based on the same set of cues or on several points in time from different cues (Elstein et al. 1978). Since it embraces an open approach using a variety of cues coming from different sources, nurses are explicitly guided by the framework on how to process the data and arrive at a hypothesis in order to better understand the patient’s situation. It is also argued that there are still rooms for assessing client’s health needs and developing a plan alongside the hypothesis generation inquiry (McCarthy 1981), although inexperienced problem solvers may find it difficult to follow this obscure framework.

There are two models of clinical reasoning that were revealed by studies that were based on Information Processing Theory, the hypothetico-deductive model and the lines of reasoning model. Each model is discussed separately.

2.3.2.1 The Hypothetico-Deductive Model

The hypothetico-deductive model is generally used to explain most of the medical students' problem-solving behaviors (Chase 1988; Jones 1988; Norman 1988). This method provides a structured method of problem solving the situation. It is the procedure that attempts to test the hypotheses and modify them depending on the outcome of the test. Greon and Patel (1985a) explained that a hypothesis is a verbal statement about a situation that may
either be true or false. In a hypothetico-deductive method, learning of problem-solving is not like learning of formulas in pure sciences. If the students are put into an unstructured situation without appropriate guidance, they tend to lose their way through a maze of possibilities.

Some investigators questioned the use of the hypothetico-deductive model by contradicting the assumption that novices in any scientific discipline will know how to solve clinical problems through this method of learning. In fact, studies (Muzzin et al. 1983; Norman et al. 1985) on the expert-novice differences in problem-solving found that other factors, such as the capacity of the short-term memory and the content of the knowledge base of problem solvers, were playing a key role in the rapid pattern recognition. Other studies also showed that experts differ from novices mainly in their existing knowledge base and the way they bring this knowledge to making inferences from the data presented to them (Elstein et al. 1990). Such knowledge could include knowledge learned from theoretical input as well as knowledge learned through daily clinical experience (Polanyi 1958).

Still others pointed out the subtlety of the experts' modification of the hypotheses during the reasoning stage. Bordages and Zacks (1984) supported the claim by affirming that the role of the knowledge organization is a distinctive factor in expert problem-solving. Elstein and colleagues (1990) also recapitulated that views about problem-solving reasoning and process
among experts are distinguished by the development of the following elements: (1) a useful knowledge base (2) the rules and criteria in identifying and applying the knowledge base and (3) the prototypes for the classification of the instances. They stressed that the knowledge structure of the experts and the novices has no difference except that the size of the knowledge base is larger and is more easily accessible for experts. Thus, health care professionals are expected to identify the knowledge embedded in the real practice and use this as a tool for guiding novices’ practice.

Besides focusing on the knowledge base and its organization underlying the clinical problem-solving, Frederisen (1984) suggested that other factors underlying the use of knowledge base should also be explored. Although the teaching of problem solving through data collection and accurate interpretation is important, the teaching of the rules for relating, selecting and structuring of patient data to one’s knowledge base is also useful in increasing accessibility of the knowledge in data interpretations and hypothesis validation. It was also reported that any attempt to teach problem solving in a specific context must consider the rules or theoretical principles in promoting problem-solving skills of beginning nurses. This could be done either by better presentations of content knowledge to be acquired or by helping students improve how to structure their knowledge base (Bowers and McCarthy 1993; Corcoran-Perry et al. 1999).
2.3.2.2 Line of Reasoning (LOR) Model

The increase of patients in acute care setting coupled with short hospital stay has also placed great demands on nurses’ abilities to care for the physiologic sphere of health. With the increasing demand of nursing attention to the impending health care needs that relate to unstable, life-threatening physiological conditions, there are now growing interests in general problem-solving in nursing. For example, the knowledge base to understand the physiological realm of health is crucial for nurses to solve problems for many seriously ill patients (Corcoran-Perry et al. 1999). Knowledge of pathophysiological mechanisms provides the expert with another level of abstraction besides the disease knowledge (Hassebrock and Prietula 1992). However, relatively little is known about the role of knowledge in solving patients’ problems to the domain-specific needs.

The line of reasoning (LOR) model, also grounded on information processing, is a new unit of analysis that describes specific cognitive processes during clinical inferences making (Corcoran-Perry et al. 1991). It is described as the representation of the subjects’ clinical reasoning for decision making, delineated as a set of arguments in which knowledge embedded within the reasoning processes leads to a conclusion (Corcoran-Perry et al. 1997). Johnson and associates (1982) and Pechtel (1985) defined LOR as ‘the partially or fully ordered sequence of conceptual actions or steps employed by
a subject in reaching a clinical judgment' (Corcoran-Perry and Narayan 1991, p.189).

When Corcoran-Perry and her associates (1999) studied the LOR of the experienced and new nurses, they found that an expert could problem solve the situation better compared to a novice. They noted that the LOR of an expert is analogous to problem representations, and possibly comprised of the diagnostic hypothesis from multiple sources of medical knowledge invoked in a reasoning context (Gomez and Chandrasekran 1984; Patel and Groen 1986). Although there was no significant result in the inter-group variability, their findings supported the notion that knowledge base and specialty experience distinguished the quality of the line of reasoning between experts and novices.

2.3.3 Evaluation of Problem-Solving Models Adopted in Nursing

The stages model theory is an alternative problem-solving method, which is described as a linear format of processing model. It consists of five main stages (Hill 1979), as follows: problem identification, problem assessment, planning interventions, selection and implementation of chosen strategies, and evaluation and verification of a solution (Hurst et al. 1991). Nursing process is also another resemblance of the stages model theory (Roberts et al. 1993). Although there have been crucial comments from nurse theorists directed to the part of problem identification, the first stage of
nursing process, this first stage still remained implicit within the assessment phase of the nursing process (Roberts et al. 1993; Yura and Walsh 1978).

While the nursing process was taught to nursing students in most pre-registration foundation programs in many places, still a small number of empirical studies were conducted to examine the effects of problem-solving ability on nurses using the stages model approach at different levels. An empirical study exploring the problem-solving between experienced and inexperienced nurses was conducted by Hurst et al. (1991) using the stages model theory. Subjects were interviewed and required to describe their perceptions of the given vignettes (drawn from clinical practice) based upon the five stages of problem-solving. The results showed that all subjects appeared to understand the stages model, but no significant difference was revealed. Even with the limited sample size, Hurst et al. (1991) still concluded that the sample group encountered difficulty in differentiating the different problem-solving stages, in particular, problem identification, planning and evaluation. He stressed that the sample group was able to understand the stages and utilize them, but failed to recognize the function of the crucial stages. He argued that the reason for this condition could be because the participants did not know the theoretical underpinnings of the model, thus they could only demonstrate the ‘doing’ aspect of the practice rather than the ‘thinking’ aspect.
It is also widely recognized that the integration of physiologic and pathophysiologic knowledge into nursing diagnosis occurs in the inference making or the implementation stage of the nursing process (Casmeyer 1989). In fact, the more nurses use the biologic knowledge base during the analyses, the more specific the physiological diagnosis becomes. Although the description is simple, the process itself is complex. How should one perform the critical analysis to the presented data? How should one characterize the evidence obtained to support the diagnosis? This gap has presented another important arena of research on the function of the stages model theory, especially on the consequences of the chosen strategy to effect the solution to the problem.

The extensive review of literature provided above showed some insights on how nurses' problem-solving behaviors could be delineated and appraised upon their cognitive processes and strategies. For instance, it became clear that problem-solving behaviors among nurses embrace unique features and characteristics, and that it is associated with the patients' context and the representation of the problem. It also indicated that specific cognitive processes and strategies of problem-solving only develop within a particular context of which the patient problem is embedded (Hassebrock and Prietula 1992). Both insights reminded the nurse faculty that in teaching problem solving, the significance of the problem solving 'content' has to go with the 'context' where it is embedded. Thus, teaching approach adopting either of the two models of problem-solving skill development is highly unlikely to serve the purpose of
offering opportunities to integrate the nurses' knowledge base and the problem-solving strategies during the problem-solving process.

2.3.4 Measuring Problem-Solving Skills in Nursing

Most of the common evaluative measures of problem-solving behaviors used a linear approach drawn upon the stages model theory to measure problem-solving performance, to name a few, the Rimboldi's Diagnostic Skill Test (1955) and the Tab Test designed by Glaser, Damtrin and Gardiner (1960). In contrast to factual knowledge, the problem-solving process of nurses in their attempts to clarify patient's problems has been a somewhat neglected domain of study. Obviously, the paradigms researchers hold affected the measurements and instrumentation used to evaluate the problem-solving models practiced by nurses. So in order to clearly distinguish the characteristics of the mental processes involved in either the stage model theory or the human information processing model, valid and reliable research on evaluation of the problem-solving skills of nurses should be carried out. It is only when nursing professionals consider the development of problem-solving skills that the measures of evaluating cognitive performance of the complex mental process are determined.

Along with the questions raised regarding the flaws of Information Processing Theory in measuring problem-solving abilities, there was strong agreement that the performance obtained was not likely to reflect the real problem-solving behavior of nurses (Hurst et al. 1991). Sherman et al. (1979)
developed the Patient Management Problem (PMP), a further extension of McGuire and Babbott's work (1967), to assess problem-solving skills using the stages model framework. Nine nursing students were presented with a simulated problem within a framework of patient care, and were asked to solve specific problems through a series of inquiries. The scores of the problem-solving performance and the examination results of the multiple-choice questions were then correlated. Although no significant relationships were found, it was said that PMP was successful in triggering early hypothesis formulation where practitioners could reinforce the hypothesis generated before leading to a confirmed solution as well as in refuting the hypothesis and re-considering the problem (Marshall 1977). However, the effects of the hypothesis generation on the data collection were not mentioned. It is possible that the tool was not sensitive enough to detect the cognitive strategies of the participants during the problem-solving task. Another possibility is that the validity and reliability of the tool was not established owing to the contextual nature of problem solving within the clinical area.

It is noticeable from the studies described above that the evaluation of problem-solving abilities centered only on examining the ultimate decision (a conclusion or recommendation) rather than the process to problem solve. Decision analysis models exhibit a reductionistic strategy which decomposes complex problems into a series of simple steps or schema, and focuses more
on the understanding of the clinical situations rather than the cognitive process (Shamian 1991). A year later, Hassebrock and Prietula (1992) suggested using diagnostic strategy to focus assessment of problem-solving skills on the quality of the reasoning. This strategy utilizes self-monitoring skills to provide a reference to meta-reasoning capacities (Feltovich 1983). Tanner and associates (1986) and Putzier's team (Putzier et al. 1985) also examined nurses' diagnostic reasoning and tested general cognitive processes, like cue acquisition, hypothesis generation, cue interpretation, and hypothesis evaluation, to support the four-stage model of medical inquiry founded by Elstein et al. (1978). In Corcoran-Perry and Narayan's study (1991), the findings of the general as well as specific cognitive processes and strategies nurses employ in clinical problems described information-seeking strategies (Payne 1976; Gordon 1980) and defined the overall approach to planning as the unit of analysis (Corcoran-Perry 1986). For instance, specific cognitive processes referred to the individual's ability to make association to the cues or set of cues with the presuppositions (Matthew and Gaul 1979).

2.3.5 Methodological Underpinnings of the Problem-Solving Studies in Nursing

In search for the appropriate method in studying problem-solving among nurses, a review of the empirical problem-solving studies in medicine showed that systematic investigation procedures were used to depict the sequential data collection and the inference within medical reasoning.
sequential data collection and the inference within medical reasoning processes (Elstein et al. 1990). The methods of concurrent thinking aloud and retrospection identified in recent problem-solving studies were some of the procedures used to obtain data on thought processes that lead to clinical problem solution (Elstein et al. 1990). Other tools also used in the medical studies were simulations and embarking on genuine problems (Elstein et al. 1990). In fact, nurse researchers can use the designs and conclusions of medical problem-solving studies as a blueprint to replicate studies in nursing problem-solving and, subsequently, influence the development of nurse education.

It is assumed that sufficient nursing knowledge and adequate problem solving can contribute to effective nursing reasoning, hence fostering optimal patient care in daily nursing duties. But is this really the case? There are some reservations with the recognition of the reasoning process and techniques subjects engaged with, especially when they face threats and uncertainties, before arriving at a decision or conclusion. Likewise, studies on decision making or clinical judgment might also not lead to exploration of the process towards clinical problem solutions because of certain limitations and biases in the paradigms. The effort of trying to understand problem solving as a strategy as well as the content knowledge for teaching and learning in professional education and practice has also become both fascinating and frustrating. It is fascinating because of the complexity in the phenomenon of
definitions and descriptions that guide professional problem-solving, thus making it difficult to comprehend.

2.3.5.1 Verbal Protocol Analysis

The attempt to uncover the covert mental process by examining the verbal protocol is certainly not a new method in nursing. A previous study stressing the role of think aloud process-tracing method has required nurses to describe the form and content of covert mental events accompanying their reasoning process (Hassebrock and Prietula 1992). In the study, the subjects were not aware of the theoretical construct. Instead, their verbal report drew up information assumed to be mainly stored in a long-term memory system. Since a subject's verbal protocol contained only information available in short term memory or mental process at the time of the investigation, the completeness or quality of their report was determined using the human information processing system (Hassebrock and Prietula 1992). Ericsson and Simon (1984) claimed that the report derived from the concurrent verbalization provided the most complete, valid account of one's thinking since information was verbalized as it was being attended to while performing a task. Hassebrock and Prietula (1992) also recommended the use of reports in asking subjects to verbalize (only) the thoughts that occur and not the general or specific accounts of these thoughts.
Despite all the values of verbal protocol analysis, its methodological and philosophical grounds are still being challenged. Some researchers questioned whether subjects could be conscious of the construct and verbally report the cognitive process of problem-solving (Nisbett and Wilson 1977). Evidences from a number of investigations using problem-solving tasks have also refuted this challenge, suggesting that thinking-aloud does not substantially affect the actual problem-solving process in terms of either its effectiveness or its temporal duration (Hassebrock and Prietula 1992). When seeking to obtain concurrent verbal reports, the choice of the task must be considered (that is, the task that is general or specific must be within an appropriate level of complexity). When conducting the protocol analysis, emphasis must be placed on devising a coding scheme (Hassebrock and Prietula 1992), which is essential because it provides an explicit framework for documenting the behavioral events. It also serves as a guide for subsequent data analysis procedure (Ridderkhoff 1991).

2.3.5.2 Thinking-Aloud Method

"Thinking aloud" is a verbal report method that functions as an instrument for collecting verbal descriptions of the mental process when embarking on a task (Hassebrock and Prietula 1992). There are two main stream of thinking aloud method: concurrent and retrospective reporting. The concurrent verbalization yields a complete report as the individual is performing a task. The retrospective report is an alternative method obtained from recall (Hassebrock
and Prietula 1992). This is achieved by means of questionnaires or interviews, which require the subjects to generate information about processes that occurred earlier in time.

In a 'think-aloud' method, the subjects are required to think aloud as they solve the problems. This technique has been used extensively to study clinical reasoning strategies of nurses and nursing students in recent years (Corcoran-Perry 1986; Corcoran-Perry, Narayan and Moreland 1988; Corcoran-Perry et al. 1999; Grobe et al. 1991; Tanner et al. 1987; Westfall et al. 1986). Evidences also support the authenticity of the data generated, stating that verbalization occurring concurrently with a problem-solving task reveals the pattern of information that is attended to without altering the cognitive processes of the subject (Payne 1980; Ericsson and Simon 1984; Kuipers, Moskowitz and Kassirer 1988).

2.3.5.3 Use of Simulation

Another approach of measuring problem-solving skills in nursing clinical settings is the use of simulation. Employing hypothetical situations has its strengths in providing an opportunity for all subjects to engage in problem-solving with the same tasks in a safe and non-threatening environment where the variables in the task are controllable (Corcoran-Perry et al. 1999). It allows the subjects to learn by working through the task with controlled stimuli. It also allows researchers to conduct in-depth study of the
subject performance, and provides rooms for comparison across subjects and tasks of different complexity (Plunkett and Olivieri 1989; Tanner et al. 1987; Thiele, et al. 1991). A recent finding on the performance of nurse subjects in simulated and actual patient situations showed that nurses tend to use similar thought process comparable with hypothetical patient cases. This implies that the use of simulations and case studies is appropriate for measuring and developing clinical problem-solving (Corcoran-Perry et al.1999). It is also for this reason that the present study used simulation by testing the junior nursing students' problem-solving processes while embarking in a simulated patient task.

However, the use of simulation has been criticized for its narrow scope and inability to account for important variables that may influence the reasoning in the clinical setting (Tanner et al. 1987). Experienced researchers also challenged the assumed representation of the responses used at the simulation to approaches used in real practice (Corcoran-Perry et al.1999; Elstein et al. 1990), saying that there is a lack of evidence to support such claim. Others were more concerned with the outcome of using 'thinking aloud' and 'stimulated recall', fearing that it may lead to a biased conclusion as what was found in many human thinking (Ridderkhoff 1991). Questions were also addressed as to whether the subjects can be conscious of and individuals can verbally report the cognitive process. Nisbett and Wilson (1977) criticized the validity of verbal reports by presenting studies in which they claimed
subjects stated plausible methods by which they had arrived at a solution rather than reports of the direct causes of their behaviors. These commentators also concluded that people tend to 'theorize' the causes of behaviors on philosophical grounds. In addition, other researchers provided evidence suggestive that thinking-aloud does not substantially affect the problem-solving task process, either in terms of its effectiveness or introspection (Hassebrock and Prietula 1992).

2.3.6 The Acquisition of Problem-Solving Skills in Nursing

Empirical studies in medical education on examining the development of the problem-solving abilities revealed that there might be a wide range of knowledge and skills required in problem-solving in health care sectors among health care professionals. However, despite claims that the development of problem-solving ability is central to generic nursing programs, still very limited literature has addressed this issue. The degree of investigations on problem-solving abilities among different level of nurses in practice as well as problem-solving skill development, albeit being on the agenda of nurse education, is still relatively weak in focus. There is inconsistency on the reviews of these two issues, mainly because the nature of problem-solving is still undefined in the field of nursing.

In current nursing literature, the issue of problem-solving is discussed alongside few crucial nursing skills required in professional practice, in terms
of general problem-solving, critical thinking, clinical judgment and decision making (Corcoran-Perry 1986), rather than clinical problem-solving among nurses specifically. The terms of 'problem solving', 'clinical judgment', 'clinical decision making', 'critical thinking' and nursing diagnostic reasoning are being used interchangeably when discussing skills involved in problem-solving in nursing practice (Kramer 1993, Roberts et al. 1993). In fact, in a paper where the issue of problem-solving development in nursing practice was explored, the writers reflected on the variability of the terms used for problem-solving in nursing (Roberts et al. 1993).

2.3.6.1 Measurement Tools to Problem-Solving Process

The measurements used to problem-solving processes varied from one research to examine another. Because of this difference, the outcomes and findings did not account for all kinds of problem-solving behaviors among different groups. For instance, comparison of the expert and novice problem-solving processes revealed that although they used more or less the same set of problem-solving processes, the knowledge base of the experts helped them enhance the quality of their problem-solving outcomes better (Balla et al. 1990; Corcoran-Perry 1986; Itano 1989).

2.3.6.2 Approaches of Problem-Solving Skill Development

Several scholars also brought up the importance of problem-solving skill development in nurse education. They referred to teaching strategies that
discuss the issues of general problem-solving and clinical decision making (Yeaw 1979, Jenkins 1985), and reckoned that it is helpful in guiding students to apply general problem-solving process in clinical problem situations. So far, there are two major streams of frameworks for teaching problem-solving to new nurses: the hypothetico-deductive model and the knowledge-driven model (Cholowski and Chan 1995). There is also an additional remark on understanding the principles and rules that are specific to the learning of problem-solving skills in a nursing specialty. The metaparadigm and related nursing models can serve as a pre-practice state for guiding the novices within a discipline. Students can use nursing models as a stimulus in practice and pursue to discover the theory (the 'knowing that') underlying their practice (the 'knowing how').

_Teaching of Problem-Solving Skills_

Readings from the literature about professional problem-solving showed that there is substantial variability in the effectiveness of problem-solving; such problem-solving behaviors tended to be problem-dependent. The nature of the problem itself was seen as a crucial factor for successful problem-solving (Elstein et al. 1990). Issues of problem specificity and the elaboration of generalized problem-solving models were also perceived as important. From what was discussed so far, it seemed that unsuccessful practitioner lacked the knowledge of the process of identifying and matching the concepts and principles relevant to the specific patient context. Failure to
recognize the closely linked problem-solving skills and the patient problem context disabled nurses in solving the patient problems in clinical situations. Thus, one cannot introduce relevant concepts or principles that are detached from its context and simply expect nursing students to use ‘knowledge’ to solve the problem. It is important that the context of the patient problem and the nursing knowledge in understanding the patients’ problem are related. ‘Knowledge’ and ‘context’ must be structured and developed into a meaningful conception in solving patient problems.

2.3.7 Knowledge, Experience and Problem-solving

Deback and Mentkowski (1986) pointed out that education promotes a broad range of abilities more than experience does. The impact of education appeared to be independent from the impact of practical experience, albeit the fact that this relative independence is merely a result of the experiential nature of nursing education. Yet, most nursing researchers examining the problem-solving process and the knowledge acquisition of nurses found disagreement about the knowledge base required and how it was being applied by nurses in problem-solving process (Corcoran-Perry and Graves 1989). Could it be that teachers normalized knowledge as the concepts crucial to a specific domain, thereby assuming that teaching of concepts could lead to an understanding of the patient’s situations? Although the nurse faculty constantly affirms with its nursing students the role of inquiry for discovery of clinical wisdom, what exactly is the ‘knowledge’
required to problem solve in nursing? Does the understanding of a patient's situation refer to the problem-solving process itself or the skills in applying this problem-solving process? Or is it the knowledge content referred to in specific nursing and health care related concepts? Nurse faculty has to find out what is the key content before they can actually teach and promote problem-solving skills.

Researches in problem-solving have consistently indicated that skill development should relate to the problem-solving knowledge of the particular domain, as well as the flexibility in applying that knowledge content in the context of domain-specific problem (Chi, Glaser and Fraser 1988). The notion that skilled reasoning depends on a well organized but flexible knowledge base is the underlying principle of domain-specific knowledge application in problem-solving (Feltovich 1983). But in current teaching situations, most teachers tend to use one model of care, yet still expect performance of care by the students in a totally different mode. Clinical skills and abilities needed by nurses are mostly defined by nursing faculty based on knowledge, experience, expectations and, to a certain extent, perceived reality of nursing.

According to Barrows and Bernet (1972), using this teaching approach does not encourage the learning of problem-solving skills. They stressed that learning of the patient problem is not possible from reading
textbooks. They also recommended that the use of a 'graded problems in a dysfunctional system' can help students appreciate the genesis of the problem because they are working backward from the problem into an understanding of knowledge and its alternative factors. And such aim is only likely to be achieved through problem-based learning, where students are first exposed to the clinical problem and its features before the relevant knowledge and its significance are introduced to the presenting problem context (Barrows and Tamblyn 1980; Schmidt 1983; Biley and Smith 1998a).

The distinction between the classically topic-oriented education and the inquiry, dynamic problem-solving approach is more prominent in education. In a problem-based learning approach, students are put in a context resembling that of a real situation in which their knowledge will be applied (Schmidt 1983). With the problem-solving approach, representations are revealed from a broad to a graded series of problem, and an integration of the students’ knowledge in approaching the solutions of these problems is actually taking place.

Indeed, nursing experience has its role in association with some professional competencies. Nurses with a baccalaureate degree demonstrated more nursing competencies as compared with their associate degree or diploma colleagues (McKenna 1971; Deback and Mentkowski 1986). Thus, the next step forward for nurse education is to conduct studies on the
performance of effective nurses in order to support expert judgment in the selection of abilities to be taught in the curricula. Instruments on assessing problem-solving competencies and examining the extent to which students demonstrate and learn also need to be developed.

2.3.8 Future Development of Problem-solving in Nursing Profession

There is an increasing argument that measurements of the complex nature of problem-solving skills demand a variety of assessment techniques to be used (Groen and Patel 1985a; Ramsden et al. 1989; Ridderikhoff 1991). Most of the studies attempting to evaluate the problem-solving abilities failed to examine the nurses' thinking processes and the outcomes concerning the solutions to the identified problems. For example, an earlier study done by Hamdi and Hutelmyer (1970) on the use of a structured assessment guide to develop the nurses' abilities in identifying the nursing care problems only highlighted the experimental group's inability to generate significantly higher number of reasons to support the process of problem identification. They did not explore the nurses' solution to the patient problems in particular. Thus, there is no doubt that the studies incorporating systematic evaluation of both the process and outcome of the specific intervention to achieve problem-solving abilities still remain limited in nursing field (Roberts et al. 1993). The nature of problem-solving in nursing is not yet well researched, and neither is the problem-solving skill development clearly defined.
More questions can be raised about the aims of learning problem-solving in nursing. Why are students disinterested in learning problem assessment skills? Could it be that the teaching interventions only focus on the teaching of the 'solution' rather than the 'problem-solving skills'? Or could it be that nurses are able to make a 'solution' yet fail to provide more explanations to the processes where the problem-solving is made? Such approach, as in many nurse education systems elsewhere, has been consistent with the emphasis of the 'banking' concept of education (Burnard and Chapman 1991) where the 'replication' (French 1992) of the students attracts more recognition. It is obvious that measures will need to be developed and taken to address the issues entailed in teaching problem-solving among nurses. The mode of educator-researcher will have to be adopted (Hammersley 1993) if evidence-based practice is perceived as a requirement basic to the existing nurse education system (Stevens and Cassidy 1999).

2.4 Learning Problem-solving in Nursing

Cholowski and Chan (1995) asserted that the teaching of clinical reasoning in nursing education uses approaches that are grounded on two problem-solving models identified in nursing studies. These models are the hypothetico-deductive model and the knowledge-driven model. Assumptions from the studies of the problem-solving process were made that hypothetico-deductive model is an effective method in helping novices develop successful problem-solving skills. It was valued as the reasoning process model used by junior
health care students (Elstein et al. 1990). Due to insufficient evidence, skepticism prevailed as to whether this method is the most reliable method in developing competent nurses on solving patients’ problem in practice. On the other hand, tributes were also given to the knowledge-driven model in enhancing nurses’ problem-solving behavior. But because of the vagueness in the description of the relationship between the knowledge base and the problem-solving process framework, this model also failed to guide the application of knowledge during the actual problem-solving process.

The reiteration of the disappointing results from the two models caused nurses’ attention to seek for alternative instructional strategies appropriate for problem-solving development. The study of Mitchell and Atwood (1975), aimed at the teaching of problem-oriented charting to junior nursing students, found that experimental group identified more patient problems in the clinical charting. However, no significant difference was found between the groups in the number of patient problems identified as a whole. A few other studies also examined the effectiveness of the different teaching methods on improving clinical judgment among the baccalaureate nursing students (de Tornyay 1968a, 1968b; Mitchell and Atwood 1975; Tanner 1982). An experimental teaching strategy was used to improve nursing students’ skills in the discovery of concepts and principles relevant to patient management problem (PMP) (de Tornyay 1968a, 1968b). Again, the result of the study indicated that the teaching intervention did not yield any significant
changes to the students' performance. Tanner (1982) also designed an experimental teaching package to develop the diagnostic reasoning of the nurses, with the belief that diagnostic hypothesis is central to reasoning. The development of the teaching materials mainly focused on the facilitation of the activation of a diagnostic hypothesis. While the video-taped situations were given to the participants, they were asked to verbalize their responses in hypothesis making. Unfortunately, the experimental teaching also did not yield significantly better performance among the two groups of subjects.

In summary, the failure of identifying common intervention to improve the problem-solving skills of nurses may be the result of different factors. The experimental teaching of problem-solving usually takes a short period of time, as what Tanner (1982) highlighted in her research report, whereas in real situation it is longer. Since clinical nursing problem is usually complex, the development of instruction aiming at the skill development of problem-solving applicable in real practice requires more time and effort within the stage of curriculum planning. Enormous empirical evidence also showed that the problem-solving skills are not to be taught in its discrete parts. The results reporting unsuccessful problem solvers in medical problem-solving studies also demonstrated that the teaching of problem identification or hypothesis generation alone does not guarantee the success of nurses in solving real patient problems.
It was described from previous sections that identification of nursing problems does not equate with problem-solving in real practice. Teaching of problem-solving skill that centers on data collection and problem identification from the problem task has no implication on the ability of problem-solving amongst nurses. Some part or some strategies of the problem-solving process is not adequately covered by the teaching strategies used. So what can be taught to improve students' problem-solving? And how should it be taught? The overriding variable affecting success in problem-solving appeared to be practice, thus increased clinical experience was believed to enhance the capacity of nurses' understanding of the clinical phenomena. Representations and the knowledge base of the individual were also found to be important for developing skills of problem identification and hypothesis generation.

In meeting the needs of a variety of patient conditions, the knowledge in examining the complexity of varying nursing situations is useful for nurses to associate the underlying factors and the specific characteristics of the different patient concerns in clinical settings. Although the knowledge content in a specific domain of nursing is crucial in a problem-solving process, there is still an urge for nurse faculty to identify the 'knowledge' that is necessary in the context of the domain-specific problems. It could be possible that the knowledge and skills are only learnt during the actual process of problem-solving.
Thus, skill development is to be alongside with the mission orientation of the nursing profession, and must be built upon the growing experience of nurses in real practice. If nursing students are expected to learn to solve clinical problems, it is essential for them to have the knowledge of the philosophical and methodological underpinnings of problem-solving models in nursing. And since learning in nursing is practice-driven, a testable model of nursing problem-solving in practice serving as a blueprint for learning how to solve clinical problems is necessary. For the nurse education to prepare nursing professionals for the next decade and beyond, the issue of matching theoretical input with clinical practice demands urgent action and redesigning. Until such problems are addressed and overcome through nursing research, the search for the suitable method in developing problem-solving skills at the curriculum level is far from over.

2.4.1 *Nurse Education within Higher Education*

Over the past decades, educational theories and philosophies influenced nurse education. In light of the rapid changes in technology and health care demands (NHS 1985; WHO 1989), nursing degree courses have become the object of scrutiny by most relevant Nursing Board. For example, National League of Nursing in United States, English, Welsh or Scottish National Board in United Kingdom, Hong Kong Nursing Board in Hong
Kong. These Nursing Boards have responsibilities on ensuring the proper level of competence required in practice.

There is now an urge to move nursing education towards baccalaureate level. The claim of moving nursing courses to a higher education level has an assumption that the university-based nursing programs can help nurses achieve the identified outcome competence in client care. This assumption has an impact on the patterns of teaching and learning in nursing. In fact, most literature has shown that the aim of the professional education in nursing curricula is a major determinant of the nursing graduates' competence in practice. Numerous researchers also acknowledged that the major issues of student learning in the nursing curriculum are the educational aims, the content of the curriculum design, the teaching methods and the student assessment.

This section discussed the role of the conceptions of teaching and learning affecting the curriculum design in nursing education, and the efforts of evaluating a curriculum in response to the notion that theory development is grounded in its practice. Examination of these theories and concepts provided some explanations to the nursing students' learning in the existing baccalaureate nursing curriculum, hence giving directions for curriculum revision. The impact of curriculum evaluation in nurse education was also considered. Moreover, the issue of 'how to learn' the problem-solving skills central to nursing practice was addressed. Likewise, the development of
problem-solving skills, focusing on the evaluation of nursing students' learning outcomes and examining how students learn in the existing nursing curriculum, was also pursued.

2.4.1.1 What and How do Nursing Students Learn Nursing?

When novices start learning nursing, the first thing they always wanted to do is know what nursing is all about. Nurse teachers literally describe this action as nursing care, although it is clear that this statement does not fully explain what nursing is all about. Nurse educators are also aware that what was described only represents part of the nursing reality. Nursing care is strongly affected by the definitions of nursing (Hancock 2000), hence the content of nursing ideologies and definitions should be included as part of the content in nursing education programs. The content that is included in the nursing curriculum has a role of explicating the type of nursing services required in the profession. This simply implies that the contents taught to the nurses in the nursing profession actually inform what nursing is.

Nursing and Nursing Ideology

If nursing practice is affected by the definitions of nursing, as what was described in the literature (Roberts 1985; Hancock 2000), then nurse educators have a job of determining the best practice for students to learn amidst the various nursing definitions and ideologies described in professional
nursing practice. In fact, these definitions of nursing are based upon different theoretical and philosophical underpinnings in viewing the human beings and professional nursing services, basically with nursing operationalized within a medical bio-psycho-social model (Sarkis and Skoner 1987). Since the past decade, nursing has been affected by new values and beliefs of human service (Monti and Tingen 1999). There were suggestions from a number of research studies that nursing should take up a more holistic model in dealing with the different aspects of human needs (Cmich 1984; Watson 1985; Valentine 1988; Torres 1990; Hancock 2000) and the different nursing practices (Holden 1991). Such model of care should emphasize on the teaching of nurses, where nurses are expected to interact with the 'wholes' of the person (Torres 1990) and to define a person as an interrelated and multidimensional whole (Fawcett 1989; Newman 1992; Nicoll 1997).

Nursing education has to prepare students to give competent and holistic nursing care to clients (Hospital Authority 1995). In this respect, nurse teachers have to be aware of the crossroads for nurse learners who have different views towards the ideologies of human care. The prior experience of the nursing students should also be taken into account when the philosophy of nursing is to be introduced as a base for professional development. This problem is subtle for nurse educators who are accustomed to the traditional nursing curriculum model, wherein a wide range of subjects known to be relevant to the current demands in nursing is available.
However, since learning in nursing is not confined to classroom settings and since the clinical components are crucial in professional education (Dietrich 1976), if learning in nursing is for practice then ‘what is to be learnt’ is crucial to future nursing practice. Indeed, now is the time to reflect and question the professional role in actual nursing practice. Most of the criticisms only focus on what is learnt in nursing programs, which may not be fully explained how the knowledge is applicable in actual practice. Little is known about the effect of the curriculum content to real nursing practice (Wong 1979; Clark 1982; Hunt 1984; Cook 1991; McCaugherty 1991; Kim 1993; Rolfe 1993; Rafferty, Allcock and Lathlean 1996).

*What is the Nursing Role?*

The nursing roles in many patient care settings are still clearly undefined, albeit the new values and beliefs of human service likely to promote new nursing roles in real practice. Despite knowing that a patient with physical illness is also affected spiritually, psychologically and sociologically (Selanders 1995), the central focus of nursing care in a variety of settings is still physical care. Ferguson (1984) observed that nurses treat patients as a mere medical model; performing procedures and tasks have become a more essential and prominent aspects of nursing rather than thinking, reflecting and problem-solving (Jacobs-Kramer and Huether 1988; Meleis 1991). Thus, the higher level nursing skills are not easily developed. Indeed, the choice of model for nursing care depended on the interpretations
of the nursing ideologies and the nature of the health setting offers (Jordan and Reid 1997).

Although holistic care was said to be the essence of contemporary nursing (Campbell and Jackson 1992; Purdy 1994; Coulon, Mok, Krause and Anderson 1996), students still practice the conventional way, described by French (1992, p. 630) as “uncritical replicators of existing nursing practice”. Nurse training has been founded on the apprenticeship system, where the student nurses occupied a dual role of learner and employee (Joyce 1999). Such phenomenon characterized the common model of clinical learning among nursing students. With the role delineation of the nursing students and health care assistants being fairly blurred, nursing students were always seen as the person to offer basic care requiring general nursing skills (Jacobs-Kramer and Huether 1988; Meleis 1991). They were also seen being of low status (Melia 1987). This was particularly true when nursing students are generally seen as the helpers to perform basic care and to alleviate part of the current manpower tension in many acute care settings. Although the learning of knowledge is absolute, it is still very hazardous for novices, who have been called to seek approvals from qualified nurses, to make independent clinical reasoning and to decide on the type of nursing care to provide.

If problem-solving is a core skill for nurses, then there is a need for understanding how nurses use knowledge and skills to solve patient problems. Professional nurses must seek to uncover the nature of successful problem-
solving abilities in different specialty areas. There is also an increasing emphasis to liberate students from didactic teaching and learning strategies and shift towards fostering a spirit of knowledge inquiry in nurse education and in nurse practice (Carper 1978; Benner 1983). Although research of problem-solving is still in its stage of infancy, evidence of studies conducted in this domain in recent decades is dramatically increasing, particularly with the personal concerns and experiences of the students in learning nursing.

2.4.1.2 The Role of Nurse Faculty in Nurse Education

In many acute care settings where treatment highly depends on sophisticated medical technology, the physiological and safety needs of the patient are first met before the other needs identified in Maslow's hierarchy (1954) are considered. The notion of task completion seems to override the safety nursing principles (Jenner 1998). For instance, since sick patients are more likely to seek for measures of relieving pain and sufferings, nurses will often offer strategies to alleviate physiological problems (McGrath 1998; Fletcher 1999). Such demand undermines the holistic model of care required in many acute care settings. In fact, holistic care is not regarded as the principle in practice. As a result, there is a growing consensus on the need to update health professionals in ensuring patient safety (Waddell 1991; Francke, Garssen and Huijer Abu-saad 1995; Hogston 1995; Nolan, Owens and Nolan 1995; Sheperd 1995; Zalumas 1995).
Nurse educators are usually seen as the formal agents who structure, provide and teach all necessary materials in the pre-registration programs where new nurses are prepared to become professional nurses. Being nurse educators, they are required to explore better ways of teaching novices in professional education. What are the health care needs of the clients? What are the expected qualities of nurses to meet the needs of the clients in current health care settings? For instance, the nurse educators should emphasize that the provision of physical care is only one of the major concern amongst other responsibilities. They should also raise the awareness of the novices on the increased risks of patients afflicted by a disease process or condition, a struggle always faced by new nurses between the completion of the task and the provision of holistic care. In fact, junior nursing students are commonly required to provide basic nursing care to the clients in acute hospital units where they are placed to practice. Although nursing students are prepared to provide competent and holistic care to the clients (Hospital Authority 1995), different levels of needs are still demanded from diversified and increasingly complex health care settings. Indeed, the term ‘competence’ in nursing depends much on the demands specific to the characteristics of different clients in different nursing settings.

2.4.1.3 New Knowledge Required for New Practice

Several studies implicated that learning of certain knowledge through the use of guided practice develops better nursing care. It was also reported
that the theoretical underpinning of nursing practice in providing physical care is composed of the biological sciences (Akinsanya 1987a and 1987b; Jordan and Reid 1997). The scope and depth of understanding the biological sciences can provide nurses the ability to identify and handle the basic needs before being asked to serve the higher levels of needs of their patients. For instance, an understanding of the underlying physiological activities of the patient's illness based on the knowledge of biological principles is required for making reasoned judgments and safe practice in clinical nursing (Corcoran-Perry et al. 1999; Fletcher 1999). As its application relates much to the physical care of the patients, ensuring safe care of the patients is also important. In fact, very little space is left for error.

From what was discussed above, knowledge of biological sciences has a potential impact on influencing the provision of basic patient care, and on the daily problem-solving practice arising from varying patient situations in clinical settings. There is also a strong link between basic science knowledge and the ability of collecting and interpreting clinical data during the process of clinical problem-solving (Balla et al. 1990). Such claims are indicative that students' learning depends significantly on the understanding of the role of knowledge in real practice.

Knowledge relevant for daily patient care, however, does not necessarily ensure that nursing competence in practice is evolving. A review
of the nursing literature indicated that the pre-registration nursing education failed to provide nursing students with sufficient background knowledge to understand the physiological phenomena they encounter at the clinical setting. The levels of biological science taught were found inadequate for practice (Akinsanya 1987a; Leonard and Jowett 1990; Courtenay 1991). In addition, the role of knowledge for nurses in practice is not only associated with the provision of physical care and patient safety. In spite of sustaining patients' safety and basic nursing care, nurses also have to work collaboratively with patients in meeting their needs to lead to recovery (Marchione and Garland 1997). It is noted that the kind of knowledge to be acquired as well as the problem-solving abilities of the nurses is vital to the quality of practice. A closer look to daily nursing routines shows that nurses use their knowledge in caring for their clients at different stages of the disease processes. To obviate the possible role expansion, and in recognition of the fact that patient acuity is increasing in most hospital care settings, the quality of nursing care should be safeguarded by properly preparing nursing students in the development of the knowledge-driven problem-solving skills.

2.4.2 Problem-solving and Nursing Curriculum

In a formal education system, teaching materials and teaching approaches are identified and selected by the teachers concerned (Tyler 1949; Bevis 1988; Burnard and Chapman, 1990). When one thinks of the effect of this model to teaching and learning, the definition and the function of the
curriculum are not to be ignored. The strengths of the specific curriculum
must be examined in line with existing educational paradigms (Chavasse
1994).

2.4.2.1 Existing Nursing Curriculum

In past decades, education in nursing was viewed as 'as a process of
changing the behavior patterns of people' - using behavior in the broad sense
to include thinking and feeling as well as overt action (Tyler 1949, p.5). In
fact, education involved changes of thought, affects and action. It was not
until recently when general education philosophies impacted on nurse
education that education was seen as a mean of communication (Jarvis 1983,
Rogers 1969). Many nursing curricula aims have been influenced by this new
perspective set out from a distinct definition of education. Burnard and
Chapman (1991) saw teaching and learning as a 'problem-solving' concept of
education. Learning was said to be occurring when the facilitators and the
learners met together and exchanged ideas, and experienced through
constructive argument and discussion. Such construct suggested that there are
still rooms for 'multiple realities' within the teaching and learning arena
(Marton 1981; Ramsden 1988). The nature of the teacher-student relationship
has changed; it also helps to shift learning as a personal responsibility (Biley
and Smith 1998b; Slevin and Lavery 1991).

Biggs (1999) also defined a curriculum as a structural framework
within which the curricular activities and assessment are targeted, and the
teaching methods chosen are likely to realize those educational objectives. In light of this definition, curriculum is therefore not only a consideration of the course aims, but should also align with the students' learning outcomes as 'the level of understanding' that lie on top of the teaching strategies and student evaluation methods is adopted. The goal of education is reflected through the content of the curriculum. The merits of the learning outcomes should deserve greater attention from people involved in curriculum building of professional studies or those who are responsible for the instructions.

2.4.2.2 Current Practice Demands and New Curriculum Design

It is recognized that the curriculum content should respond to the needs of the rapid social change and scientific discovery (Arthur and Baumann 1996). In line with the changing needs of human service, nursing has to cherish a philosophy that nurses can offer the best care to the patients (Hospital Authority 1995). The professionalism of the nursing discipline must distance away from the medical model and role of doctor's handmaiden (Skeet 1978; Fawcett 1989; Lister 1991; Keogh 1997). Instead, the concepts of andragogy, humanism and reflection should become the key components in the nursing curriculum (Reed and Proctor 1993). To maintain the status quo of the role of nursing students in the current environment would mean a cessation of the quality assurance in patient care. New nursing philosophy focusing holistic care with the demands of psycho-social nursing care requires nurses to rest on the knowledge of behavioral sciences at the expense of
biological sciences (Trnobranski 1996). With the recognition of the emphasis of behavioral sciences in basic patient care, some of the bio-medical science subjects (e.g. physiology, pathology and microbiology) included in the curriculum had to be condensed to make rooms for the new areas of knowledge as observed by Margaret (1995).

In majority of the clinical settings, nurses need to care for the complex problems of patients in different manners. In most cases, they are required to solve problems with different disease conditions or related to their responses to illness (Fletcher 1999). Previous discussions of the literature have assumed that nursing students do need to acquire the knowledge and skills relevant in their pursuit of solving complex problem-solving in many clinical care units. There is no doubt that nurse educators must ensure that nursing students learn the relevant domain-specific knowledge and demonstrate its application in practice. This also demands curriculum planners to be sensitive enough to bring in content knowledge in order to address the issues emerging in real practice. They also need to be aware of the new demands of the changing role of nurses to professional education, especially in terms of the knowledge domains required in practice (Urden 1989). However, there is always a struggle for nurse educators to judge the most effective way of educational preparation of nurses, particularly when there is a lack of criteria and evaluative materials. At times, there are also
some limitations on the inability to define the reality of nursing practice (Bottoroff and D'Cruz 1985; Bevis and Clayton 1988).

Clearly, the understanding of the role of knowledge in problem-solving skill learning calls on for revealing the form of knowledge conceived by nursing students. The relevancy of the knowledge to nursing requires no verification from the authorities but the person who is actually involved in the problem-solving context. Knowledge, from this sense is no more absolute and certain, since it is context-dependent during problem-solving (Elstein et al. 1990). Emphasis is on the qualitatively different ways knowledge and skills are learnt and applied to process the clinical data in problem-solving (Thomson 1987; Le Var 1988). Although ample researches have been carried out on nursing students at the baccalaureate level, no systematic research of undergraduate nursing courses in evaluating the extent to which nurse education integrated with higher education modifies patient care (Herbener and Waston 1992) has yet been undertaken.

So how could nursing students differentiate what is essential to the learning of nursing, and how do they know when to use the knowledge fundamental to nursing practice? From this perspective, nurse educators need to reflect on the following questions: ‘Who is responsible for selecting content relevant to professional nursing in the generic nursing curriculum, and what are the criteria for the selection of knowledge and skills relevant to
the professional practice? 'What are the benefits gained by nurses from the instructional strategy within the formal educational programs?' 'How do nursing students apply what they had learnt to become competent practitioners who have sound knowledge base, are self-reliant and have critical ability to solve patients' problems?' (Winson 1993)

These questions drew the nurse educators' attention on their accountability and responsibility to stakeholders in assuring the relevance of the design of nursing curriculum to nursing practice (UKCC 1986; Cowman 1996), and to their desire of achieving similar academic development as other professionals (Barnett, Becher and Cork 1987; Gould 1999). Nurse educators are demanded to make most effort in helping students understand the role of the relevant knowledge whilst taking charge of their own learning and application of knowledge into practice (Mountford 1996). The aim is to introduce and permeate this concept among the nurse faculty in the existing nurse education system.

2.4.2.3 *New Nursing Requires New Conceptions of Teaching and Learning*

Nurse education is seen as a means of enhancing professionalism (Keogh 1997). However, some nurse scholars pointed out that the transition of nurse education into higher education has failed to ensure the benefits of patients. In particular, the challenge has been directed towards the variation in biological science education among different nursing programs (Leonard and
Jowett 1990; Wharrad et al. 1994). If biological science has a significant role to safe practice and problem solving in nursing (Margaret 1995; Jordan 1997), then the foundation nursing programs offered in the higher education institutions must be characterized with strong emphasis on biological sciences. This does not only enhance the understanding of clinical nursing but is also directly applicable and beneficial to patients (Jordan 1997). Commentary towards the deficit of the baccalaureate nursing curriculum also focused on the content and the instructional strategy, and suspected that the undesirable outcomes of problem-solving learning were likely due to the chosen content and the teaching methods that limited the students' understanding of the patient representations.

With the recognition of the emphasis of behavioral sciences in patient care, students entering tertiary education need to be guided on 'how to study' and 'how to learn' if they were to deal with many separate subject areas where deep learning is required (Thornton 1997). One cannot deny the fact that in nursing learning, the practice discipline has always focused on the knowledge of learning through 'doing', with experience having its place in knowledge development in nursing (Urden 1989). However, how knowledge is gained and developed at the classroom level has been ignored and left unrecognized. Thus, research is needed into the evaluation of both the content and quality of nursing curricula, especially in relation to the roles to the nursing practice.
Although investigating the relationship between the precise biological knowledge to patient care outcomes is a difficult and challenging task, the need of evaluating the curriculum in relation to the future requirements of the health care service is still crucial (Ben-Zur et al. 1999; Montague 1981). Nurse faculty should also reflect on their responsibilities in optimizing the students' learning of the practice-based knowledge. They need to develop instructions that will facilitate students' integration of a wide range of subject content parallel to the study of nursing, consequently leading to the understanding of what nursing is all about.

2.5 Curriculum Evaluation

Recently, there has been a call for curriculum reform in nursing, and its impact should not be undervalued. The disparity in teaching and learning conception among teachers and students, and the goals of nurse education in relation to the new nursing, are some of the common topics appearing in current nurse education researches. The little attempt to explore whether the existing professional education curriculum serves to produce competencies required in real practice was another important issue. In fact, students' inability to apply or transfer the content knowledge to their practice was seen as a consequence of the curriculum that failed to provide them a chance to transfer their knowledge base or to adopt the cognitive skills involved in making transitions across contexts.
In order to facilitate better integration of knowledge, nurse faculty has started to examine the students' view of learning, which differs from that of being taught. The call has made nurse educators become aware of the effects of educational philosophy to the knowledge and skill learning among nursing students. They have also started working for remedy, especially with the evaluation of nursing competence at the curriculum level, hoping to identify the flaws in the curriculum design and search for a more valid and reliable curriculum for professional education in nursing.

2.5.1 Teaching and Learning: Approaches and Outcomes

Biggs (1992) proclaimed that the learning approaches could be influenced by personal inspiration and teaching approaches whereby different levels of cognitive outcomes are encouraged. This is further supported by the claim that effective teaching puts students in situations where they are facilitated and commended to develop more complex conceptions of learning and practice the use of deep, holistic learning approaches (Ramsden 1988). On contrary, poor teaching and inappropriate assessment result in a surface approach where students use inappropriate and low-order learning activities (Biggs 1999). Thus, it can be inferred that the nursing students' learning approaches of problem-solving could represent his or her overall learning within the nursing curriculum.
Teaching method is designed to generate or elicit desired student outcomes in achieving the cognitive and behavioral objectives laid down in the curriculum. Although there is sometimes a mismatch between the teaching method and the learning approaches, this can be modified by either changing the forms of learning they are pursuing or by changing the level of understanding that the practice required. For example, a change in the teaching method or student assessment may affect students' motivation and eventually lead them to modify their learning approaches. Within the curriculum, teaching methods and student assessment are integrative complex factors influencing the approaches of learning among students (Biggs 1999). Processes of assessment or evaluation can provide a signal to students about the kind of learning they are expected to attain. It also reveals the accomplishment of the educational goals or objectives as well as the level of competence of individual students required in the professional education. Since students attempt to choose strategies that will apparently maximize their academic performance, assessment should by no means be isolated from what is learnt or from the ends learning is meant to accomplish (Ramsden 1988).

Despite the notion that assessment method is considered good if it promotes teaching and learning (Ramsden 1988), there is still some suspicion that creativity and deep learning orientations of the students are inhibited by the traditional assessment method adopted in a curriculum. An inappropriate
assessment method could limit the students from adopting the kind of learning approach that leads to better understanding and unique application. This method of student assessment only reinforces the reproduction of knowledge and focuses on memorization (Bowers 1993). Hence, it is crucial that representations of teaching-learning activities and student assessment in the curriculum should be derived from various educational theories and committed to the different levels of student outcomes. Teachers promoting student-centered learning should be aware that reinforcing the students of the processes leading to the achievement of the outcome (the learning process) is as valuable as the outcomes itself (the learning outcomes).

2.5.2 Curriculum Design and Curriculum Evaluation

Nurse educators in the curriculum planning area should know the aim of nursing curriculum. Curriculum design for the academic preparation of nurses should be based on the premise of professional education; it should not only be directed to academic advancement but also to the fulfillment of the professional mission to the whole community. In the more recent work in general education, Alvin Toffler (1970, p. 363) made a strong allegation to curriculum planners who knew very little of the impact of a curriculum, "...nothing should be included in a required curriculum unless it can be strongly justified in terms of the future." Such claim prompted the curriculum planners to design professional education programs. The key of curriculum evaluation concerned largely on the quality of learning reflected by the
learning processes and the levels of conceptual understanding to the contents that are central to the professional practice.

2.5.3 A Legacy of Curriculum Evaluation

The issue of curriculum evaluation always concerns with the improvement of teaching for nurses in relation to patient outcomes. Unfortunately, most of the evaluation of nursing programs has been limited only to the level of nurses' academic growth, without researching on the effectiveness of the program in terms of patient outcomes (Herbener and Watson 1992). In fact, there were allegations that education evaluation makes very little reference to the impact of education on the professional performance. As a consequence, professional educators were constantly affirming and reaffirming that the teaching of knowledge in the nursing curriculum was relevant to practice and pertinent to direct patient care (Ormerod 1993).

In this chapter, literature has showed that the expanding nursing role and the changing nursing programs on nurses' delivery of patient care were also found to be crucial. While struggling within the common issues in education, nursing curriculum planners were able to justify that the inclusion of subjects from a wide variety of health-related disciplines were able to provide nurses with the basic professional competence.
However, the debate of curriculum content and the relevancy to nursing practice continued to be challenged and the notion of teaching 'context' that describes nursing to be in question. This could be partly accounted to the complications of the discrepancy in teaching and learning conceptions. Other reasons provided were the lack of specific criteria on the level of appropriateness of teaching methods being adopted and the absence of a required level of knowledge and content needed for practice. The absence of guidelines from the statutory bodies for professional curricula building and the equivocal role delineation demarcated in existing nurse practice were also some of the contributing factors (Jordan 1993; Pearson and Clarke 1994; Wharrad et al. 1994).

A relatively untapped area in nursing, insights drawn from previous studies are scarce. In fact, only the views of general educationalists are used to explain part of students' learning experience in nursing. In this study, it is anticipated that by means of examining how the nursing students conceptualize the content, more knowledge about the ways the students understand the content (biological science concepts) and the context (respiratory nursing phenomenon) in which it is presented will be generated. The significance of the learning approaches of the Chinese nursing students in the local territory and its impact to learning problem-solving will also be considered. Despite certain limitations, this study still contributes to the curriculum debate in nurse education. And considering the teaching and learning background in the
current nursing education scene, insights for a model of problem-solving curriculum that suits Chinese nursing students in the Hong Kong setting will eventually be adopted.

2.5.4 *Curriculum Reform in Nursing Education*

The re-structuring of nursing education paradigm fitted well with the innovative mechanisms brought in from the arena of general education. Emphasis has now shifted from a teacher-centered approach to a student-centered approach. The curriculum has also changed from a content-based to a process-based focus (Ramsden 1988; Cowman 1998). Not only were the ability of nurses to fulfil new nursing roles developed (Ben-Zur et al. 1999), insights that professional education should aim at preparing nurse students deal with complex and ambiguous aspects of nursing settings in future health care system were also achieved (Oermann 1994; Walton 1996). These new demands from nurses and the changes of educational philosophy paved way for curricular reform, both at the content and at the process levels (Booth 1995; Hegge 1995; Larson 1995; Ben-Zur et al. 1999).

2.6 **Conclusions**

Researches have shown that nurses' problem-solving skills are variable in any clinical setting (de Tornyay 1968a, 1968b; Sherman et al. 1979; Hurst et al. 1991). A number of influential documents have stipulated this concern in professional education (Hospital Authority 1995; King's Fund Centre 1990;
Australian Nursing Federation 1989; Bramwell 1992; International Council of Nurses 1989; Royal College of Nursing 1990; Registered Nurses Association of British Columbia 1992). Reports also showed the need of developing a valid and reliable tool for measuring and evaluating the problem-solving abilities in nursing, particularly when there is a deficiency in developing problem-solving abilities. If nurses were to meet the challenges of the ever-changing health care demands, then the development of problem-solving skills should be the emphasis of the nursing programs. However, still very little nurse education studies center on the development of problem-solving skills in the Hong Kong context. It is because of the lack of empirical findings in this area that the current study was conducted. Extending from previous work of problem-solving studies in nursing, this study used empirical approaches including representative cases focusing on the examination of the problem-solving processes, the related strategies, and the knowledge base adopted by the novice nursing students when they embarked on the problem-solving task. It is anticipated that the findings of this study can serve as a framework for designing a curriculum that promotes nursing problem-solving abilities.
Chapter 3

BIOLOGICAL SCIENCE TEACHING IN
AN UNDERGRADUATE NURSING CURRICULUM

3.1 Introduction

Biological science courses have always been associated with heaviest workloads in nurse education. In fact, students generally perceived the courses as difficult (Akinsanya 1987a; Race and Holloway 1992; Chapple, Allock and Wharrad 1993; Pearson and Clarke 1994). And with the pre-registration education being upgraded to tertiary education, the approach of taking a wide range of parallel study of many other health sciences subjects even posed further problems. It seems that the burden of studying a variety of subjects was the main cause of students’ learning difficulties, although other factors that inevitably affect students’ learning experience might also come into play. Perhaps by means of examining possible presentations of subject matter, the learning difficulty student encounters in their foundation nursing programmes can be realized.

Could it be possible that cognitive gains of biological courses are not translated into enhanced patient care as what teachers might have expected? There are a limited number of empirical studies examining the relationship between biological sciences and nurses’ educational outcomes. Results have
indicated that different interests of teachers and students actually affected their views of the relevancy of the subject content to the nursing practice. Recent research and students' own experiences on the role of biological sciences in nursing curriculum were also somewhat ambiguous. The disparity of the teaching of biological science knowledge to nursing practice and the possible learning outcomes is recognized throughout this chapter.

This chapter is divided into two parts. In the first part, the author discusses common approaches used to teach biological sciences courses in nursing curricula. In the second part, a brief biological science content on the topic of respiratory regulation of acid-base balance is reviewed. This topic acts as evidence to the problematic areas faced by a teacher teaching this subject. The approach and the context where this knowledge is presented will be the focus of discussion when improvement of learning is concerned.

3.2 Can Students Learn How to Relate Biological Sciences to Nursing?

3.2.1 Shifting Focus of Health in Nursing Curriculum

The 'decompartmentalization' of nursing knowledge is an inherent problem to students' learning in the traditional nursing curriculum. Most of the biological sciences content is given in a form of decontextualized biological parts adjoining an understanding of the human body functions. By focusing on health, and not at the same time exposing them to illness and
relevant human responses, the nursing program actually diminishes students' integration of knowledge and inadvertently constructs a barrier to learning (Knowles 1990). Starting from a primary health concern, many teachers interpreted it as an injunction to teach Anatomy and Physiology. This subject matter is usually learned by the students in their first year of pre-registration nursing program, without associating this knowledge to theories of disease process. In fact, pathology and related theories about abnormal body function are not explored until the stage when the concepts of 'disease' become central to the nursing program.

The problem with teaching biological sciences related only to 'health' is that students often have difficulty in relating biological science-based theory to their clinical experience. Students perceive biological science subjects as discrete parts prior to the learning of a body of knowledge central to nursing service. Thus, in recent years, a new conceptual evolution focusing on the perspective of health within illness is starting to emerge in nursing curriculum. While health has been identified as one of the key paradigms in nursing (Fawcett 1984), the new concept of 'health to illness continuum' in generic nursing curriculum now focuses teachers on the teaching of 'health' rather than 'illness'.
3.2.2 Lacking of Structure and Coherence in Nursing Curriculum

The nursing literature revealed that there was no clear definition of the extent to which biological knowledge is required to ensure a client’s safety (Wilson 1975; Akinsanya and Hayward 1980; Montague 1982; Akinsanya 1987a). The biological knowledge was found to be ‘ill-defined’, and the knowledge application in nursing ‘unstructured and haphazard’ (Wilson 1975). There was no clear distinction given to the breadth, level and depth of biological knowledge required for safe nursing practice (Wilson 1975; Akinsanya and Hayward 1980; Montague 1982; Akinsanya 1987a; Courtenay 1991; Chapple et al. 1993). This was also explicitly or implicitly supported by subsequent research studies on the evaluation of undergraduate nursing programs (Courtenay 1991; Chapple et al. 1993).

3.2.3 Teaching Strategies in Nursing Curriculum

Nursing education in tertiary education is characterized by multi-professional input. However, the increasing costs of university education and decreasing budget on teaching resources led teachers to the option of giving lectures to a large number of students. Lecture is known to be a teacher-centered activity that allows mainly didactic teaching. Lecture is also considered to be a teaching method that limits students’ deep thinking (Harvey and Vaughan 1990; Schmeck 1988). This means that students receive factual information layer upon layer, which they describe as not correlating to the nursing context where it supposedly should function. Hence, the
accumulated fact is not readily accessible and utilized as a tool to interpret the phenomenon in practical settings. As always true, students express concerns on their inability to relate the biological knowledge learnt from mass lectures to a nursing context.

In order to improve learning, universities and colleges introduced general learning skills on their orientation programs. However, doubts were raised on the value of this attempt to improve student learning, especially when no evidence to consider how students think about specific content within particular contexts was given. Neither the teaching of 'pure' biological sciences nor general study skills helped students improve their learning in terms of understanding the subject matters within a specific discipline. Thus, it was not surprising to find some students making every effort to adapt their learning approaches to the assessment demands to make their academic life easier.

The 'pure biological' model taught in a university-based nursing program is often 'bio-mechanistic' oriented. Illustration of the abnormalities in human bodies is often given at a cellular level. As a result, some students begin to dread bio-science learning (Nicoll and Butler 1996) instead of appreciating the possible human responses due to such bio-mechanistic changes. If educators do not contemplate to remedy the situation, more and more students will face great difficulty in studying biological sciences. An
examination of the relationship between the students, the learning and teaching, and the subject content itself may be necessary to uncover the loopholes while students embark on the learning tasks. It will also provide teachers with information on how to encourage the changes expected from the students, as well as trigger conceptual changes among students by providing better instructions of content delivery.

3.3 Review of the Subject Content of "the Regulation of the Acid-Base Balance in Normal Respiratory Physiology"

To shed some light on the analysis of the baccalaureate nursing students' conceptualizations, a description of the biological science knowledge in the area of 'respiratory regulation of acid-base balance' is presented. Both the nursing role and the application of scientific knowledge to real life settings are explored. Implications of the theoretical understanding of the content in nursing care contexts are also examined.

3.3.1 Key Concepts and Principles Relevant to the Topic of Acid-Base Balance Regulation

It is important to ascertain the extent to which students think the biological content relates to their understanding of the topic of acid-base regulation. Detailed readings of current textbooks and recent journal articles for health professionals and nurses were conducted to delineate concepts related to this topic. The relevance of the contents university-based nursing
students comprehend and their ability in applying their knowledge to problem-solving tasks were also determined. As a result, a number of key concepts and rules of the biological science was generated (Table 3.1). They were summarized in three parts, the clinical component, the pure science component and the compensatory component. These concepts represented essential information which was used as the basis for the students' understanding of the topic of 'acid-base balance regulation', the reasons why this subject content should be included in a nursing education curriculum, and the concepts that appear in their conceptualizations.
Table 3.1: Key Concepts and Rules of Biological Sciences Relevant to Acid-Base Balance Regulation

<table>
<thead>
<tr>
<th>Concepts about ABG</th>
<th>Textbook 1</th>
<th>Textbook 2</th>
<th>Textbook 3</th>
<th>Textbook 4</th>
<th>Textbook 5</th>
<th>Journal 1</th>
<th>Journal 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Acid-base measurement and overall body function</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Definition of pH measurement</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Definition of acid and base</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Rule of acid-base balance</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Rule of body metabolism and acid-base status</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Definition of ABG measurement</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. ABG components and normal ranges</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td>8. Clinical significance of ABG test</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>9. ABG and oxygenation assessment</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>10. Definition of acid-base imbalances</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Types of acid-base disorders</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Causes of acid-base disorders</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Compensation mechanisms for abnormal acid-base status</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td>14. Roles of buffer systems</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Levels of compensation</td>
<td>✓</td>
<td></td>
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</tr>
</tbody>
</table>

- Textbook 2: Hudak et al. (1997)
3.3.2 Assessment of Acid-Base Measurement

The concept of fostering adaptation in nursing is comparable to the ultimate health care goal aimed at restoring the state of well-being of a person (World Health Organization 1985). Nursing contributes significantly to the care of patients with various health problems by performing quick, accurate assessment and prompt interventions. Nursing assessment provides a framework for nurses to detect rapid changes in the patients’ condition and the identification of possible risks to their health.

Knowledge of how the lungs regulate acid-base balance is an important basis for assessing patients with abnormal lung functions. To provide supporting information for the study, an assessment of acid-base measurement will be presented. Blood gases test that can help nurses determine the patient’s status of oxygenation and the acid-base balance will be discussed. It is crucial that nurses know this information because once severe acid-base disturbances occur, dysfunctional regulatory mechanisms underlying many pulmonary diseases can cause of death of a patient.

3.3.2.1 Measurement of Acid-Base Parameters

The core responsibility of an acute care nurse is the problem-solving ability based on sound reasoning and characterized by integration of the body of knowledge from biological, behavioral and nursing sciences (Hudak, Gallo and Benz 1997). Nurses need to build a foundation in order to render rational
decisions and make immediate responses to clinical cues. In human care, nurses have to appreciate the fact that human body has physiological and psychological mechanisms that compensate for the lack of equilibrium. They also need to know that in some situations, the human body cannot adapt to the outside environment. This is particularly important when respiratory patients are being cared for in acute hospital settings. Their roles also become crucial when patients' adaptation and coping mechanisms require assistance (Hudak et al. 1997).

Nurses play an advocacy role for their clients, and are responsible for helping them conserve their energy and maintain equilibrium. But how does the normal human body remain in homeostasis? A principle containing a list of concepts and rules borrowed from the biological science context showed that the respiratory regulation of acid-base balance is a key principle governing the overall acid-base balance in human body (Black and Matassarin-Jacobs 1993). This principle is fundamental knowledge required from a nurse because it helps them appreciate the dynamics of acid-base regulation from time to time, and from patient to patient. Knowledge of normal physiology and pathophysiology of the patients presenting abnormal conditions also prepare nurses to anticipate possible events in clinical settings (Hudak et al. 1997). Thus in the following sections, the role of acid-base state and its relationship to the overall body function are presented.
Every human body has a remarkable ability to maintain plasma pH within normal range. Acid-base status reflected by the pH value depends on the balance that is built between carbon dioxide (an acid) and blood bicarbonate (a base). An acid is any substance that carries and can donate a hydrogen ion (H+), while a base is a substance that can accept or combine with H+. For the purpose of this study, the term base and alkali are used interchangeably. In a normal situation, the balance between acids and bases in the blood stream is 20 parts base to 1 part acid. This is the key principle that governs all regulatory process of acid-base balance inside the human body. The 1:20 ratio (ratio of acid and base) also indicates that the body bases and acids are in perfect balance (McCance and Huether 1998; Hudak et al. 1997; Holt 1986; Metheny 1996; Horne and Derrico 1999; Tasota and Wesmiller 1994).

When the pH value remains normal, the body function and related bodily activities are in equilibrium. If the amount of acid increases or the amount of base decreases, the ratio of 20:1 ratio is disrupted and results to more acids (lowering of pH, i.e. acidosis). If the amount of acid decreases or the amount of base increases, it results to more bases (rising of pH, i.e. alkalosis). After cellular metabolisms, the majority of the metabolic wastes (e.g. CO₂ and H+) are removed via lungs and kidneys (Metheny 1996; Horne and Derrico 1999; Tasota and Wesmiller 1994). Figure 3.1 shows the cellular activities and forms of metabolic wastes.
The Acid-Base Parameters

When caring for clients who encounter unstable acid-base conditions in acute health care settings, it is crucial for nurses to remember the acid-base ratio which is the prime rule controlling the acid-base balance processes. In a normal situation, human body will remain in homeostasis through a series of internal compensatory mechanisms in order to balance the concentration of acids and bases. The best way to evaluate acid-base homeostasis is by measuring arterial blood gases (ABG). ABG test is a measurement that reflects the arterial oxygenation status of a patient. Using ABG test, nurses can then draw conclusions regarding the state of tissue oxygenation of individuals (Best and Taylor 1967). In order to make interpretations from ABG result, knowledge of the ABG profile and its normal values is essential (Holt 1986). The components and the normal values of ABG are listed (Holt 1986; Tasota and Wesmiller 1994; Hudak et al. 1997).

1. pH: pH value measures the acidity or alkalinity of the body fluid. This value is the negative logarithm of the hydrogen ion concentration.
As the hydrogen ion concentration increases, the pH drops (more acid present); as the hydrogen ion concentration decreases, the pH rises (less acid present). Normally the pH value of arterial blood is 7.40 with a normal clinical range of 7.30-7.50. It is also worthwhile to note that there is variation of normal blood gas and acid-base values among individuals who are still within the level of equilibrium.

(2) \( \text{PaCO}_2 \): This is a value obtained by a direct measurement of dissolved carbon dioxide in the blood plasma. \( \text{PaCO}_2 \), expressed in millimeters of mercury (mmHg), is the partial pressure of carbon dioxide in the arterial blood. It reports the ventilatory status of a person. This value also reflects the respiratory component of acid-base balance. Normally this value is 40 mmHg, with a clinical range of 30-50 mmHg. It is important to note that the values of \( \text{PaCO}_2 \) and \( \text{HCO}_3^- \) have a negative correlation in the Henderson-Hasselbach equation (Bourke and Brewis 1998).

(3) \( \text{HCO}_3^- \): Bicarbonate (\( \text{HCO}_3^- \)) is formed by the breakdown of carbonic acid (\( \text{H}_2\text{CO}_3 \)) in the red blood cells and the renal tubular cells in kidneys. It migrates out of the blood and renal tubular cells into the plasma to combine with various cations (or the basic ions). This function is one of the major roles of kidneys in acid-base balance;
the value reflects the metabolic component of acid-base balance.

The normal bicarbonate concentration in arterial blood is 24 mEq/liter with a range of 22-28 mEq/liter.

Three variables, hydrogen (H\(^+\)), carbon dioxide (PCO\(_2\)), and bicarbonate (HCO\(_3\))\(_{\text{r}}\), are principally involved in the acid-base balance of the body area (Taylor 1967). All these three factors are directly related to each other (according to the Henderson-Hasselbalch equation \([H^{+}]\alpha PCO_{2}/[HCO_{3}]\)) (Bourke & Brewis 1998).

(4) **BE:** Base excess (BE) value reflects the non-respiratory portion of acid-base balance. It reflects an increase or a decrease in the total amount of base present to buffer body acids. The measurement is reported as either a base excess (+ve) or base deficit (-ve). The result depends on the metabolic alkalosis or acidosis that exists. The normal BE is 0 with a clinical range of ±2 mEq/liter of acid or base. It is also evident that a close relationship exists between the value of HCO\(_3\)\(_{\text{r}}\) and BE.

(5) **PaO\(_2\):** This is a value of the partial oxygen pressure in the arterial blood plasma. PaO\(_2\) is determined by the person's ability to oxygenate the blood. Hence, the level of alveolar PO\(_2\) varies with alveolar ventilation. Measurement of arterial PO\(_2\) (PaO\(_2\)) is profoundly
affected by regional changes in ventilation/perfusion ratios, such as in terms of body temperature, hemoglobin numbers, hemoglobin saturation etc. The normal reading is 80-100 mmHg. A saturated oxygen (SaO2) measurement only provides a cross-reference for the accuracy of PaO2 (Hudak et al. 1997, p. 309).

(6) SaO2 (oxygen saturation): ABG report usually goes with an oxygen saturation (SaO2) result. SaO2 is expressed as a percentage of the total capacity for hemoglobin to carry oxygen. The PaO2 that the hemoglobin is exposed to is the major factor that determines the amount of oxygen. The close relationship between the amount of oxygen that hemoglobin is carrying and PaO2 can be illustrated by the oxyhemoglobin dissociation curve (Hudak et al. 1997). Arterial saturation has a close correlation with the saturation obtained from the pulse oximeter only if the arterial saturation is above 70% (Black and Matassarin-Jacobs 1993, p. 933).

In summary, the acid-base balance is based primarily on two measured parameters, pH and PaCO2, and secondarily, on the derived parameters of: bicarbonate (HCO3-) and base excess (BE). The normal arterial blood gas values (Hudak et al. 1997; Tasota and Wesmiller 1994) are also presented in Figure 3.2.
Figure 3.2: Normal Arterial Blood Gas Values

<table>
<thead>
<tr>
<th>Normal Parameters</th>
<th>Normal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.40</td>
</tr>
<tr>
<td>Normal range:</td>
<td>7.35-7.45</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>40 mmHg</td>
</tr>
<tr>
<td>Normal range:</td>
<td>35-45 mmHg</td>
</tr>
<tr>
<td>PaO₂</td>
<td>100 mmHg</td>
</tr>
<tr>
<td>Normal range:</td>
<td>80-100 mmHg</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>24 mEq/liter</td>
</tr>
<tr>
<td>Normal range:</td>
<td>22-26 mEq/liter</td>
</tr>
<tr>
<td>BE</td>
<td>0</td>
</tr>
<tr>
<td>Normal range:</td>
<td>±2</td>
</tr>
<tr>
<td>SaO₂</td>
<td>100%</td>
</tr>
<tr>
<td>Normal range:</td>
<td>98-100%</td>
</tr>
</tbody>
</table>

Clinical Significance of Acid-Base Measurement

Nurses are often required to handle particular individuals who are in a state of homeostatic disturbances, especially when they have signs of acid-base interference. They need to understand the role of arterial blood gases before differentiating the causes of the patients’ health problem. Most of the time, they have to delineate the underlying problems of the individual as reflected by the ABG values. Hence, it is vital that they have some knowledge about the clinical significance of each ABG parameter in making interpretations of clinical signs and laboratory results. This knowledge contributes significantly to their assessment, especially when a baseline necessary for the early recognition of various conditions detrimental to patients is used. The interpretation of the results can help indicate the ventilatory state, hypoxemic state and tissue oxygenation of the patient. It also enables nurses to carry out accurate assessments of further changes, plan and implement appropriate
interventions, and respond and anticipate immediate prescriptions and orders from doctors.

The values of the ABG parameters where major acid-base disturbances can be recognized are examined subsequently (McCance and Huether 1998; Hudak et al. 1997; Holt 1986; Metheny 1996; Horne and Derrico 1999; Tasota and Wesmiller 1994).

(1) $pH$: pH value is always presumed as the first indicator for acid-base disturbances. Acidemia means the pH value in the blood is <7.35, whereas Alkalemia means the pH value in the blood is >7.45. For individuals to survive, one has to keep a pH value of 7 or above.

(2) $PaCO_2$: This parameter reflects the ventilatory state of a person. A $PaCO_2$ value between 30-50 mmHg indicates ventilation within normal limits; this is kept normal by the central chemoreceptors on the surface of medulla in the brain. A high $PaCO_2$ (>45 mmHg) is called hypoventilation, ventilatory failure or hypercapnia whereas a low $PaCO_2$ (<35 mmHg) is called hyperventilation or hypocapnia. A carbon dioxide increases (due to hypoventilation), the blood pH drops (become acidemic).
(3) $HCO_3^-$ (Bicarbonate): When PaCO$_2$ is normal, decreased bicarbonate ($<22$ mEq/liter) results in acidemia. Increased bicarbonate ($>26$ mEq/liter) when the PaCO$_2$ is normal results in alkalemia.

(4) BE (Base Excess): This value refers directly to the amount of bicarbonate and/or the other bases in the blood. Non-respiratory processes influence bicarbonate and base excess.

(5) PaO$_2$: This value reflects the hypoxemic state of the person. The lung is the key organ functioning for the oxygenation and ventilation of the body. Several situations exist when PaO$_2$ is less than the normal limits (90 mmHg). Normal newborn and elderly aged beyond 60 years have a value range lower than the normal limit. This reading of PaO$_2$ is an indicator of the individual's oxygenation status. For example, PaO$_2$ of less than 80 mmHg is termed mild hypoxemia; PaO$_2$ of less than 60 mmHg is termed moderate hypoxemia whereas PaO$_2$ of less than 40 mmHg is called severe hypoxemia.

(6) $SaO_2$ (Hemoglobin Saturation): As the amount of hemoglobin decreases, the amount of oxygen carried by the hemoglobin decreases. Normal values for oxygen saturation in arterial blood is greater than 95%.
Understanding the ABG Parameters and Acid-Base Status

Acid-base balance refers to how the human body deals with the substances of acid and base (Hudak et al. 1997; Metheny 1996). Therefore, nurses should first learn how the body maintains a balance of acid and base concentrations. Since all body cells are responsible for metabolizing energy production, it is vital that nurses realized the maintenance of the various body functions and the results of the metabolic waste products and disposal (Metheny 1996; Horne and Derrico 1999; Tasota and Wesmiller 1994). And since normal body mechanisms that regulate acid and base amounts are produced by cellular metabolisms (see Figure 3.1), nurses should also be aware of the mechanisms in producing these concentrations inside the body.

The first step of the mechanism is the conversion of foods by body tissues to water (H₂O) and carbon dioxide (CO₂). Most of the carbon dioxide (CO₂) activities are done at cellular levels. When the CO₂ pressure in the cells goes beyond 40 mmHg (which is the normal arterial value of CO₂), CO₂ flows into the plasma. In the plasma, it can combine with water (H₂O) to form carbonic acid (H₂CO₃). The amount of dissolved CO₂ gas in the plasma is usually 800 times more than that in the cells (Hudak et al. 1997, p. 319), thus the 20:1 ratio is impaired, resulting to acid-base imbalance. If the carbonic acid (H₂CO₃) dissociates into hydrogen ion (H⁺) and bicarbonate (HCO₃⁻), most of the hydrogen ions form a loose association with the buffer in the plasma (i.e. plasma proteins), thus reducing the number of free hydrogen ions
produced. By converting to a form of hydrogen ion (H\(^{+}\)), carbon dioxide (CO\(_2\)) are subsequently removed from the body. Through the conversion of carbon dioxide to carbonic acid (H\(_2\)CO\(_3\)), which dissociates to hydrogen ions and bicarbonate (HCO\(_3^{-}\) + H\(^{+}\)), the hydrogen ions are excreted by urine through the kidneys (in form of ammonium, NH\(_4^{+}\)). However, the amount of hydrogen ions removed from this pathway is less than 1% (Metheny 1996, p. 159). Majority of the metabolic wastes and carbon dioxide are removed through the lungs.

From the acid-base compensatory mechanisms described above, it is clear that acid-base imbalances can cause life threatening situations within hours or days (Hudak et al. 1997; Metheny 1996; Tasota and Wesmiller 1994). This situation can be real in a person with serious renal disease. In fact, it will just take a few minutes for individuals with breathing difficulty to develop a fatal acid-base imbalance measurement. Thus, a good understanding of the ABG parameters and acid-base status can help frontline nurses understand the acid-base balancing act. In this sense, monitoring of the acid-base status can inform nurses about the risks underlying an individual’s health problems.

3.3.2.2 Implications to Clinical Interpretations

There is no doubt that the major determinant governing acid-base homeostatic state is the 1:20 body acids and bases ratio (i.e. 1 part of carbonic acid CO\(_2\) to 20 parts of bicarbonate HCO\(_3^{-}\)). The amount of acids and bases
inside the body is important in maintaining the ratio of acid-base and thus affecting the pH value. However, the acid-base status is not the only cause of the pH value. If this ratio is disturbed, the pH value changes. In fact, the changes of pH value can take some times in this situation. ABG topics in most nursing literatures often propose a 'quick-step' process for the interpretation of an ABG result in terms of acid-to-base balance variation (Tasota and Wesmiller 1994; Metheny 1996; Holt 1986). The process tends to just inspect the numerical figures of the ABG profile in determining the existence (or non-existence) of acid-base disturbances. pH, HCO₃⁻, and PCO₂ variables are assumed as the determinants of an acid-base state, and it is believed that by evaluating the values of this composition, nurses can tell whether the individuals present acid-base disorders or not. However, nurses fail to recognize and describe the underlying physiological or pathophysiological mechanisms before they give accounts to the alterations of values of ABG parameters. This knowledge is vital for nurses to initiate the problem-solving process and develop their clinical interpretations.

In reviewing the common errors of nurses in evaluating acid-base measurement results, the reporting of the CO₂ content is often the most confusing. The ABG measure usually includes electrolyte determinations (Metheny 1996), and items of 'PaCO₂' shown on a laboratory form is actually an index measuring the sum of bicarbonate and dissolved CO₂ gas. In light of the normal acid-base ratio within the human body, CO₂ content primarily
reflects the concentration of bicarbonate (HCO₃⁻). The ‘CO₂’ value is also largely an indirect measurement of the non-respiratory (or metabolic) component in the context of acid-base balance. Thus, quick ABG interpretation methods emphasize the evaluation of the values of HCO₃⁻, and PCO₂ in relation to pH.

The value of PaCO₂ is a reliable monitoring index in specifying the ventilatory state that primarily leads to the outcome of oxygenation condition (McCance and Huether 1998; Holt 1986). The term PaCO₂ and CO₂ actually refers to the gas form of carbon dioxide in two different contexts. It is important to clarify whether these technical terms refer to the gas in the arterial blood (PaCO₂) or the total CO₂ content within the alveoli. Instead of introducing the term ‘CO₂’, individuals pursuing the interpretation of an acid-base measurement report have to be familiar with the definition of the specific terms and the context in which these terms are used. For example, PaCO₂ (partial pressure of carbon dioxide) denotes the carbon dioxide concentration in the arterial blood. CO₂, on the other hand, shows the carbon dioxide gas content (the CO₂ gas content) at the alveolar level. PaO₂ is a sign of the oxygen concentration in the arterial blood (partial pressure of oxygen); whereas O₂ represents the oxygen gas content (the O₂ gas content) in the alveoli.
An ABG measure can be an index of both the acid-base and oxygenation conditions (Hudak et al. 1997; Metheny 1996; Horne and Derrico 1999; Tasota and Wesmiller 1994). However, the inclusion of the O₂ content in the reporting can be a brainteaser to many nurses. Although the value of PaO₂ appears on an ABG laboratory form, the evaluation of the ABG result seldom involves this value. Interpretation of PaO₂ value is often isolated from the findings of other ABG parameters, even though this value can help nurses assess the person’s hypoxemic state. For instance, any increase in the PaO₂ can lead to carbon dioxide narcosis, a possible deadly condition (Holt 1986). Small elevations of PaO₂ can also stimulate the respiratory center to increase breathing (Black and Matassarin-Jacobs 1993). In fact, in chronic airway diseases, the PaO₂ level is relatively low. This is because the large amount of PaCO₂ reduces the amount of ventilation by reducing all brain functions, hence causing damage to the respiratory center. With a decreased sensitivity to carbon dioxide, breathing largely depends on a hypoxic drive.

In chronic airway disease, the content of carbon dioxide acts as a hypoxic drive to breathing control apparatus in the medulla. Therefore, nurses must know how to maintain PaO₂ at a level lower than the normal. They should also be familiar with the function of oxygen therapy, and must realize that reasonable oxygen concentration (until the PaCO₂ is raised to 60 mmHg) is beneficial to the patient’s oxygenation because it does not reduce ventilation (Hudak et al. 1997, p. 317). The mutual relationship between the ventilatory
state and oxygenation and the acid-base balance is also a basic knowledge for all nurses to acquire when they embark on any clinical ABG interpretations.

It is evident from the preceding discussions that cellular metabolisms in the body and the role of the lungs to remove metabolic wastes are constant. In fact, compensatory mechanisms in acid-base balance do not separate from the normal lung functions. In evaluating an acid-base condition from an ABG profile, the reporting of respiratory component (carbon dioxide, PaCO₂) is important in understanding the measures of the non-respiratory component (bicarbonate, HCO₃⁻) with respect to the rule of ‘acid-base 1:20 ratio’. When PaCO₂ value is assumed as the respiratory components of a primarily ventilatory acid-base status, the value of the PaCO₂ (which mutually depends on the value of PaO₂) in some way reflects the oxygenation condition. Removal of dissolved CO₂ gas is another important criterion for identifying the condition of ventilation and the amount of PaCO₂ in the blood of a person. These two measurements, in addition with other parameters in an ABG profile, certainly reflect the acid-base status and its regulation. Therefore, the PaCO₂ and PaO₂ parameters also form an index to guide the detection of abnormal acid-base changes.

In a normal situation, ventilation refers to the gas flow inside the air passages. Any interference with the normal ventilatory function of the lungs will lead to inadequate oxygen saturation, resulting to diminished tissue
oxygenation (Hudak et al. 1997). In general, if the PaCO₂ is high, the lungs are not functioning well within the ventilation process (hypoventilation). If the PaCO₂ is low, the lungs are having excessive ventilation (hyperventilation). Perfusion, on the other hand, refers to gas diffusion governed by the pressure gradients among the gases within the alveolar and arterial levels. If there is an increased PaCO₂ in the blood, then PaO₂ will decrease. As a result, the dissolved O₂ content flows from the arteries to the cellular level diminish. The lessened oxygen content subsequently affects the normal cellular metabolism and the regulation of acid-base balance in the body.

ABG test entails information about the oxygenation status of a person. According to Holt (1986), the arterial O₂ content (PaO₂) partly depends on the lung function in supplying oxygen to the blood and the hemoglobin oxygen saturation level on the oxyhemoglobin dissociative curve. Just a PaO₂ value alone cannot tell the reasons why oxygen level is increased or decreased in the blood. Thus, in assessing the oxygenation state, nurses have to know the transportation and saturation of O₂ and CO₂ gases as well as the cardiac functions of the person. Knowledge on the role of pulmonary ventilation and perfusion, the pressure gradient of PaO₂ and PaCO₂, and the total gas content at the cellular and arterial levels are fundamental for all clinical nurses. With this knowledge, they are able to detect whether there is acid-base disturbance or not. They can also discern whether the causes are due to respiratory or non-respiratory (metabolic) components (Hudak et al. 1997,
p. 308). Conditions of the systemic circulation, which largely depends on the cardiac output, are also supplementary data that clinical nurses can utilize to know the determinants of acid-base states and real tissue oxygenation (Hudak et al. 1997).

3.3.3 Evaluation of the Acid-Base Disorders

After defining the terms and episodes related to the normal acid-base balance regulating process, this section describes acid-base imbalances and the different types of acid-base disorders. The definition of acid-base imbalances depends on the pH value; pH value of < 7.30 is called acidosis while pH value > 7.50 is alkalosis. The primary cause of acid-base imbalances is related to the respiratory and non-respiratory parameters (Hudak et al. 1997). There are two types of acid-base imbalances, namely, respiratory acid-base disorder (respiratory acidosis and respiratory alkalosis) and the metabolic acid-base disorder (metabolic acidosis and metabolic alkalosis). Understanding the different types and underlying mechanisms of acid-base disturbances can greatly assist nurses in assessing the problem embedded within the interaction of acid-base disturbances and regulating acts.

3.3.3.1 Knowing the Definitions and Causes of Acid-Base Imbalances

The primary causes of disturbances in the two types of acid-base disorders - respiratory acidosis and alkalosis, and metabolic (non-respiratory) acidosis and alkalosis - are either the amount of the bicarbonate or the carbon
dioxide concentration in the blood. This knowledge is also basic when nurses undertake interpretations of acid-base abnormalities in clinical settings. Respiratory acid-base imbalance is caused by abnormal ventilation. There are two abnormal conditions associated with abnormalities in PaCO₂ level. Each one of them will be dealt with separately.

*Respiratory acidosis.* This means high arterial PCO₂ level caused by hypoventilation (hypercapnia or high PaCO₂). Most of the causes are related to the ventilatory aspects of lung function, e.g. obstructive lung disease, depression of respiratory center, neuromuscular disorders, hypoventilation with mechanical ventilator, and other factors that limit the lung expansion such as chest wall deformities, injuries and pain (Hudak et al. 1997, p. 319). If the respiratory center is depressed, respiratory acidosis will also exist in normal lungs. This knowledge informs us of the role of maintaining normal pulmonary function in promoting acid-base balance regulation.

*Respiratory alkalosis.* This means low arterial PCO₂ level caused by hyperventilation (hypocapnia or low PCO₂). Causes of respiratory alkalosis are mostly related to heart and lung diseases, thus leading to insufficient oxygenation. The oxygenation problem may be caused by the following reasons: alveolar hypoventilation, diffusion defect, right-to-left shunt, mismatching of ventilation and blood flow in the lungs (Hudak et al. 1997, p. 316). Diseases like pulmonary emboli, pulmonary fibrosis, hyperventilation
with mechanical respirator, asthma, pneumonia, severe anemia, brain damage, congestive heart failure, anxiety, septicemia, fever pregnancy, hepatic insufficiency and salicylate poisoning all explain why the arterial blood is not carrying the normal amount of oxygen (Hudak et al. 1997, p. 319).

With the two types of respiratory acid-base imbalance, it should be noted that even when the hypoxia is corrected, respiratory alkalosis (hyperventilation) still continues (Hudak et al. 1997), an indication that there are multiple causes for hypoxic state across the listed diseases. For example, when impaired hemoglobin oxygen-carrying capacity and poor cardiac output occurs, the development of hypoxic situations becomes apparent. Subsequently, the body has to get rid of a great amount of volatile excretion products brought forth by such hypoxic result. In all these conditions of hemoglobin impairment, cardiac output and ventilation to the whole acid-base balancing process, nursing assessment should always focus on the monitoring and observations of these circumstances.

Metabolic processes other than respiratory causes can also affect the acid-base status of a person (McCance and Huether 1998; Horne and Derrico 1999). Metabolic acid-base imbalance is caused by abnormal metabolic rate, resulting in an abnormal amount of H+ concentrations from metabolic acids or excessive loss of salts (HCO₃⁻). When a non-respiratory process leads to a result of acid accumulations or bicarbonate loss, the bicarbonate values drop
below normal range, making the base excess values negative. On the other hand, when a non-respiratory process leads to a result of acid loss and excessive bicarbonate accumulations, the bicarbonate values rise above normal range, rendering the base excess values positive. In such case, base excess becomes an indicator of excessive amount of bases and bicarbonate.

There are two abnormal conditions associated with the abnormalities in excess of bases or bicarbonate concentration. Both are presented in the following section.

*Metabolic acidosis.* This means increased production of acids. The causes of metabolic acidosis (of non-respiratory factor) are basically due to an increased accumulation of anions (e.g. \( \text{HCO}_3^- \) and \( \text{Cl}^- \)) like phosphate, sulfate and creatinine found in renal failure, and a decrease of bicarbonate anions. It could also be an accumulation of lactic acid (lactic acidosis) or excessive ketoacids that result in diabetic ketoacidosis, alcoholic ketoacidosis, poisoning of salicylates and methyl alcohol (Hudak *et al.* 1997, p. 322). Other conditions are associated with a high level of serum chloride, mostly found in people with diarrhea, excessive drainage of pancreatic juice, ureter-sigmoidostomy, obstructed ileal conduit, renal tubular acidosis, intravenous hyperalimentation, and over-use of acetazolamide (Diamox) and ammonium chloride (Hudak *et al.* 1997, p. 322).
People with the above listed problems tend to accumulate abnormal amount of acidic substances in blood and react with the usual amount of bicarbonate, thus resulting to a reduced level of bicarbonate and base excess. Nonetheless, there are also conditions of a lack of bicarbonate (low HCO₃⁻), thus leaving a great amount of acids in the body. For example, when a person is exhausted after excessive physical exercise, the body tissues do not have enough oxygen. The body is unable to metabolize lactic acid accumulated in the blood. As a result, the lactic acid combines with the normal amount of bicarbonate, thus leaving a low base excess. Respiratory distress and failure is another classic example of lactic acidosis caused by severe hypoxemia (Hudak et al. 1997). If there is tissue hypoxia, lactate production due to incomplete metabolisms in the body cells will occur. If the same principle applies, a person who has breathing difficulty for a period of time will also result in increased lactic acids. Nurses must therefore be aware of the possibility of lactic acidosis among people whose acid-base status changes rapidly within a short period of time.

Metabolic alkalosis. This means a state of excessive loss of salts (acidic in nature), leading to increased bicarbonate (high HCO₃⁻) and base excess. The increase of alkali are caused by the loss of acidic fluid (from vomiting and naso-gastric suctioning), rapid correction of chronic hypercapnia with accumulation of excessive bicarbonate (high HCO₃⁻), treatment with diuretics, corticosteroids, excessive administration of alkali substances, Cushing's
disease and severe potassium depletion (Hudak et al. 1997, p. 320). It is common that excessive infusion of alkaline substance will cause short-lived alkalemia, although it does not associate with elevated bicarbonate values at all. Apart from monitoring the overall acid-base status of the ABG profile through reading the pH value, the reading of the HCO\textsubscript{3} is also critical for the assessment of people who develop these health problems.

### 3.3.3.2 Meaning of Compensation and Correction in the Acid-Base Balance Context

After knowing the many factors that affect the acid-base status in various situations, the body mechanisms required in resolving such problems are presented. There are two ways that the acid-base circumstances can be reverted back to normal. The first approach is by compensation using buffer systems. During the compensation process, the body automatically initiates the buffer system that starts the mechanism for returning the pH value to its normal limit. As the pH value does not completely return to its normal limit, such information should be brought towards nurses' awareness since it allows them to decide the primary cause and the compensating process when examining an ABG profile (Hudak et al. 1997, p. 325).

There are three types of buffer systems in the body: buffers in blood (Hemoglobin, plasma proteins, free HCO\textsubscript{3}), respiratory buffer (CO\textsubscript{2}), and renal buffer (HCO\textsubscript{3}). The goal of the buffers, the most essential elements of the compensation process, is mainly to return the pH value to its normal limit.
If there is respiratory acidosis (high CO₂), the kidneys will compensate the acid-base disturbances, according to the acid-base ratio 1:20, by retaining bicarbonate (HCO₃⁻). However, compensation can only take place when the body system is of normal physiological function. In fact, the results from the compensation process differ according to the severity of the health problems underlying the acid-base status (Methney 1996, p. 167).

Any change in values of an ABG profile is indicative of either an improvement or deterioration of the primary cause from the affected system, even when the pH value or the acid-base ratio is well beyond normal limits. As in many situations of acid-base disorders, the compensatory process can bring the pH values back to normal. An abnormal acid-base ratio (an acid-base ratio greater or less than 1:20) with pH value beyond normal is a definite uncompensated acid-base imbalance. If the value reflected is almost returning to normal, this implies a partial compensation is taking place. If the pH value returns to normal, then it means there is complete compensation. For example, when pulmonary function is impaired, the kidneys will stand by and start the compensatory process anytime. If there is respiratory acidosis (high CO₂) due to inflammation, the lung function is improved by providing antibiotic therapy, administration of bronchodilators and vigorous bronchial hygiene. This lowers PaCO₂ and returns the pH values towards normal. In most acid-base disorders, treatment of the underlying cause is an alternative way to put the pH value to almost near the normal limit, but the
compensation process is not equivalent to the correction of the underlying problem.

It is important that health professionals attempt to initiate actions that involve interventions for correcting abnormality rather than just helping the person compensate within the body. In fact, nurses can do more to aid in the compensatory process. For example, nursing strategies to relieve breathing difficulties are no longer treated as a nursing routine. Instead, these measures are considered significant nursing actions in promoting the compensation process. In light of the different effects of compensation and correction to acid-base imbalances, clinical nurses should look into the meaning of correction and compensation in relation to the acid-base regulatory process.

In both compensation and correction, the human body has to make extra efforts to maintain a normal pH through various body mechanisms. Correction involves addressing the primary problem that causes the acid-base disturbances, whereas compensation attempts to resume the acid-base balance to homeostasis by maintaining pH balance. Correction aims to resume the impaired function of the affected system. It is therefore helpful for nurses to know that there is no over-compensation for solving acid-base problems in a body, although there is over-correction for replacing normal regulation process. Corrective interventions for such patients tend to aggravate the compensation by leading to homeostasis and creating a possible new problem.
For instance, if a respiratory acidosis patient was compensated by the renal buffer system, and the order of mechanical ventilation is applied to correct the problem, the patient will have the outcome of an increased pH above normal limit. This exemplifies the unexpected outcomes of the over-correction to acid-base imbalances.

In respiratory acidosis, the elevation of carbon dioxide (high PaCO₂) attracts compensation through metabolic process. Compensation takes place while the kidneys excrete more acids and less bicarbonate, a try to return the pH value towards normal. Even after compensation, the body does not fully compensate the respiratory acidosis in maintaining a low level of PaO₂ as a hypoxic drive. In respiratory alkalosis, low PaCO₂ is compensated through metabolic process of the kidneys. By excreting bicarbonate (HCO₃⁻), the amount of acid to base is returned to the ratio of 1:20. These compensatory processes usually take a few days to complete.

In metabolic acidosis the major characteristic is low HCO₃⁻ or negative base excess. The ketoacids produced through abnormal metabolic process will react with the bicarbonate (HCO₃⁻), leaving a low bicarbonate level. Compensation takes place by hyperventilation, thus lowering the PaCO₂ level and adjusting the ratio of acid-base (PaCO₂ to HCO₃⁻) towards 1:20. This compensation occurs in the lungs, is quick and only takes few hours. Metabolic alkalosis is characterized by a high bicarbonate (high HCO₃⁻). Body
compensation works by means of hypoventilation of the respiratory system, raising PaCO$_2$ to a level of 50-60 mmHg before other hypoxic stimuli to prevent further hypoventilation take over (Hudak et al. 1997, p. 324). The compensation process usually involves an increase or decrease in the amount of PaCO$_2$ or HCO$_3^−$. There are possibilities that these two substances will be in high level, yet the two abnormal values will balance each other, thus bringing it back to normal pH values. The hypoventilation process that regulates the acid-base disturbance occurs over several hours.

3.3.3.3 Relationship of Measurement of Acid-Base Parameters and Evaluation of Acid-Base Disturbances

In the previous sections, it was clear that the four types of acid-base disorders were basically developed upon the interference of the 20:1 base-to-acid ratio. Once this ratio is disrupted, alterations of acid-base status occur. It is also a fact that the compensatory process triggered by the lungs to a non-respiratory acid-base imbalance situation usually takes a few hours to complete. Meanwhile, the compensatory process activated by the kidneys often takes a few days to bring back the situation to normal. These are all essential pieces of information for nurses to know and realize should such disturbances occur. Since the respiratory system reacts to the compensation process from few minutes to several hours, specific nursing care in relieving breathing problem is necessary. Nurses also need to know that the compensatory mechanisms to the acid-base disorders are complemented by
accurate treatment. Since medical treatment is not the only way to help regulate the imbalance, nurses have a very significant role in facilitating compensatory process when a situation of acid-base disturbance occur.

3.3.3.4 Implications for Nursing Assessment

In today’s hospital settings, patients are more likely to develop acute and serious health conditions, which tend to vary due to the disease processes. In fact, many patients’ diseases and conditions have acid-base disturbances as the underlying factor. Categorizing or recognizing pure types of acid-base disturbances as a basis for appropriate nursing actions had proven difficult for nurses. On one hand, they have to get hold of the information regarding the types and causes of different acid-base disorders. On the other hand, they have to address focused nursing assessment and specific nursing care to maintain homeostasis.

It is true that nursing care should be holistic. When considering the importance of acid-base regulation, nurses should maintain, at all times, good lung and kidney functions to enhance the compensation process. They should always be ready to provide accurate and timely actions during the acute phase of the disease process where the acid-base disturbances may occur. In addition, nurses should also look for signs of abnormality and know what to do when certain changes to the homeostasis occur to patients. Prompt nursing assessment to acid-base disturbances is fundamental. The role of focused
nursing assessment and good nursing care also has strong implications for quality patient outcomes. For example, the facilitative role of nurses towards client with respiratory acidosis is apparent. If nurses know that acidosis caused by respiratory factor are compensated by exhaling more carbon dioxide to increase ventilation, explanations can then be given to patients encouraging their collaboration in promoting effective breathing.

This is just one of many examples in which nurses can do better results in improving patient care. Nurses also need to deal with meticulous monitoring and anticipated suitable nursing care. Although they recognize the essential role of pharmaceutical therapy for metabolic alkalosis and metabolic acidosis, nurses should never forget their roles in assisting the acceleration or deceleration of the ventilation rate of those who suffer respiratory acid-base imbalances. Nurses should believe that professional care is more important than merely carrying out medical orders.

3.4 Implications to the Teaching of the Topic Content

One can refer to relevant information provided in textbooks or other references to develop a framework of basic knowledge necessary for solving acid-base problems. Yet tremendous efforts have to be made to understand the intricacies of acid-base problems and to develop specific problem-solving skills for daily clinical interpretations. Furthermore, the interpretations of nurses upon clinical observations and assessment could be an asset proving to
the medical counterparts of the impetus and competence of nurses when prompt intervention is to be taken immediately after the nursing problem-solving process.

What is provided in this chapter is not encompassing all the information necessary to solve most clinical acid-base problems. Some of the given facts are only true in the biology and chemistry arena. Not all of these concepts are readily applicable in solving patient's problems in real situations, unless the relational aspects of the conceptions are understood (Ramsden 1988). The descriptions of the mechanisms underlying the different types of acid-base imbalance and the compensation process seem to oversimplify the possible dimensions and aspects of changes that are involved during incidents of different acid-base disturbances and its compensation. One good example is the equation $\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- + \text{H}^+$. It is not too difficult to see that by pure chemical computations, elevations of PaCO$_2$ actually result to increased HCO$_3^-$. From a physiological perspective, however, nurses need to understand the normal human body mechanisms in compensating the acid-base imbalance. They should be aware that a person's HCO$_3^-$ would only rise after several days because the renal functions have to reserve more HCO$_3^-$. Even though one is likely to see the role of the lungs and kidneys in the acid-base balance regulation, it is not easy to elicit and assume the functions of these two body systems, especially when operating under a range of multifaceted processes.
In understanding the concept of acid-base regulation, it is important that the essential components must be identified. This has been successfully presented in table 3.1 and figures 3.1 and 3.2. Though majority of the components is illustrated in this chapter as having interlocking relationships, the descriptions of their reactions are over-simplified. The concepts reflecting the relevant biological sciences knowledge content were illustrated using the three main components, clinical, pure science and compensatory. Since it was not the author's intention to propose the direct applications of any one of these components, they were not described in full. Instead, the information presented here only described a fragmented fashion for easy readability.

It is vital that the presentation of information should focus on quality rather than quantity. Association and integration of acid-base balance factual information should be built upon the principles of pure biological science knowledge and the compensatory phenomenon. The information should also be linked to the three components (concepts of pure biological science, clinical component and compensatory component) to help develop events that explain a fuller picture of the acid-base regulation phenomenon.

Conceptualization of the three components is useful in forming a scientific framework (Figure 3.3 and Figure 3.4) for nurses to delineate the complex data, and subsequently transform this relevant information into a clinical phenomenon pertinent to a nursing perspective. For example, an
ABG profile can be incorporated in an acid-base disorder context. Events related to all the parameter values and compensatory function could be drawn together as a whole for clarifying and explaining the present phenomenon. This kind of scenario functions as a platform for nurses to deal with the information when they embark on a typical nursing assessment setting. The use of correct technical terms and chemical symbols to represent different defining characteristics of the participating elements also helps nurses distinguish the meanings of individual elements or components and their roles in the acid-base balance regulation. It is imperative that the relational aspects of different levels and the range of physiological events be clarified by means of a few inter-related diagrams. The representation of various flowcharts framing the diagrams can demonstrate the scientific relationships of the essential elements and events that reflect the complexity and sophistication of the course of actions in acid-base regulation.

Most nursing students have difficulties integrating science knowledge in clinical nursing. In most cases, they fail to relate the underlying mechanisms of daily clinical phenomenon to a particular respiratory care setting (Akinsanya 1987a; Race and Holloway 1992; Chapple et al. 1993; Pearson and Clarke 1994). With more and more emphasis on comprehensive nursing assessment for accurate clinical interpretations, nurses' role need to be reinforced to bring biological science knowledge into the nursing practice. Nurse educators and clinical nurses need to facilitate the learning of practical
knowledge. More attempts and efforts must be made to improve learning, for example, by means of implementing clinical bedside round and journal clubs in hospital settings where clinical acid-base problems are brought up for discussion. Representation of every single component or procedural step that nurses come across in their classrooms or clinical setting should be at all times taken back to a nursing context. This is definitely important in encouraging nursing students to recognize the commitment to understand and anticipate peculiar human responses. Nursing students should also develop skills in identifying abnormality among individuals in any health care setting.

Nursing knowledge is not common sense. Learning in this discipline requires nurses to make extra efforts to develop a personal synthesis and internalization of the information to its context, and then try to transform this internalization into a body of nursing knowledge. The attempt to internalize a clinical phenomenon into a personal meaning involves the recall of the relevant knowledge content and the functions of one's cognitive strategies to relate these contents. With this process, a nurse develops a 'better' qualitative way of understanding the subject content which, hopefully, will prepare him/her apply his/her knowledge to solve problem in clinical patient care situations.
Figure 3.3 Diagram Showing the Typical Conceptualization of Acid-base Balance Regulation Abstracted from Textbooks and Journal Articles

1. ABG components and its normal range
2. Clinical significance of ABG parameters
3. Definition of acid-base imbalance
4. Causes of acid-base disorders
5. Types of acid-base disorders
6. ABG measurement & oxygenation assessment
7. Acid-base measurement and overall body functions
8. Definition of ABG measurement
9. Definition of acid and base
10. Definition of pH
11. Principle 1: acid-base balance
   pH = 20:1 = HCO₃⁻/PCO₂
12. Principle 2: body metabolisms and acid-base status
   H₂O + CO₂ → H₂CO₃ → HCO₃⁻ + H⁺
13. Levels of compensation
14. Compensatory mechanisms
15. Types & functions of buffer systems

Key Concepts
Related Concepts
Relationships between Concepts
Figure 3.4 A Summary of the Typical Conceptualization of Acid-base Balance Regulation Abstracted from Textbooks and Journal Articles
Chapter 4

RESEARCH METHODOLOGY AND DESIGN OF STUDY

4.1 The Research Design

One of the aims of this research was to qualitatively investigate the different ways in which students understand or perceive the phenomena or aspects of the 'world' around them. 'World', in this context, refers to the 'content' of a particular aspect of biological sciences knowledge given to students in the initial stage of their learning. In order to solicit relevant and distinctive data about the ways of conceptual understanding, a specific method allowing the findings to stand clearly in relation to the phenomenon of the investigation was adopted. This method is known as phenomenography (Marton 1981).

Phenomenography is a research approach for mapping qualitatively different ways in which people experience, conceptualize, perceive and understand the various aspects of the world (Marton 1986). It is a research method designed to answer certain questions about thinking and learning. The strategies for conception learning involved in a phenomenographic study provides a platform to interpret variations between the different ways of responding to and experiencing the phenomenon appearing to them as the content of the study. It is a means of understanding the dynamics of learning.
and the relationship of the underlying educational systems. In short, phenomenographic research exhibits the internal relationship between the experience and the experienced (Lybeck, Marton, Stromdahl and Tullberg 1988). This methodology provides a way for nurse educators to gain access to the learners' errors and misconceptions at a subject content level. It also offers a possible solution to the process of how students construct their theoretical world. This research approach not only provides insights on curriculum restructuring to capitalize students conceptual shift towards a set of formal theories, at the same time, it also allows changes to happen in the direction of establishing new nursing knowledge in respect to the demands of contemporary nursing development.

This chapter is divided into five sections. The first section discusses the significance of phenomenographic approach to this study. The design of the study, the construction of the interview protocol and the interview tasks (the task of "the regulation of acid-base balance in normal respiratory physiology" and the "respiratory nursing assessment" problem) are also presented. In the second section, the pilot study and the implications of the results to the main study are discussed. The third section centers on the discussion of data collection and analysis procedures. The fourth section discusses validity and reliability of the data, while the last section considers ethical issues involved in this study.

Each section is presented separately in the following paragraphs.
4.1.1 Introduction

This study highlights the role of qualitatively different students’ conceptions to some clinical phenomena, and their views to infer a knowledge base for the improvement of clinical problem-solving skills. A closer view on nursing students’ conceptualizations of biological science knowledge and the relationship of these conceptualizations to their problem-solving approaches are depicted. Such argument provides beliefs that sufficient knowledge to accommodate good integration of various science and nursing knowledge must first be developed in order to become effective problem solvers. Theoretical base must be constructed which by subsequent interpretations and actions makes clinical phenomenon meaningful to learners.

A sample of nursing students from a four-year university-based generic nursing program was interviewed through ‘think-aloud’ method, an approach purposely designed to capture students’ (the experienced) “ways of experiencing” while actually working with clinical problem-solving tasks (the phenomenon). The perspective focused on the qualitatively different ways these students go about understanding the biological concepts and handling data concerning respiratory patients, all of which entailed some fundamental problem-solving skills. The researcher believed that an investigation of the heuristics of problem solving among nurses would enable a richer
understanding of the individual's meanings to the conceptions of knowledge content and the conceptions to the clinical phenomenon.

4.1.1.1 Phenomenography

It is the essence of this research approach that the internal relationship between the experience and the experienced in learning conceptions of the students and the conceptual understanding to the problem-solving context in clinical nursing situations where the experience is embedded be explored (Marton and Booth 1997). According to Marton and his research team (1997), one cannot describe a 'world' independent of their descriptions, nor can one separate the experiences of an individual from their described phenomenon. Thus in selecting a methodological framework to suit this line of inquiry, phenomenography was employed because it forms a strong premise for exploring the ways student nurses experience the conception learning to the clinical phenomenon which they handle in daily problem-solving contexts. With phenomenography, there is a relatively greater possibility in uncovering the underpinning experiential descriptions about learning to become problem solvers as well as elucidating information regarding successful clinical problem-solving processes.

Most research studies on problem solving were based on a first-order perspective (Marton and Booth 1997), and followed an information-oriented investigation which does not guarantee comprehensiveness and in-depth explorations of the different ways of experiencing the problem-solving
individual’s experiences, which contains trivial but completely important evidences, also divulges the attributes to the effectiveness of nurses’ problem solving. This particular way of experiencing the phenomenon is outstanding, and can provide well-informed data (Marton and Booth 1997). It is also systematically focused on the investigations along second-order perspectives in describing both the subjects’ experience and the learning context (Marton 1981).

If one wants to study the ‘world’ as perceived by the students, the object of inquiry must start from the person experiencing his/her own world of learning within the second-order perspective (Marton 1981). For this particular study, the approach focused on the second-order perspective (Marton 1981; Marton and Booth 1997). No attempt was made to describe things as they are. Instead, descriptions of experience were solely presented according to how things appeared to the subjects’ perspectives. And to find out the extent whether students have achieved competence of the teaching aims, an exploration of their course of learning from a first-hand experience was made. Rooms were also provided for student nurses to appreciate and define their ‘personal knowledge’, which could be part of their existing theoretical base relevant to the nursing practice. To know more about ‘implicit theories’ in problem solving, “the ways of conceptualizations” and “the ways of understanding clinical phenomenon” were used as the main themes, in
of understanding clinical phenomenon" were used as the main themes, in accordance to the notion of studying "the ways of experiencing their world" as suggested by Marton and Booth (1997).

It is envisaged that a unique range of "categories of description" characterizing the descriptions and explanations of different problem-solving approaches and its theoretical underpinnings will be generated by the students (Marton and Booth 1997). It is also expected that detailed analyses of the "categories of description" will enable clear delineation of different personal variations, eventually leading to a new hierarchical model of "ways of experiencing" by students (Marton and Booth 1997). Furthermore, outcomes of the qualitatively different ways nursing students deal with the 'problem' (referring to the phenomenon presented in the interview for as a simulated problem-solving context) are expected to generate intuitions in designing alternative teaching approaches, or suggestions in revising instructional strategies used in conventional curriculum. Once the significant dimensions of variations from this 'categories of descriptions' are extracted at a collective level, 'outcome space' interpreted as a collective form of learning outcomes can then be developed. The 'outcome space' created upon the learning phenomenon could indicate a range of possible learning outcomes that characterize the 'conceptualization' and 'conceptual understanding' of the nurses. These 'outcome space' can also be transformed to alternative knowledge relevant to their understanding of a specified nursing context. It
can even be used by nursing faculty who is seeking to delineate key elements of successful clinical problem-solving.

4.1.2 *The Design of the Study*

The philosophical underpinnings of this study are already discussed in Chapter 1. In brief, the study aimed to delineate how nursing students conceptualize the knowledge content of biological sciences, and to identify how they apply these knowledge in solving a problem in a specified nursing context. From the outset, the researcher delimited the phenomenon that was of research interests and used it as the object of this study. Considerations on discerning the structure of the phenomenon against the backgrounds of the nursing situations it might experienced in were also made, to distinguish its salient features and to look at it with others’ eyes and still be open for further developments (Marton and Booth 1997, p.129).

Although phenomenography emphasizes the ‘richness’ of verbalizations of the learners, the data can only be encapsulated if the research adopts a second-order perspective and the answers are analyzed using a second-order description of the experienced phenomenon (Marton and Booth 1997). When a second-order perspective approach is adopted, the personal ideas of the researcher are withheld and the meanings of the statements to the particular problem as reflected by the ‘actual experiences’ of the students are reserved. In this study, the researcher was also a learner in
learning a certain phenomenon around his/her world. Thus, exploration of the students' descriptions and understanding of the phenomenon and the 'problem task' becomes the starting point for this study.

Thinking-aloud interview, the most common method of collecting data in a phenomenographic study, was used as the data collection protocol. The interviewees were asked to undertake a task and report on their experiences of how they had gone about the task by reflecting over their learning, in a state of 'being aware of his / her own awareness of something' (Marton and Booth 1997). The interviewer also worked together with the interviewees, facilitating them to bring forth their awareness of the undertaking of the task. For this reason, the study was constructed in three main components: the design of the interview protocol, the construction of the tasks, and the analysis of the interview data. The design of the study consisted of two phases: the pilot study and the main study. In the following section, the process in which the interview tools were developed and how the analytic work was taken on are presented.

4.1.2.1 The Design of the Interview Protocol

Since phenomenography examines the interplay between the students' processing and understanding of the knowledge, it is extremely crucial that the design of the interview protocol should not be based on a framework mainly drawn from the teacher's perspective (Marton, Hounsell and Entwistle
1984). Otherwise, it will run into the danger of imposing pre-determined inquiry framework on the interpretations of the students’ experience and, ultimately, creating an atmosphere not conducive to acknowledging the students’ experiences and efforts. Therefore, an interview protocol that facilitates free flow of students’ verbalizations in terms of their relations to the subject matters is essential. It has to take into consideration the interviewer’s main role in bringing the interviewees back to the focus of reflection. Not only does this account a change in the way the methodology is used, it also involves a shift in perspective. In this study, the interview was designed to allow for the ‘thinking-aloud’ process of the students. The interview method can minimize predetermined answers and acted as a platform for them to articulate as complete as possible reflections of their learning experiences. The researcher only attempts to use the probing questions to help the inactive students to think explicit and verbalize their thoughts on the spot. Being mindful of exploring students’ understanding of 'the regulation of acid-base balance in normal respiratory physiology' and to a nursing problem situation, two problem-solving contexts were carefully formulated: the task of the respiratory regulation to acid-base balance and the respiratory nursing assessment problem task.

4.1.2.2 The Construction of the Problem Task

The role of task complexity during the clinical problem-solving processes drove the researcher to construct a clinical patient situation task
that triggers the individuals to identify the content knowledge and the underlying cognitive processes to represent their problem-solving behaviors (Corcoran-Perry and Narayan 1991). In this study, the construction of the problem task was the primary challenge to the researcher. Trying to determine what the students' conceptualization of some biological science knowledge was, and what effects the conceptual understanding of the knowledge had on their problem solving of a respiratory nursing phenomenon, two tasks based on varied characteristics of problem contexts were designed. These two tasks were used in the pilot phase of the study.

The two tasks were sent to two nurse specialists and two expert nurse researchers for validating the degree of relevancy and validity of the data with respect to exploring the problem-solving process in patient care setting. Feedback from these experts subsequently led to more revision of the task, until the level of complexity appropriate to the nursing students was achieved. Amendments were also made on some wordings of the probing questions before the tasks were used in the two interviews. The duration of each interview in the pilot study was between one to one and a half-hour. After the transcription of interviews, descriptions of the two tasks were analyzed and categorized. Themes and patterns of the subjects' conceptualizations and problem-solving approaches were subsequently identified. The common comments of the subjects not only guided the researcher in using the statements and expressions relevant to their learning, it also provided new
insights into students’ in-depth and holistic thinking process. This not only led to further refinement of the interview structure, it also served as the platform for triggering the cognitive elements involved in the problem-solving tasks for the main study.

The task characteristics, revealing subjects’ problem-solving processes, are depicted below.

Construction of Task 1 was based on the review of the classical physiology and pathophysiology textbooks and updated journal articles of the selected topic area (Table 3.1). The knowledge content in these references also formed the basis of analyzing the students’ responses to understanding the topic of acid-base balance and its respiratory regulation. Task 1 (Diagram 4.1, p. 141) simply requested the students to describe and explain what they understood about acid-base regulation principles and its possible features. Verbalizations of the conceptions about the biological knowledge were done by the delineation of the subjects’ cognitive steps while managing the information, an indication that they remembered and understood the concepts before arriving at a meaningful interpretation of the phenomenon. This task entailed descriptions of both qualitative and quantitative features of the elements involved and the phenomena related to acid-base regulation from different perspectives. Task 1 was considered valid due to the high relevancy of its identified content knowledge to the actual nursing practice.
Construction of task 2 was based on the extraction of actual patient data and the researcher's clinical observations from hospital acute care settings. Additional health statistics on current mortality rates for the common respiratory diseases were also considered to increase the 'realness' of the inclusion of a patient situation of a particular respiratory disease. Content validity of Task 2 (Diagrams 4.2 & 4.3, pages 142 – 143) was considered from two perspectives: (a) the extent to which 'patient care situation' is representative of situations nursing students normally encounter in actual practice, and (b) the degree to which the responses of nursing students to the simulation are similar to the kind of responses they would give in the actual situation (Tanner et al. 1987).
Interview Task 1

A less experienced nurse would like to know the regulation of acid-base balance in normal respiratory physiology.

Please draw a FLOW CHART to help your explanation to this less experienced nurse. You can also draw diagram(s) to add to your descriptions while you are explaining every event that may happen in this situation. Label the diagrams with the appropriate names of the substances that you are describing.

Discuss your diagrams and the labeled parts on each step involved during the explanation process, so that the less experienced nurse can keep track of what is going on.

You are expected to show the result of every event in the FINAL FLOWCHART as clearly as possible.
**Interview Task 2**

A less experienced nurse would like to learn from you what would happen to the client in the clinical case summary given on the following page.

You are expected to discuss with the less experienced nurse on the issues about:
1. How would you proceed to find out the problem of this client?
2. What are the underlying mechanisms which could have caused his problem?
3. What are the possible nursing diagnoses relevant to this client's condition?
4. What is the major nursing diagnosis appropriate to this client? and why?

Please draw a FLOW CHART to illustrate your steps in considering the situation on what happens to the client as stated in the case summary.

To help your explanation to the less experienced nurse, you can draw diagrams and give appropriate labels upon each diagram which shown in the flow chart, such as: label the substances given in your diagrams if it is necessary.

Discuss your diagrams and labeled parts during the explanation process to each step or the changes that involved, so that the less experienced nurse can keep track of what is going on.

Your FINAL FLOWCHART should show the end result of the events as clearly as possible.
Interview Task 2

Clinical Case Summary:

A man of 65 years factory worker is admitted to your unit with profuse sweating and dyspnoea. He was diagnosed with chronic bronchitis ten years ago.

He is a chronic smoker, but he never drink alcohol. He consumes 10 to 20 cigarettes a day.

He has recently consulted his family doctor because of fever and prolonged coughing.

Upon arrival, he complained of shortness of breath, feeling feverish, and coughing with greenish-coloured sputum. He was also found to be cyanotic over the lips. His blood was drawn for ABGs test after resting 15 minutes on room air.

On health assessment, his vital signs were:
temperature (oral) 38.5 °C, blood pressure 150/90 mmHg, pulse 90 beats/minute, respiration 28 breaths/minute which is labored and shallow.

The ABGs findings was stated as following:

\[
\begin{align*}
\text{pH} & \quad 7.41 \\
\text{PaO}_2 & \quad 45 \text{ mmHg (in room air)} \\
\text{PaCO}_2 & \quad 44 \text{ mmHg} \\
\text{HCO}_3^- & \quad 28 \text{ mEq/litre} \\
\text{Base Excess} & \quad +2
\end{align*}
\]

His chest X-ray film reveals right lower lobe infiltration, and he was then diagnosed with right pneumonia.
4.1.2.3 The Structure of the Interview

The structure of the interview is another essential part of a phenomenographic study. One of the main aims of the interview was to draw the focus of the subjects to the three research questions, using liberated, free-flow discussions. The more students pursue the 'think aloud' process, the more their conceptualizations in regard to the presented learning context will be discerned. So to unfold the various structures of students' thoughts in relation to the role of the biological subject content knowledge to the understanding of the client's problem situation, the researcher focused on the verbalizations of students' conceptions to map qualitatively different ways of conceptualizations. This structure also constituted the format and the probes used for each interview. Key questions were presented to illustrate and summarize the effects of the probes that were used in the 'think-aloud' context. Although a list of relevant probing questions was prepared prior the interviews, the researcher did not try to ask all the questions, nor was the sequence of the questions fixed. It was basically an interviewee-driven process; the researcher only acted as an active listener throughout the interview. Using this approach increases the richness of the data set, thus providing a good basis for making cross-references to the difficulties linked to this learning experience.

The difficulties of giving inner accounts associated with the learning experiences could lead to possible frustrations. Students could also become
defensive when the liberation of one's exposition is limited by incompetence. On occasions when an interviewee is unfamiliar with the two-tier thinking processes and might require more probing at the time the interpretations or descriptions were not possible, the researcher tried to maintain open and genuine attitudes. The researcher also expressed unconditional regards to the responses of the students. Judgment based on theoretical underpinnings of the researcher was suspended to avoid imposing unnecessary threats or bias to the students. Sensitivity to the possible associations of the complexity of the interview task and students' academic performance was also attended to. To avoid generating unpleasant feelings, interviewees were given top priority on choosing the time and schedule of the interview. It was noted from the scheduling of the interviews that descriptions of the students' experiences were more favourable after they received their academic reports. These were some of the characteristics of the study design that possibly dispute the environmental factors that might influence the problem-solving behaviors of students when they embark on a problem-solving task, both in a simulated patient situation as well as in real clinical settings.

*The Interview*

Ference Marton, the founder of Phenomenography, stressed that interviews of phenomenographic studies have two levels (Marton and Booth 1997). On the first level of the interview, the two parties are involved in a situation of interpersonal contact (Hammersley and Atkinson 1995). On the
second level, the interviewer acts as a facilitator whilst the interviewee is free to pursue reflections of one's underlying thoughts and experience. In this level, it is quite common that the interviewee puts up a defense structure for protecting oneself against any resistance or rejection that might occur, particularly when s/he feels some conflicts while verbalizing the learning difficulties of the whole learning experience. Thus this event has to be handled carefully. The interviewer has to develop the sensitivity in spotting the potential of the interpersonal relationship as well as the ability of maintaining it. The interviewer also has to master the skills of balancing between overcoming the defense and the issue of distancing in the reflective part of the interview (Marton and Booth 1997).

The Probes Used in the First Interview Task

There were two types of probes used for the interview. Probes used at the beginning of the first interview level served as a social discourse. The probing questions, drawn from broad but apparent information about their overall learning experiences, were as follows:

- What is your view about the difference between learning in a university and a secondary school?
- What kind of adjustment was needed (if any) when you started your nursing course in the first year of study?
- What kind of obstacles did you experience in the second year of your nursing study?
When the students felt less threatened by the underlying tone of the probes, they became more engaged in a direct and authentic discourse. This led to the second level of the interview. To promote free-flow verbalization of experience undertaking a task or clarifying the interpretations of the different things the interviewee has said in the interview, interview probing questions according to the research questions of the study were carefully developed. The ‘what’ and ‘how’ questions were the key probing structures in this study. These probing questions were purposely constructed to address the themes of the task situation and to focus on the demands of their reflections.

Every student coming to the first task was provided with some ground rules. After studying the text that contained the task(s), they were allowed to start at any time they were ready. To help clarify interpretations or responses of the verbalization process, prompts were given by the interviewer when necessary. However, they were instructed not to seek information from the interviewer. Subjects were given a maximum of one and a half hour to complete each task.

The first task provided the circumstances for students to directly state their comprehension of a piece of biological sciences information. It drew information of the subjects’ experiences through the articulation of their understanding on the subject content “the regulation of acid-base balance in
'less experienced nurse' as clearly as possible the learning and understanding of the basic concepts and principles about the varied acid-base states and arterial blood gas measurements, and the mechanisms of the different levels of compensatory responses for maintaining human body equilibrium. The simulated 'less experienced nurse', who attended to the exposition of the student informants, served as the receiver of information. Being a person with supposedly less knowledge about the subject content, it was anticipated that the students would feel more relaxed while verbalizing their learning experiences. The students were also asked to summon every single step and event that led to their description of a picture about normal respiratory regulation of acid-base balance.

After students responded to the first task, they were asked to apply the knowledge they conceptualized into the second task. This created a premise for envisioning the conceptualizations of the biological science knowledge that has taken place. It also informed the researcher what conceptualization meant for the students in this context. An understanding how these students applied their conceptualizations into the second task characterizing a respiratory nursing assessment situation was also made possible.

Students' conceptualization of the biological sciences knowledge was called upon by a key question "What is meant by 'the regulation of acid-base balance in normal respiratory physiology'?" The following instructions were given to students when they initially approached the task:
balance in normal respiratory physiology?" The following instructions were given to students when they initially approached the task:

- You are required to read the questions. You may also read the text as many times as you want. While you are addressing the question and attempting to respond, please describe and give an account of what you see. You are expected to shed light on the meanings of every item or step that you come across with when you think of the content about the regulation of acid-base in normal respiration. You can draw diagrams or flowcharts while giving your explanations.

While the students were approaching and making an effort to delineate the task, probing questions for further clarification and verification were raised.

- What does this problem mean to you?
- How do you read this problem?
- Tell me what are you actually thinking of when you read the problem in this way?
- What are the key concepts you have identified from this problem, and why are they related to this problem?

Along the descriptions of the thinking processes, students were also asked to further elaborate by describing the situations or events that lead to the final result.
• How do you understand this problem? Can you elaborate or describe a little bit more on this claim?
• What are the premises and arguments you adhere to which directed you to come to this assertion?
• How do you make up the framework or structure that you described just now?
• What do you need to know more in order to come to the solution and why do you need this information?

At the end of the interviews, concluding-like probing questions were asked.

• Are you satisfied with your work or in the way you try to answer this question?
• Would you like to say more on any one point apart from what you have already described earlier on?
• Do you want to add more to what you have just described?

Students feeling a need to expand or revise their original answers were given opportunities to provide supplementary descriptions or explanations at the end of the interview.
4.1.2.4 Sampling

Sampling Strategy

To ensure that the chosen participants can truly illuminate the richness of their individual experiences (Baker, Wuest and Noerager 1992), a briefing session to introduce and explain the purpose, procedure and time involved in the interview was arranged. Only students who have just taken the course covering the content knowledge required in the problem-solving task and who were willing to participate in the interview were invited. Second-year nursing students were selected because they have just completed a respiratory course where the biological science knowledge was taught. They were also about to apply this knowledge into practice during the period of clinical placements in acute ward units at local public hospitals. A total of twelve students volunteered to take part in the main study by signing an interview scheduling form. None of these subjects were previously approached in the pilot study.

Although variations in the sample size were found in various empirical studies concerning medical and nursing reasoning process (Corcoran-Perry 1986; Tanner et al. 1987; Tschikota 1993; Taylor 1997), in most instances the sample size of each group is between 11 and 19. Majority of the samples was also divided into groups of differing level of knowledge and experience. For this study, purposive convenience sampling method providing an adequate and appropriate sample was used. No additional information was sought
except when the data to sustain tentative findings along the data collection and analyses procedures was considered insufficient. The sample size of 12 was considered adequate because no more new concepts or themes were emerging, even after further information on a particular aspect of the data was collected. In fact, data saturation was observed in the study (Woods and Catanzaro 1988).

**The Demographic Characteristics of the Sample**

Demographic data of the twelve participants were classified according to gender, age, educational level before entering the nursing program, the science subject(s) studied before entering the undergraduate nursing program, and the results of these science subject(s) in the public examinations at their secondary and post-secondary level. Only two nurse students were older than 25 years of age; the rest of the students' age was comparable to the age of the matriculation graduates in Hong Kong population. Most of the participants came directly after their matriculation schooling. Only 25% were male; this percentage was similar to the whole school population of the nursing program in the university.

The distribution of the informants in the different categories is calculated and compared in Table 4.1. Characteristics of the informants reported here will be further analyzed and delineated in relation to their learning of nursing in subsequent chapters when appropriate.
### Table 4.1 Summary Table of the Demographic Characteristics of the Informants (n) and the Class as a Whole

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Numbers (n=12)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>9 (39)</td>
<td>75% (78%)</td>
</tr>
<tr>
<td>Male</td>
<td>3 (11)</td>
<td>25% (22%)</td>
</tr>
<tr>
<td><strong>Age group</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-24</td>
<td>10 (47)</td>
<td>83% (94%)</td>
</tr>
<tr>
<td>≥ 25</td>
<td>2 (3)</td>
<td>17% (6%)</td>
</tr>
<tr>
<td><strong>Education level</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form 5</td>
<td>3 (7)</td>
<td>25% (14%)</td>
</tr>
<tr>
<td>Form 6</td>
<td>0 (0)</td>
<td>0% (0%)</td>
</tr>
<tr>
<td>Form 7</td>
<td>9 (43)</td>
<td>75% (86%)</td>
</tr>
<tr>
<td><strong>Science learning background</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>9 (44)</td>
<td>75% (88%)</td>
</tr>
<tr>
<td>Human Biology</td>
<td>4 (5)</td>
<td>33% (10%)</td>
</tr>
<tr>
<td>Chemistry</td>
<td>9 (43)</td>
<td>75% (86%)</td>
</tr>
<tr>
<td>Physics</td>
<td>9 (41)</td>
<td>75% (82%)</td>
</tr>
</tbody>
</table>

The number inside the bracket ( ) denotes the figures of the whole class of Year 2 students.

*The Secondary Science Background of the Informants*

84% of Year 2 students in the 1996 intake took either the subject of Biology or Human Biology, and passed the public examination at the secondary or post-secondary level (General Enquiry of Applicant Information, Hong Kong Polytechnic University 1996). From the sample group, nine students (75%) completed school matriculation level, the other three (25%) left after form-five secondary level. All the twelve students took science subjects, either during their secondary or post-secondary schooling. Although Biology, Chemistry and Physics were the most popular science...
subjects, results of the Hong Kong Certificate of External Examination (HKCEE) and Hong Kong A Level Examination (HKALE) showed that only 33% of the students took the subject of Human Biology at their secondary level. This figure was similar to the secondary students (20%) who took the Biology subject at the secondary and post-secondary level in the Hong Kong population (Hong Kong Examinations Authority 2000a; Hong Kong Examinations Authority 2000b).

Performance for each science subject was categorized according to pass or fail results. In summary, only one student failed in the Physics subject. The rest obtained satisfactory results in the public examinations. The total number of subjects who possessed secondary level biological knowledge and had passed HKCEE and / or HKALE was twelve, a strong evidence that the cohort of nursing students have satisfactory basic science knowledge background. Since all the twelve nursing students passed the science subjects at the HKCEE and HKALE, the assumption that variations occurring in the learning outcomes due to science knowledge background could be excluded. With their prior biological science knowledge before entering the nurse education, the problem-solving behaviors of the volunteer students in this study could also be representative of the same cohort of undergraduate nursing students in the pre-registration nursing program.

The results are summarized and shown in Table 4.2.
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<td>1 Clarence</td>
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<td>&gt;25</td>
<td>Post-secondary level Form 7</td>
<td>☑ (p) CEE</td>
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<td>2 Jeanie</td>
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<td>21-24</td>
<td>Secondary level Form 5</td>
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<tr>
<td>4 Susan</td>
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<td>Secondary level Form 5</td>
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<td>☑ (p) CEE</td>
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<tr>
<td>5 Brenda</td>
<td>F</td>
<td>21-24</td>
<td>Post-secondary level Form 7</td>
<td>☑ (p) ALE</td>
<td>☑ (p) ALE</td>
<td>☑ (p) ALE</td>
<td>☑ (f) ALE</td>
<td>(f): subject with a failed result in ALE</td>
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<tr>
<td>6 Carol</td>
<td>F</td>
<td>21-24</td>
<td>Post-secondary level Form 7</td>
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<td>7 Alix</td>
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<td>10 Solomon</td>
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<td>21-24</td>
<td>Secondary level Form 5</td>
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<td>12 Leo</td>
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</tbody>
</table>

☑ denotes the student has taken the subject in the secondary or post-secondary school

(p) denotes a result of pass obtained in HKCEE (Hong Kong Certificate of Education Examination) or/and HKALE (Hong Kong A Level Examination)

(f) denotes a result of fail obtained in HKCEE (Hong Kong Certificate of Education Examination) or/and HKALE (Hong Kong A Level Examination)

### 4.2 The Pilot Study

Approval was sought from the Human Ethics Committee of the Hong Kong Polytechnic University to conduct the pilot study. The pilot
study was carried out prior the actual research to verify the feasibility of the research procedure (Portney and Watkins 1993), with an anticipation of the possible conditions that might happen in the main study setting. It was also a good chance to enhance the features of the main study, since the weaknesses, errors and failures of the design that are sometimes overlooked were detected prior the commencement of the main study. It also allowed the researcher to revise and modify the instruments and procedures until the desired research design was achieved.

After completing the validity and reliability tests of the problem tasks, a group of baccalaureate nursing students from the same university nursing program where the main study would be conducted, and who had recently been promoted to the third-year program was invited to participate in the pilot study. According to Portney and Watkins (1993), a small number of subjects are already considered sufficient in a pilot test. Thus, only three volunteered nursing students were invited to participate in the pilot study. These three students were excluded from the sample group of the main study.

4.2.1 Results from the Pilot Study

‘Task 1’ and ‘Task 2’ were the tools used for data collection. ‘Task 1’, the descriptions to the “regulation of acid-base balance in normal respiratory physiology” concepts, served as the first interview task. Its characteristics
describe their understandings of the elements and the events involved in the acid-base balance and the regulatory mechanisms, and provide descriptions of their conceptions by means of verbal explanation to a less experienced nurse. ‘Task 1’ merely provided a representation of their conceptions of acid-base balance and regulation. They were not required to give any information about the application of this conceptualization.

Given the context of explanations provided by the students to the less experienced nursing student, anticipated conceptions of ‘respiratory regulation of acid base balance’ concepts fell into three main areas:

(1) the understanding of the normal and abnormal acid-base balance conditions and its underlying causes,
(2) the understanding of the pure science principles in regulating acid-base status, and
(3) the understanding of the compensatory events related to the buffer systems and its underlying mechanisms.

A review of the literature on the content knowledge of the topic of ‘acid-base balance and regulation’ and consultation of current textbooks and updated journal articles nursing students generally use in nursing studies as their reference materials was carried out (see Chapter 3 for detailed explanation). As a result, a framework to structure the content substances (the participating elements and involving events about “regulation of acid-base
(the participating elements and involving events about “regulation of acid-base balance in normal respiratory physiology”) commonly found in the literatures was designed. Details of the framework were already given in Chapter 3.

A series of questions that triggered students to solve the client’s problem embedded in the ‘Clinical Case Summary’ characterized ‘Task 2’. These triggering questions, sometimes acting as cues, were structured to encourage students to generate a few hypotheses and develop a few possible nursing diagnoses. The ‘Clinical Case Summary’ provided students some background information about the problem. The task construction was based on the belief that students are able to find the solution for the client’s problem through appropriate selection of nursing diagnosis and justification of final choices. While students worked on the data contained in ‘Task 2’, they were expected to recall their conceptualization of the first task to understand the problem emerging in the second task. They were also expected to provide explanations for the choice of a major diagnosis and justify the validity of the working hypothesis they are claiming.

In ‘Task 2’, the concept of ‘regulation of acid-base balance in normal respiratory physiology’ was incorporated to a simulated, hypothetical client situation in order to solicit students’ responses in problem solving. The clinical case summary represented the different types of problem-solving
Students were then required to attend to the cues regarding the client's clinical data, such as the age, occupation, life styles, vital signs, past health history, current health status, medical diagnosis, examinations and laboratory findings. The nursing assessment problem was complex, albeit the students were familiar with the conception of 'respiratory acid-base regulation' being embedded in the problem context. It required the students to demonstrate the application of their conception in explaining the phenomenon presented to them in the problem.

The students were also expected to solve the problem presented in the text using their interpretation of the presented cues, and the linkages made to the domain concepts of the knowledge base concerned. The effectiveness of their problem-solving approach rested on a number of factors. First, all written representations in the problem (completeness of the data) was to be considered. Accuracy in interpreting the cues (accuracy of data interpretation) can also help develop an initial perception to the situation. The quality of interaction with the clues identified, and the associations made to the prior knowledge all greatly enhanced their reasoning ability, especially in justifying the interpretation of the details of the client's condition entrenched in the problem.

Apart from the construction of the two tasks, an interview protocol was also developed to guide the interview with the subjects. The probing
Apart from the construction of the two tasks, an interview protocol was also developed to guide the interview with the subjects. The probing questions were used to elicit the narrative descriptions of learning experience. Initial analyses of the interview data from the pilot study led to further modification of the interview structure and refinement of the probing questions and strategies.

4.2.2 Revision of the Interview Protocols

The data analysis stage of the pilot study generated valuable insights and concerns from the different respondents. Some limitations of the interview tasks were also revealed. Minor alterations were made to the instruments used in the overall research plan of the main study. Revisions were mainly done in four areas. Each revision is briefly presented.

The first revision related to the interview plan of the main study. During the interview process, the students felt incompetent, especially when they had some reservations in responding to the subject-specific questions. Some of them assumed the interviews had something to do with their academic performance, so they had difficulties in differentiating between the role of a teacher from a researcher. To fully reveal students' true experiences and avoid association of a student's comments with a judgment of academic performance, all three participants were informed right at the onset that their responses would only be used within the research context and will have no
implications whatsoever on their academic results. To make it convenient for students, the interviews were scheduled according to their timetable, and were conducted only after they received their academic reports.

Although students were frequently reminded of the nature of the object of the study (that is, to investigate how students learn and understand the subject-matter knowledge), and were constantly invited to verbalize as much as what they know and understand about the specific subject content as possible, they still felt threatened. Despite acknowledging their responses in every aspect, students were still hesitant in certain aspects. They even attempted asking the researcher (who is also the subject teacher) to 'help' them answer the questions. To avoid signs of intimidation, a second revision was made highlighting the role of the researcher during the interview. The interviewer reiterated throughout each interview that she is taking up the role of a 'researcher' more than a 'teacher. The interview sessions were also held in 'relaxed' environment in an attempt to keep their level of anxiety to a minimum. The opening questions used at the beginning of the interviews were of 'inviting' rather than 'challenging' nature. Probing questions that function to lead participant's free flow of thoughts or ideas were projected through the attitudes of the researcher.

The 'assistance' that was constantly sought from the researcher during the interviews put forth the third revision, mainly focusing on the
appropriateness of the probes for the ‘think-aloud’ interviews. The possible impact of the probes to students, who might experience hard feelings when unable to distinguish between a questioning probe from a confrontational probe, was taken into account. The use of non-specific probes which brought in only superficial and unfocused descriptions (Portney and Watkins 1993) about the issues of concern in the pilot study was also avoided. Instead, probes more specific to the study were developed alongside the reconstruction of the interview tasks (Appendix B). The researcher became more aware of sustaining the effects of the probes to the anticipated responses given in task interviews.

The last revision focused on minimizing the stress level of the participants. Again, the interview was conducted in a friendly manner. Although the participants volunteered, attempts were still made to engage them to think aloud throughout the interviewing process. To avoid creating an impression that the interview is more of a form of oral test, prompting statements reminding them of their discourse were given throughout. There was no preset time frame for each question; responses were not inhibited at any point of time. Snacks and drinks were also served during the interviews.

4.2.3 Reconstruction of the Interview Tasks

Reconstruction of the interview tasks involved two parts. The first part was related to how the scope of the contexts in the tasks was set. The
students expressed great difficulties in describing their understanding while
reading the tasks, particularly with the second interview task. Most of them
expressed concerns of their inability to manage a large amount of clinical data
inherent in the problem context due to limited clinical experience in real
nursing settings. This concern led to modifications on the variation and
complexity of the task, particularly to the syntax used and the number of
questions embedded in each task.

The second part was associated with the presentation of the stipulated
task requirements in the interview tasks. According to Alexander and
colleagues (1993), the task requirements shown in a form of a connected
discourse text, should reflect a specific domain content which is facilitative of
the cognitive processing of the interviewed students. So at the onset of the
interview, it was made clear to the students that the interview tasks require
them to verbalize their understanding to the embedded situations and
develop relevant solutions. However, two students found it difficult to
verbalize their understanding of the subject matter in front of the researcher,
especially when they claimed they could not ‘talk to themselves’ about their
own thinking processes on the understanding of the context-specific content.
Thus, a third party was added to the task context by bringing in the role of a
‘less experienced nurse’ in the scene as an amendment to the preliminary
version of the interview task. The emergence of the ‘less experienced nurse’
not only allowed substantial intellectual processing of the subjects for the
study, it also allowed ways of sharing one's understanding to someone who knows very little about the subject content. This construct has greatly enhanced students' critical thinking abilities as well as increased their self-confidence regarding the perspective of another person who is inexperienced in this nursing field. A few wordings were also added to the two tasks to encourage the subjects in describing and keeping track of every single event, along with the reasoning process, to someone who is naïve to the subject-specific matters concerned.

Problem contexts must be constructed and defined to match the level of the students. The hurdles met by the students during the tasks in the pilot study brought the researcher's attention to the need of meticulous efforts in task construction for uncovering students' understanding of theoretical knowledge. The responses revealed various biochemical components and interactive episodes that were involved in the acid-base regulatory process. In Task 1, to minimize overloading of information, the simulated context simply asked students to describe their understanding about the significance of the 'regulation of acid-base balance' and the 'role of the respiratory system in the regulatory process'. The part on 'renal system in the regulation of acid-base balance' from the initial version was purposely eliminated. In Task 2, the ABG findings of the patient's condition guided the students in solving the nursing assessment problem. The findings provided an indication how the
characteristics and features of acid-base disturbances are associated with common respiratory problems in clinical settings.

4.3 Procedures of Data Collection and Data Analysis

In any data collection procedure, the structure of the interview and the framework of the analysis should reflect and inform the research paradigm with regard to unfolding the characteristics of the conceptions in students' learning processes and outcomes. During the data collection process (through interviews), simultaneous analysis of data is actually taking place since the responses given by the participants lead the interviewer to ask subsequent questions appropriate to explore the contexts that the subject previously referred to (Marton and Booth 1997). In short, the phenomenographic data collection and data analysis are inseparable. The close relationship of this inter-dependence is delineated in the following sections.

It is crucial that the researcher is familiar with the specifications prepared in conjunction with the goals of the interviews because as the interview progresses, patterns of responses and the key concepts of the content knowledge will start to emerge. Since the researcher is the expert of the contents and organization of the subjects' verbalizations, s/he has to determine how the responses should be interpreted in the context of the informants. The researcher, therefore, has to continuously ask himself /
herself, 'What kind of data will confirm my understanding?' 'What kind of data will enrich my understanding?' (Lincoln and Guba 1985; Patton 1990). The researcher, who was the interviewer for the 'think-aloud' sessions, paid absolute attention to uncover the inherent meaning of the students' verbalizations. The researcher also endeavoured to bring the interviewee's reflection back to focus throughout the problem-solving process. Probing questions had to be addressed to the student at any time the researcher was not clear of the verbal descriptions. On certain occasions elaboration was encouraged to re-evaluate and / or reconfirm the interpretations interviewees made to the critical aspects of the phenomenon earlier on (Marton and Booth 1997).

The pilot stage enabled the researcher to practice the skills of using probing questions during the interviews, as well as master the skills of facilitating 'think-aloud' descriptions and hitherto reflections. There were times when clarification and repercussion were required in the verbalization process; this provided an indication of the approximate time required for each phenomenographic interview. Although the subjects were expected to say aloud while embarking on the tasks, general interviewing guidelines were still observed (Babbie 1992). Since the interviewees were expected to divulge personal information about their learning while learning difficulties are also being unfolded, the interviewer tried to be as pleasant and friendly as possible - a sign of invitation and recognition to their responses. Each interview was
then audio-taped. The recorded interviews were transcribed verbatim; the verbatim transcript of each interview was then thoroughly analyzed.

4.3.1 Data Collection Procedures

4.3.1.1 Data Collection during the First Interview Task

In the data collection procedure, the students were asked to study the text of the task they were trying to verbalize their conceptions on before attempting to answer the questions. The following specific probes were asked:

- How do you read this text (problem)?
- After you read the text, how do you plan to respond?
- What are you looking for when you first read this problem?
- Which particular part of the passage draws your attention most?

Probing questions used to trigger informants' responses to a task are key features of a phenomenographic study (Marton 1986). Special probes could help trace every detail of the processes that contributes to a neat conceptualization. Here are some of the probes adopted for revealing the sources of their descriptions:

- When you write down the symbol 'pH', 'PCO₂' or 'ABG' here, what do you mean?
- Tell me more what you were actually thinking of when you listed out all the major components of the ABG profile.
- You are saying the acid-base regulation is important, why?
• You have described the normal values of the ABG test, and just now you try to say how the changes of pH indicate the acid-base imbalance. So tell me more what does the relationship between the ABG measure and the acid-base balance mean for you?

• How did you arrive at that point?

• What else would you like to add at this point?

For more information on the context in which the students' descriptions were based upon, readers are recommended to make references to the discussion of the biological science knowledge about the control of pH and ions homeostasis discussed in Chapter 3.

4.3.1.2 Data Collection during the Second Interview Task

In Task 2, students were requested to tackle a nursing assessment problem related to the respiratory nursing field, to incorporate their understanding on the areas of knowledge about 'the regulation of the acid-base balance in normal physiology', and to provide justifications when they explain it to a 'less experienced nurse' who does not know how to identify the nursing diagnosis of a respiratory patient. A clinical case summary was the premise where the nursing students applied his or her understanding; this application of knowledge was seen as the underlying reasons pertinent to the assessment of patient's health conditions from a nursing perspective.
Cues on the data of the client who has a common pulmonary problem in an acute hospital setting were documented in the clinical summary. These cues included age, gender, occupation, lifestyle, past health history, clinical manifestations, physical assessment findings and results of relevant laboratory examinations and tests, and, finally, current medical diagnosis. Each student was called upon to say aloud his / her thoughts on anything s/he ever comes across with. They were expected to clearly delineate and define the explanations of their understanding to the subject-specific knowledge. The students also made an effort of tracking every step or event in the thinking process, and justify each decision along the development of appropriate nursing diagnosis for the patient presented in the clinical case. They were expected to draw diagrams and flowcharts divulging the details of the cognitive process to answer the questions given in the task.

When students worked on Task 2, they were asked to study the text of the task thoroughly. Opening question raised were as follows:

- How do you read this problem?
- After you read the text, what does this problem mean to you?
- What are you looking at when you first read this problem?
- Do you go to the passage first or do you go directly to the question statements?

These probing questions were used to disclose the propositions underlying the students' understandings to the problem-solving tasks. As they
were addressing the issues or were attempting to respond, more probing questions were directed for the purpose of tracking their reasoning processes. Some of the examples used in Task 2 interview were shown:

- **Tell me more what you are actually thinking of when you say this factor is crucial to determine the severity of the health condition, and why?**

- **You are saying the presence of the vital signs is very important as it is closely relating to his current medical diagnosis. How do you notice that and what helps you to make such relationship?**

- **What are the key terms or the symbols you have identified from the text when you make this comment of the patient's situation?**

- **Why did you start from another perspective when you gave this definition? Can you elaborate or describe a little bit more about this?**

- **How do you make up this framework that you have described just now?**

- **What other information do you think is needed in order to solve this problem?**

In these two interviews, prompts were put forward when the students were thinking aloud their processes, for example a pause in the verbalization of hiccups. These prompts also acted as a reminder to students whenever articulation of the thinking processes was impossible, or whenever a request for further elaboration to sustain one's claims was needed.

- **Yes, I have got what you say!**

- **So, any more about this part?**

- **Ha, these are the ideas that you understood!**
• *What are you actually working on when you are saying nothing? (or when there is a pause)*

• *I missed the part when you explained this point, can you repeat it again?*

After the students attempted to apply their understanding of the biological science knowledge to the nursing assessment context, more soft probing questions were directed before they concluded their sessions. These questions meant to draw the reflection of the students to confirm the descriptions and reasons they had given along the problem-solving processes.

### 4.3.2 Data Analysis Procedures

This section discusses the procedures and techniques for the data analysis, starting with the search for extracts that unfold verbal descriptions of the students’ perspectives. These extracts were examined against two contexts: (1) in the context of other extracts drawn from all interviews that relates to the identical or related themes; and (2) in the context of the individual interview (Marton and Booth 1997). Though the sample was homogeneous, the research centered only on one aspect, conceptualization and problem-solving approach, seeking to realize the dimension of variation while holding other aspects frozen.

Variants in students’ expressed ‘ways of experienced’ were sought. Similarities and contradictions of the students’ expressed understanding to
that of the interviewer unfolded as two groups saw things differently. The pool of data contained two sets of materials, one pertaining to individuals and one pertaining to the group. Descriptions coming from the same subject were viewed from two different perspectives to provide two different contexts for discrete statements relevant to varying aspects of the object of research (Marton and Booth 1997). The researcher focused not only on the content of students' experiences. The dimension of variation among the subjects' descriptions of experiences was also examined.

To obtain reliable and objective observations, biases in the interpretation of raw data were avoided. Objective measuring procedures were used to generate rich and self-contained data. For this study, analyses of the protocols were complemented with sketch works done by the participants during the interviews. Observations made by the researcher also formed part of the analytic processes. Coding procedures and schemes were derived when analyzing the verbal protocol context using thematic data. The coding assigned to the segments was constructed from themes originally derived from the raw data analyses. Reflections on the characteristic elements in the raw data also helped draw distinct criteria in guiding further segmentation procedures.
4.3.2.1 Conduct in the Analysis Procedure

It is crucial that the researcher sets the tone for the analysis procedure, and determines what kind of information is specifically relevant to the domain of the study. During the analysis process, the researcher has to detach from the context where the students' conceptual understandings are delineated, although there is always an inclination to develop inconsistent explication especially when a large amount of data between cases is being processed. The researcher also has to develop critical analytic skills in steering the processing procedures and formulating a structure for a complete analysis of the data (Portney and Watkins 1993). The theoretical foundation of the researcher, therefore, is of utmost importance in prescribing the ways of initial segmentation. When themes with sustained characteristics are depicted, they could evolve to operational definitions of data-driven categories (codes) and eventually frame the direct multi-layered analysis and elucidation of the analysis procedure.

4.3.2.2 Actual Protocol Analysis Procedure

The protocols were delineated, qualitatively searched and described in terms of the relational, experiential and content-based aspects (Marton 1986, p.33).
Transcription of Verbalization

The first step of the data analyses involved the verbatim transcriptions of the audio-recorded interviews (hereby named as 'protocol'). In addition, more data were collected, such as the sketch work of the participants and the notes of the interviewer's observations during the verbalization. The transcribed protocols were printed into a text-ready format for the researcher to read through carefully and repeatedly. Data other than the subjects' verbal protocols were also inserted into the transcriptions as much as possible.

Segmentation

Research results on language understanding have demonstrated that boundaries of phrases in dialogues are marked by pauses (Erisson and Simon 1993). These pauses are usually realized when the participants failed to articulate their conceptual understanding, i.e. suggestions of a short break between ideas or proceeding to a new statement. Combination of these pauses and linguistic structure are signposts for making small segments of a verbal protocol. van Someren and colleagues (1994) suggested a clear methodology of analyzing think-aloud protocols by dividing it into segments. Segmentation is easily done on a printed text of completed transcribed verbatim. A special designed form for segmentation can also accommodate numbering system for protocol segments, allowing remarks to be given to each segment. The segmentation process for this data analysis step contributed to the formulation of a coding framework, which not only
enabled organization of the protocol segments for a provisional structure of subjects' representations, but also provided ease of retrieval of protocol fragments at any stage of the data analysis procedure.

*Actual Analysis and Coding Process*

The analysis and coding procedures mainly dealt with mapping a particular segment to the coding category within a coding scheme. After the segmentation procedure, the protocols were divided into considerable segments of verbalizations. Each segment was simply a reflection of an 'assertion' made by a subject at any given instance of reasoning behaviour on the task (Newell and Simon 1972; Hassebrock and Prietula 1992). The various identified episodes emerging from the fragments of statements formed the fundamental elements of the subjects' verbalizations during the problem-solving process.

In reviewing human problem-solving approaches, context-free isolated statements are often meaningless if there is no connection between the individual problem-solving behaviors and the problem situation (van Someren *et al.* 1994). The researcher believed that coding significant episodes was more reliable in analyzing human reasoning especially when this is not easily revealed through small fragments of statements. Thus, in the actual analysis, fragments of statements belonging to a particular coding category were highlighted in the printed protocol. Trunks of statements describing the
complicated cognitive processes and the theoretical elements in problem solving were accentuated for ease of acquiring multifaceted cognitive behaviors. The highlighted portions reminded the researcher of the specifications and the conceptual focus allured in each category. It acted as a reference guide to subsequent data analysis whenever the researcher had confusion recognizing some of the contents belonging to the identified coding categories. This mechanism also helped the researcher avoid collecting evidence that was either inappropriate or insufficient to answer the research questions in the study.

In the earlier stages of the protocol analyses, coding categories were constructed along the segmentation procedure, with the descriptions of each category acting as the operational definition of the coding categories. Each coding category denotes an abstraction of the complicated thinking process characterized by diversified patterns and specifications. To facilitate the coding process, printed protocols were formatted with wide margins so that writings of assigned codes and remarks were possible. The codes were either the characteristics or descriptions of each element; it could also be an episode contributing to one of the significant outcomes along the reasoning processes.

The development of 'categories of descriptions' from the participants' verbalization was the primary outcome of the research. Through a continuous
process of unrelenting scrutiny, the researcher reached a stage of data saturation when no more new category or theme was depicted. When data saturation stage was reached, a preliminary coding framework was formulated (Kavanagh and Broom 1997). Although it was envisaged that the framework constantly interacts with the philosophical input and methodological desires of the researcher, the coding categories in this study were primarily derived from the theoretical constructs and conceptual strategies of the students' verbalizations.

Relevant coded protocols composed of a range of coding categories characterized with attributes or properties of distinctive pursuits were thereafter obtained by adopting the proposed coding framework. This coding scheme provided an explicit tool for documenting behavioral events and serving as a guide for structuring the protocol analysis (Hassebrock and Prietula 1992). This self-contained coding framework also distinguished the levels of representations from the protocols of the subjects in this study.

*Identifying an Analysis Protocol for Problem Solving Studies*

Problem-solving studies normally focus on the investigation of cognitive processes associated with the interactions between the individual and the task context. Chi, Glaser and Faar (1988) pointed out that skillful problem solving is contingent on the knowledge of the problem solver on a particular domain as well as the experience in applying that knowledge in the
context of domain-specific problems. In a problem-solving study context, it is impossible for a few verbal statements or several descriptors to represent a category code. As each protocol involves multi-layered sub-processes and information, it is usually the task of the researcher to transform these verbalizations into a more meaningful representation of the subjects. A coding framework which eases the interpretation of verbal protocols, making it more systematic for the data analysis, is required.

Analysis of think-aloud protocols is one approach of revealing the knowledge and cognitive processes used by a person while performing a task because the data analysis methodology favours the 'discovery of the intellectual processes' (Hassebrook and Prietula 1992). For this study, the continuous stream of verbalizations was regarded as evidence for understanding the processes involved in the underlying representations of knowledge as well as the covert reasoning and associated conceptual operations that contributed to a problem solving task. In Task 1, for example, the analysis orientation of the research depended primarily on the knowledge of the subject matters and the reasoning involved in understanding this domain-specific content. Besides the notion of data-driven analysis, the analysis procedure was also affected by the researcher's knowledge of nurses' problem-solving through vigilant observations of the performances of nurse problem solvers in various nursing contexts. Reading a wide range of
literatures about problem solving studies also enlightened the researcher to search for ways of improving nurses' problem solving abilities.

To investigate how individual nursing students learn and adapt to a nursing domain where they reason and apply the acquired knowledge according to the emerging contextual demands (Hassebrock and Prietula 1992), modifications and development of the framework for verbalizations coding were only made appropriate for the subjects in this cohort. The operational definitions of coding categories not only guided the protocol analysis, it also formed the basis for formulating a prototype coding scheme. The domain-specific coding scheme elucidated the protocols into meaningful representations of their conceptualizations as well as applications of these conceptualizations. For example, part of the nurses' problem-solving processes emerged during the initial stage of recognizing written representations of the tasks. Characteristics of the sub-processes of data recognition were also recognized. Codes were then assigned to these characteristics before they were used to extract segments of protocols that specify the cognitive processes and the involving conceptual operators. The knowledge states and the specific cognitive strategies were individually identified, forming the categories of descriptions implying the levels of conceptualizations and the problem solving approaches among university nursing students.
The researcher has summarized the mental processes in developing the analysis protocols for this study as follows (Figure 4.1):

**Figure 4.1  Overview of Protocol Analysis**

- Raw protocols
  - Segmented protocols
    - Theoretical foundation
  - Predicted coded protocols
    - Preliminary coding scheme
  - Coded protocols
    - Confirmed coding scheme

The printed protocol was formatted in a four-column table. The first column contained the category number (code number). The 'category' column (column 1) was the space where the researcher specified the code that the following excerpts entailed. The second column specified the segment
number that was given to the raw protocol. There were two level of analyses conducted on each segment listed in column 2. The knowledge (such as the definitions and classifications, the hypothesis, the data interpretations, and features of pathophysiological conditions) used for the conceptualization by the subjects were all indicated by underlined keywords or fragments shown in column 3. The third column was the excerpt describing the verbalizations of the knowledge base extracted from the protocols. The last column was the conceptual operators and strategies (such as skills in searching and analyzing, comparing and contrasting, associating, monitoring and evaluating) identified along the descriptions of statements.

4.3.2.3 Categories of Description Characterizing Conceptualizations and Problem-Solving Approaches

Knowledge about domain-specific problem-solving behaviors can help articulate and appreciate the representations of the interactions between the nursing students’ domain-specific content and the demands of the problem-solving tasks. The descriptions labeled to the protocols are also essential elements of potential conceptualization or problem-solving approaches. It is also necessary to maintain the truthfulness of the data hence the findings must be consistently data-driven.

The data interpretation behavior was assumed as a type of problem-solving approach as it pertained to a different orientation through the
problem-solving process. In fact, the statements coded in the problem-solving protocols of Task 2 indicated that some students have different interpretations of the signs and symptoms of the client in the simulated case. As segments were subsequently extracted from the protocols and identified as a sub-category of a code, descriptions depicting the representations of behaviors in various stages of problem-solving process were gathered and constructed as a coding category. For example, within the ‘logical integrated’ approach, students exhibited a few problem-solving behaviors: registering all written information and recognizing the cues, framing the events and the relationships within a derived principle, formulating and confirming hypotheses, evaluating and verifying the evidence to the solution etc. Descriptions of these sub-processes hence became the sub-categories of this problem-solving approach.

After providing the descriptions of the sub-processes derived from the protocols, an initial framework of conceptualizations and problem-solving process for Task 1 and Task 2 was developed. The framework was not constructed for the purpose of setting a standard (Corcoran-Perry et al. 1999). Instead, they were used as guides for the data analyses. If the verbalization of the participants were different from the guides, a new framework was established to represent a new distinct concept and problem-solving approach. They included information about cue gathering and interpretation, reasoning and decision-making (rationales or arguments), and
conclusions made by the participants. Indeed, the framework documented both the accuracy and erroneous representations of the conceptualizations. It also helped decrease coding subjectivity and increase coding reliability (Corcoran-Perry et al. 1999). Every subject’s framework was represented as a template, a unique form of conceptualization or problem-solving process that a subject attended to in the presented interview tasks. The template covered the knowledge content, the cognitive processes and the arguments made by the students.

Code labelling was carried out for individual protocols. Codes of similar content (i.e. the conceptualization and the problem-solving approach) were then compared with one another to ensure that categories of descriptions can be distinguished according to similarities and differences. Individual problem-solving approaches were also treated as a distinct representation of problem solving. The demarcation between variations among the approaches was driven by insights generated within the research data. Attributes and features of problem-solving processes were obtained directly from overt verbalizations; ‘alternative problem-solving approaches’ only emerged after meticulous analysis was carried out. From a phenomenographic perspective, the problem-solving approaches that were recognized composed the ‘categories of descriptions’ in the study.
4.3.2.4 Relationship Between the Bio-Medical Knowledge Conceptualization and the Problem Solving Approaches

Through the analysis of the findings of the two tasks, an understanding of how the students used their knowledge base to tackle the domain-specific problem was exposed. The matching of these conceptualizations to the problem-solving approaches also served as a window of determining whether the knowledge acquired and understood was applied to the problem-specific context. This approach served not only as a platform for examining the relationships between these two elements, the researcher was also able to realize the tactics of promoting the transfer of students' knowledge to the nursing task context.

4.3.2.5 Internal Validity of the Analysis Outcomes

Prior to analyzing the protocols, no attempt was made to identify the students. This has greatly reduced the level of bias in the analyzing process. A number-checking system was used to enforce internal validity, and participants were given a chance to review and proofread the transcribed verbatim. The students were also asked to check the initial outcome of the analysis. When students have difficulties commenting on their discourses, explanations about the characteristics of each category together with the coding scheme adopted in the study were provided until they agreed to the researcher's interpretations of the representations of their verbalizations.
4.4 Validity and Reliability of Phenomenographic Studies

Phenomenography is about describing people's experience of various aspects of the world, the objective being to find out the object of experience and the content of thought. The focus of this research approach is on the descriptions of the world and about the people experiencing it (Marton and Booth 1997). Efforts are made to uncover the understanding students have on a specific phenomenon, and to sort them out into conceptual categories. Usually, a second-order perspective to see and describe students' conceptions of reality is taken (Marton 1986; Marton and Booth 1997).

In this particular study context, phenomenography took on a different mode. There was no intention to enforce any philosophical explanation to describe what the students were experiencing. The research only focused on the biological subject matters students learned, dealing with students' representation of the underlying ways of conceptualizing the subject content, or ways of experiencing the learning situation. And by doing so, it clarified what their experiences meant in the domain-specific content. The obtained data from the interviews were also analyzed from the students' perspectives. Categories of descriptions, the variation in ways of experiencing the conceptualization and its application, were the primary outcomes of the study. The following question guided the research, "What are the critical aspects of ways of conceptualizing and experiencing the reality that enable the students to manage it in a better way"? Within this framework, the most
essential and distinctive structural aspects of the relation between the individual and the phenomenon presented to them, which could either be the subject matter, the learning task, or the problem situation, were looked at.

The validity of the study was enhanced by careful construction of the interview tasks and the interview protocol. The structure of the interview and the probing questions used in the interviews were also designed to encourage student's verbalizations. Similarly, the reliability of the study was ensured by the responses of the subjects given to the interview tasks in the pilot study. All the students understood the requirements of the tasks and attempted to describe their understandings to the situations embedded in the tasks. In the subsequent data analysis procedure, the essence and the detailed descriptions of the conceptualizations and the understandings of the nursing situation were always recognized from the perspectives of the students.

The frameworks of the participants' conceptualization and problem-solving approaches were sent to two nurse experts for validation. These experts have strong background knowledge in advanced physiology studies and years of solid experiences in acute care settings. Serving as consultants, they explicated the specific knowledge content in a particular domain and cited the cognitive processes and the rationales that the subjects used during the conceptualization and problem-solving process. This was a valuable opportunity of revealing alternative concepts and approaches that could be
easily overlooked by the researcher. Accurate and inaccurate cues finding, flaws in the interpretations of cue clusters and faulty reasoning could also be spotted before the commencement of the main study. When comparing the level of agreement between the two experts in the validation exercise (Pope, Ziebland, and Mays 2000), discrepancies identified between both parties were resolved through thorough discussion. Hence, the findings were by no means based on the subjective judgments of an individual researcher alone.

4.5 Ethical Considerations

Ethical approval was sought from the “Committee on Ethics in Research on Humans” of the University. During the briefing session prior to the commencement of the study, the potential participants were fully informed of their roles in undertaking the interviews. Questions about the purpose(s) of the study were also clarified and answered. The participants were also told that they could withdraw from the study anytime without any obligations. Only students who signed the interview appointment form as an indication of their consent were approached. A total of twelve students volunteered to participate in the study. Pseudonyms were used throughout the transcribed verbatim, thus anonymity was strictly observed throughout. The verbatim interview was kept in a locked cabinet; no access was granted except to the researcher. Data obtained from the study was only disclosed for the purpose of disseminating the research findings. After the data coding and
analysis stage, all the data will be kept for three year and would be destroyed afterwards.

The interviewer was aware of the sensitivity of the interviewees, particularly when the participants developed a sense of negative feeling as a result of failing to tackle the problem solving part due to insufficient reasoning or application of one's knowledge base. When participants felt inferior on their inability to recall and retrieve the relevant data required for the tasks, the researcher showed utmost care. Although some subjects demanded assistance during the interviewing process, the researcher-teacher-interviewer did not compromise to the request. Respect and courtesy for students' uneasiness, in particular when they considered the task to be a formal assessment, was shown. Besides the choice of the interview setting, the attitude of the researcher also promoted a relaxed atmosphere, allowing for students' free articulation of problem-solving processes.