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Design, development, and psychometric analysis of a general, organic, and biological chemistry topic inventory based on the identified main chemistry topics relevant to nursing clinical practice

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DESIGN, DEVELOPMENT, AND PSYCHOMETRIC ANALYSIS OF A GENERAL, ORGANIC, AND BIOLOGICAL CHEMISTRY TOPIC INVENTORY BASED ON THE IDENTIFIED MAIN CHEMISTRY TOPICS RELEVANT TO NURSING CLINICAL PRACTICE

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has been accepted as meeting the requirement for the Degree of Doctor of Philosophy in the College of Natural and Health Sciences in the Department of Chemistry and Biochemistry, Program of Chemical Education.

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ABSTRACT

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This two-stage study focused on the undergraduate nursing course that covers topics in general, organic, and biological (GOB) chemistry. In the first stage, the central objective was to identify the main concepts of GOB chemistry relevant to the clinical practice of nursing. The collection of data was based on open-ended interviews of both nursing and chemistry teaching faculty as well as practicing nurses. From the resulting interviews, three themes emerged: topics that were Important--had a direct application in nursing clinical practice; topics that were Foundational--not directly important for nursing clinical practice but facilitated the understanding of the important topics; and topics that were Not Important--did not have a direct application or were not significant in nursing clinical practice. Utilizing the data collected, a list of clinically relevant chemistry concepts was developed. The resulting list was compared with the opinions of nursing and chemistry faculty at the national level.

The second stage involved the design and development of an assessment in the form of a concept inventory. The General, Organic, and Biological Chemistry Concept Inventory (GOB-CTI) is a 45-item, multiple-choice instrument designed to assess students' conceptual understanding of the main chemistry concepts identified as essential in clinical nursing practice.

This dissertation describes the developmental process of the individual items along with an evaluation of a pilot version of the instrument. In developing items for this instrument, essential concepts were identified through a series of expert interviews and a national survey. Individual items were tested with students from the target population for clarity and wording. The pilot version of the instrument contained 67 items covering the range of identified concepts from the first stage. The pilot version was tested with a sample of 458 students and a revised version tested with a sample of 200 students. Data from the two pilot studies were used to evaluate each item and narrowed the total item count to 45. A detailed analysis is given to illustrate how items were selected and/or modified for the final version of the instrument. A psychometric analysis performed on data from the 45-item final version was used to evaluate validity, reliability, and item statistics. The final version of the GOB-CTI has a Cronbach's alpha value of 0.763. An expert panel assessed face and content validity. Convergent validity was established by comparing the results from the GOB-CTI instrument with the General-Organic-Biochemistry Exam (Form 2007) of the American Chemical Society (GOB-ACS).

This instrument was developed in collaboration with nurses, nurse educators, and chemistry instructors to focus attention on the subset of chemistry concepts deemed essential to practicing nurses. By using this concept inventory, chemistry instructors may better understand the incorrect ideas and difficulties their nursing students have in chemistry.

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"Two roads diverged in a wood, and I,
I took the one less traveled by,
And that has made all the difference."
Robert Frost

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CHAPTER I

INTRODUCTION

There have been significant changes in nursing and nursing education in recent years. The roles of nurses have changed and are becoming more complex and more demanding. The current expression in the nursing world, “high touch, high tech,” reflects the need for nurses to demonstrate the ability to combine humanistic skills with scientific knowledge and technological elements. Nurses should possess a high level of critical thinking skills and positive self-efficacy in the profession, especially in troubleshooting situations (Simpson, 2002). For example, general care nurses must be cognizant of the cytotoxicity and potential side effects of different drugs, drug dosage and concentration, and waste disposal of byproducts of toxic drugs (Scalise et al., 2006). It is important that nurses question, analyze, and make decisions based on appropriate scientific knowledge. Because of the increased expectations of nursing as a profession, the need for a strong scientific foundation is more imperative.

The research in this dissertation focused on a general, organic, and biological (GOB) chemistry course that covers basic topics in GOB chemistry. The course is a requirement in the nursing program of the institution at which much of the research was performed. It is a course typical of the chemistry course(s) required nationally by Bachelor of Science in Nursing (BSN) programs. The students in the course were mainly allied-health majors, especially nursing.

Studies concerning science courses required for nursing programs suggest that nursing students are challenged by bioscience courses, have negative attitudes toward the relevance of science, and lack confidence in studying these subjects (McCabe, 2007).

Statement of the Problem

This research study focused on an undergraduate course that covers a broad range of topics in GOB chemistry at a mid-size, western U.S. state university. The quandary of what should be taught in GOB chemistry and how it should be taught in allied-health programs is not trivial. This problem is heightened given the anxiety of pre-nursing students who fear that requirements of the course may close doors and opportunities for them (Jordan et al., 1999; McCabe, 2007). Undergraduate nursing students often feel stressed by the cognitive load and content detail in their program (Nicoll and Butler, 1996). Despite the need of nurses for more knowledge in science, the nursing education literature shows that the level of science knowledge is far from being fulfilled (Scalise et al., 2006). While many studies document the importance of science content within nursing undergraduate programs, the depth and breadth of the content to be taught remains unclear (Friedel and Treagust, 2005). Research has identified that appropriate bioscience content knowledge possessed by nurses enhances their practice and that the incorporation of suitable scientific knowledge will help nurses in their clinical judgment and safe nursing practice (Torrance and Jordan, 1995). According to constructivism, the primary learning theory currently utilized by many chemistry educators, educators cannot transfer knowledge they possess directly and intact to the students. Students must "build" the knowledge on what they are given, thus making knowledge gain a highly personal process. Consequently, it is important to help pre-nursing students build their own

knowledge to be successful with the course and ultimately in their profession. Therefore, there is a need for exploration of different teaching approaches and assessment for such a high cognitive load and time-demanding course as GOB chemistry.

Purpose of the Study

The overarching goal of the research consisted of two major objectives. The first objective was to identify the main concept of GOB chemistry relevant to the clinical practice of nurses. Based on these topics, the second objective of the project was to develop and test a GOB chemistry topics assessment instrument. Consequently, this study initially involved identification of topics in the GOB chemistry course that are relevant to the clinical practice of nurses. Walhout and Heinschel explored the perspective of nursing professionals regarding the ranking of topics included in a nursing chemistry course. Although there has been a multitude of advances in medicine during the two decades since their study, there were no additional published studies pertaining to the main chemistry topics nurses should understand in order to be good practitioners. Also, there were no studies available comparing perspectives both among nurse educators and GOB chemistry instructors and between the two groups regarding the relative importance of the various topics.

After identifying the main topics relevant to clinical practice, the next phase of this research was the design and development of a GOB chemistry concept assessment (a concept inventory). In the last two decades with the advent of the Force Concept Inventory (Hestenes et al., 1992), concept inventories have been developed and used to identify students' alternative conceptions in different areas of science and engineering (Richardson, 2004). Despite the abundance and progress of concept inventories in

different areas of science, there is a void of conceptual assessment in the area of biochemistry (White, 2005). Only a limited number of conceptual questions have been developed by educational researchers to obtain qualitative data on students' alternative conceptions in topics such as metabolism (Grayson et al., 2001, Anderson and Grayson, 1994), protein synthesis (Kaplan and Saccuzzo, 1997), and antibody structure (Schonborn et al., 2002). There is currently no published concept inventory in the area of GOB chemistry.

It is anticipated that the instrument developed in this research will provide a tool to measure students' learning of the selected topics and determine whether students have the required knowledge to successfully manage other courses in the nursing program that require the fundamental knowledge of GOB chemistry. Additionally, the instrument can be used as a guide by the GOB instructor to monitor learning of the important topics taught in a GOB chemistry course deemed relevant to nursing clinical practice.

Research Questions

This study investigated the main topics of a GOB chemistry course perceived as relevant to nursing clinical practice and the assessment of the pre-nursing students' conceptual understanding as framed by the following research questions:

Q1 What are the topics in a GOB chemistry course that are perceived by experts to be relevant to nursing clinical practice?

Q2 Is there a consensus among the nursing educators and GOB chemistry instructors and between the two cultures regarding the topics perceived to be relevant?

Q3 How does one appropriately measure pre-nursing students' conceptual understanding of the topics perceived by the experts to be relevant to clinical practice?

Significance of the Study

This study enabled the identification of the main GOB chemistry topics perceived by experts to be relevant to the nursing clinical practice. The collaboration with nurse educators and GOB chemistry instructors in identifying the topics is a novel element of the study and a way of building a bridge between the two cultures of chemistry and nursing. The information can assist the GOB chemistry instructors to better understand which topics to emphasize in their teaching. The study also can inform the nursing instructors of courses such as of pathophysiology, nutrition, and pharmacology about the level of chemistry knowledge of the students who enter into the nursing program. By associating these topics with clinical examples, the pre-nursing students should be more motivated to learn (Pintrich et al., 1993). The results of this study support that experts from the two cultures agree that these chemistry topics would make more sense if they were taught in the context of relevant examples to nursing practice. Ultimately the nursing student's self-efficacy toward chemistry may improve which could directly impact his/her confidence with the nursing profession (Friedel and Treagust, 2005). The topics identified in this study are those perceived by experts to be the most relevant to clinical practice; it should be a goal that by the end of the GOB chemistry course, the pre-nursing students have a good understanding of these topics.

The relevant topics identified in this research were used to develop a GOB chemistry concept inventory. With a GOB chemistry concept inventory, chemistry instructors will have the opportunity to evaluate and understand the knowledge level and difficulties that the pre-nursing students have with chemistry, especially with these main topics identified to be important to the nursing clinical practice. Without understanding

these topics, student learning is a collection of memorized facts and problem solving algorithms. By using this concept-based assessment, instructors may better understand how to assist these students to become more successful on their paths in the health sciences. The instrument will be a beneficial addition to the few existent conceptual assessments in the area of biochemistry. Ultimately, the research established a framework to build a bridge between the two cultures of chemistry and nursing.

General, Organic, and Biological Chemistry Course

The GOB chemistry course is the only chemistry course the pre-nursing students are required to take at the University of Northern Colorado where much of the research took place. It is a five-credit course that counts double in the students GPA for admittance into the nursing program. The population of this class is primarily freshman- and sophomore-level students. This course consists of four hours of lecture and three hours of laboratory per week. In a typical 15-week semester, the course rapidly progresses from atomic structure, bonds, and acid-base chemistry, to organic chemistry, and to biomolecules and their metabolism. The class has a high cognitive load due to the multitude and variety of topics presented. The prerequisite for the course is high school chemistry or CHEM 103, a remedial general chemistry course. The combined dropout/withdrawal/ and failure rate of this course is approximately 25%-30% (personal communication).

Initially, the nursing baccalaureate program at this particular university required a two-semester sequence of chemistry. The first semester course (five-credit hours including lab) consisted of approximately two-thirds general and one-third organic chemistry; the second semester course (five-credit hours including lab) was

approximately one-third organic and two-thirds biological chemistry. This course was recommended to be taken in the freshman or sophomore year and was listed under the nursing program requirements. In 2003, the Nursing School revised their curriculum and requested that the two-semester course be condensed into a single-semester five-credit hour course including lab. The current CHEM 281 “Fundamentals of Biochemistry” was designed by Richard M. Hyslop to meet this request. The course was piloted in the Spring of 2004 and became the course that it currently is in the Fall of 2004. The Department of Chemistry and Biochemistry offers CHEM 103 as a recommended prerequisite course for CHEM 281. CHEM 103 is a course suitable for students who have not had high school chemistry or for those who need a remediation of the subject material.

Delimitations

This study potentially can be subject to the following delimitations:

1. The instrument design and the results collected with this instrument are pertinent to a GOB chemistry course designed to be taught in one semester.

2. The research investigated the understanding of the main topics relevant to clinical practice by pre-nursing students enrolled in a GOB chemistry course at two universities. The instructor effect or the individual demographics such as gender, age, and previous science background were not analyzed, although these variables could have an effect on the outcome of the study.

3. The sample of experts included nurse educators, nursing graduate students with a minimum of two years nursing practice experience, and GOB chemistry instructors that volunteered to participate in the study. This made the sample a convenience sample

instead of a random one. Also, the sample of the students enrolled in the GOB chemistry course who volunteered to participate in the study was a convenience sample.

4. The results are applicable only to a GOB chemistry course and not to all the chemistry courses that may be requirements in different nursing programs.

5. The larger the number of respondents, particularly greater than 200, the better the study results or the study “power” (Houser, 2008). A study with high power has a greater chance of yielding significant results. Larger samples tend to yield normally distributed data, which are more easily generalizable. A survey at the national level will strengthen the generalizability of the study. Though a survey was done, the final analysis of the survey was not part of this study.

Definitions and Abbreviations

Alternative Conceptions

The scientifically inaccurate understanding that individuals have developed about a natural phenomenon. Alternative conceptions are topics held by individuals that are inconsistent with the accepted scientific definition or understanding of that concept (Treagust, 1998).

Biosciences in Nursing

McKee (2002) identifies biosciences relevant to nursing practice as chemistry, biochemistry, genetics, anatomy, physiology, microbiology, nutrition, pharmacology, and pathology.

Concept Inventory

A multiple-choice instrument designed to evaluate whether a person has an accurate, working knowledge of a specific set of topics (Richardson, 2004).

Distracters

The incorrect answers to a multiple-choice question.

General, Organic, and Biological Chemistry

This course is a survey of the general, organic, and biological chemistry topics designed for allied-health science majors.

General, Organic, and Biological Chemistry Topic Inventory

The GOB-CTI is a multiple-choice instrument that aims to assess conceptual understanding of the main GOB chemistry topics relevant to nursing clinical practice.

Nurse Educator

A professional who prepares and implements a nursing education program and prepares students to qualify for licensure as a registered nurse.

Self-efficacy

Peoples' judgments of their capabilities to organize and execute courses of action required to attain designated types of performances. It is concerned not with the skill one has, but with judgments of what one can do with whatever skills one possesses (Cousin, 2009). Self-efficacy beliefs are investigated by asking individuals to report the level, generality, and strength of their confidence to accomplish a task or to succeed in a certain situation (Pajares, 1996).

Social Constructivism

The belief that individuals construct their own realities and that "learning is a social process of making sense of experience in terms of extant knowledge" (Orgill, 2007).

Theoretical Framework

A system of ideas, aims, goals, theories, and assumptions about knowledge, how research should be conducted, and how research should be reported; a theoretical framework is the analytical instrument of education research.

Topics

Topics are broad content areas that can encompass multiple topics.

Organization of the Study

The research described in this dissertation encompassed a multi-faceted study that utilized qualitative, quantitative, and psychometric research methods. In the design of this research, several steps were employed. The main phases of the project were: 1A. Identification of the main GOB chemistry topics relevant to nursing clinical practice; 1B. Validation by experts of open-ended questions based on the main topics of GOB chemistry; 2A. Determination of what students think about the topics and why; 2B. Identification of distracters based on students' alternative conceptions; 3. Development of multiple-choice questions pertaining to the main topics perceived by the experts to be important or foundational; 4. Utilization of the instrument in data collection; 5A. Item analysis; 5B. Review and refinement of the instrument based on item analysis results; 6. Second round of data collection and comparison of the instrument results with the General-Organic-Biochemistry Exam (Form 2007) of American Chemical Society (GOB-ACS) results; 7. Presentation of the instrument based on valid and reliable data. Each of these steps are described in detail in appropriate chapters of the dissertation.

The body of this dissertation contains six chapters. Chapter I presents an introduction, statement of the problem, purpose of this study, the research questions,

definition of terms, delimitations of the study, and organization of the study. Chapter II proceeds with a review of the literature relevant to the importance of bioscience in nursing and concept inventories. Chapter III describes the general methodology, framework, and procedures that were employed to gather data for each phase of the study. Chapter IV and Chapter V provide, in the form of two manuscript articles, the analysis, results, and discussion of the data collected in different stages of this dissertation study. Chapter IV concentrates more on the qualitative aspect of data collection and formulation of a list of chemistry topics relevant to the nursing clinical practice. Chapter V describes the design, development, and psychometric analysis of a General, Organic, and Biological Topic Inventory (GOB-CTI). Chapter VI presents a summary and conclusion of each research question posed, the implications of the study, and future research.

CHAPTER II

REVIEW OF THE LITERATURE

The literature review presented in Chapter II is organized in two parts. The first part of the chapter is focused on literature related to the role of biosciences in nursing education. The perspectives of nurse educators, chemistry instructors, and nursing students of bioscience in the nursing program are presented. The second part of the chapter reviews the research related to the development and psychometric analysis of concept inventories.

Biosciences in Nursing

During the past 50 years, nurse education internationally has changed significantly from a hospital-based apprenticeship system to more academic programs and in some countries to degree-level programs. Also, there have been significant changes in the nursing profession and the roles of nurses have changed significantly (Friedel and Treagust, 2005). Nurses are expected to assume more diverse roles and increased leadership responsibilities such as to be autonomous practitioners, prescribe medication, perform patient education, and make decisions regarding the patient's condition (Bullock and Manias, 2001). Since the roles of the nurse are changing and there is an increase in expectations of nursing as a profession, the need for a strong scientific foundation is more demanding. Nurses must keep pace with the increasing complexity and diversity of their roles as well as with the new knowledge and technical

skills of the field (Banning, 2003, Prowse, 2003). It is important that nurses question, analyze, and make decisions based on appropriate scientific knowledge, which generates the need for the nursing students to be exposed to an extensive knowledge of biological and physical science topics for a competent and safe practice (Casey, 1996). It has been proposed that bioscience knowledge also improves the communication between nurses and other professionals and the communication with the patients (Jordan and Huges, 1998)

A Brief History of Biosciences in Nursing Education

Modern nursing education attributes its beginnings to Florence Nightingale with the founding of the Nightingale School of Nursing at St.Thomas' in London. This was the first school in which students followed a defined curriculum and received training in different aspects of nursing. The students received theoretical training coupled with clinical experience in the hospital ward. In the United States, the nurses' work during the Civil War brought to light the value of a formal education for nurses. Three years after the end of the U.S. Civil War and thirteen years after the opening of the first Nursing School in London, the first three Nursing Schools opened in the United States (Webb, 1997).

The study of life sciences has been part of the nurse education curriculum since 1922, when the life sciences were introduced into the General Nursing Council Syllabus in England and Wales (Giorgi, 1985). For decades, nursing and nursing education was subordinate to the medical profession. The biosciences were taught according to a medical model of care. In this model, nursing relied on medicine to define and teach the necessary content of biological sciences (Giorgi, 2000). Because of this dominance,

some people, even presently, may feel the role of nurses is only to support the medical staff and carry out the instructions of the physician. Spouse (2000) analyzed nursing students' images of nurses and the nursing profession and the effect of these images on their practice. Some of the students perceived the role of a nurse "as a nurturing relationship, requiring angelic patience, good humor, and compassion beyond normal endurance." These images and perceptions are supported by the media as well as some of the nursing instructors. According to the media, nursing practice equates to acute care settings facing life and death drama, in which nurses perform skillful practice with technical equipment and administer drugs (Friedel and Treagust, 2005). Some nursing instructors emphasize in their teaching the skill nurses perform giving the students the perception that this is the aspect they should accord special attention (Barnard, 1999). It is thought that the ability to critically think and analyze critical situations is the job of only the physicians.

The Report of the Committee on Nursing (Briggs, 1972) recommended changes in nursing education and emphasized the need to make the nursing profession distinct from the medical profession. This recommendation revealed the difference in opinion regarding which aspect of nursing, either the scientific or humanistic, should be emphasized. Holford (1981) considered that physiological topics such as the "chloride shift" make no difference to the ability of the nurse to care for a patient in distress. He suggested that the responsibility of the medical staff is to study the physiology of the process; the nurses are responsible only for patient care. In the desire to gain independence from the medical model of nursing and gain recognition as a distinct profession, nursing education has leaned towards the social and behavioral sciences such

as psychology and sociology (Trnobranski, 1997, Chapple et al., 1993). The orientation toward the social and behavioral sciences has had an influence on the way the biological sciences where taught, perceived, and used by nurses. According to the UK nursing education literature, part of the curriculum accordingly was dedicated to psychosocial sciences so there was less time allocated to biosciences (Davies et al., 2000, Chapple et al., 1993, Trnobranski, 1997). Wynne et al. (1997) argue that nursing may develop a form of "incomplete holism." According to these mentioned authors, the concept of holism is defined as "the acceptance that health is determined and defined by inter-related social, psychological, and biological factors."

Wilson (1975) presented one of the first studies in the area of biological sciences in relation to nursing highlighting that bioscience knowledge is "unstructured and appeared to be haphazard" in nursing education. Akinsanya and Hayward (1980) have called for a systematic study of biological sciences and defined the bionursing model in an attempt to make biological sciences more applied to nursing. Although the goals of medicine and nursing are not mutually exclusive, Akinsanya suggested that there is a difference in perspective in the way that nurses and doctors use their knowledge of biosciences in practice. Doctors tend to make decisions at the micro level, while nurses use biosciences more at the macro level. Based on these observations, the necessary bioscience knowledge should be taught independently from that of medicine in a more relevant way to the nursing clinical practice (Akinsanya, 1984).

The neglect of biological and physical sciences that relate to nursing in favor of the behavioral model of nursing has led to an imbalance in nursing knowledge which

hinders the nurse's ability to practice safely. The behavioral model of nursing care has had the effect of devaluation of biosciences (Jordan, 1999; McVicar and Clancy, 2001).

There has been an ongoing debate about the role of biosciences in nursing, what content is relevant to nursing practice, and the depth and the way it should be taught (Charlton, 1991, Courtenay, 1991, Gretsy and Cotton, 2003, Davis, 2010). In a recent UK study (Davis, 2010) with registered nurses undertaking a program of study to become non-medical prescribers, it was revealed that nurses have limited biological science knowledge. The study investigated nurses' perspectives regarding studies in biosciences in their pre-registration nursing courses. This case study was based on questionnaires and interviews. Questionnaire analysis identified that 57.1% of participants (n = 42) indicated biosciences in their pre-registration nursing program had been limited and 40.5% stated the biosciences content had not prepared them for their roles on registration. Those reporting extensive coverage of biosciences were all over 41 years of age and had qualified before 1995. The greatest coverage of biosciences in pre-registration programs was reported in relation to anatomy and physiology, with relatively limited coverage of microbiology, pharmacology, or biochemistry. Respondents considered all five topics to be important.

In the current U.S. Bachelor of Science in Nursing (BSN) degree program, biosciences are presented to nurses initially in their prerequisite science classes. In the nursing program of the university at which this dissertation research took place, courses such as General, Organic, and Biological (GOB) chemistry (Fundamentals of Biochemistry), Biology, Anatomy and Physiology, Pharmacology, Pathophysiology, and

Nutrition in Health & Illness are prerequisites for acceptance into the nursing degree program.

Biosciences and the Theory Practice Gap

Nursing students encounter difficulty in transferring their knowledge into practice. Research in nursing education has revealed a disconnect that exists between what is taught in courses and what is required for practice. The practitioners have difficulty in relating theory to practice. This discrepancy is referred to as the theory practice gap (Caon and Treagust, 1993, Jordan et al., 1999, Gretsy and Cotton, 2003). This discrepancy between theory and practice was first documented in England by the Lancet Commission on Nursing (1938) and presented again by the Platt Report (Hector, 1964). Biosciences are important to nursing education; however, students do not always see a clear link between bioscience theory and clinical practice (Clancy et al., 2000). Akinsanya (1987) and Tronbranski (1993) suggested the need for the adaptation of "pure" science in order to be more suitable to the needs of the nursing profession. Often the science content presented to nursing students is too detailed and creates difficulty for the students to determine what is important for clinical practice (Chapple et al., 1993). Barnard (1999) conducted a qualitative study that explored the perceptions of Australian nursing students, nursing instructors, and science instructors regarding the science and behavioral content in the nursing program and their perception of the relevance of such content to clinical practice. The study analyzed the factors that impact the integration of theory and practice. The analysis of data collected through a survey, interviews, and field notes resulted in several key themes. One of the themes was that perceptions about nursing could influence content selection and depth of study. The students appreciated

what was relevant based on their own perception of what nursing clinical practice may imply. The instructors decided on the content taught based on their own perception of the world of nursing practice. This perception not always considered how the nurses should think and solve problems but rather from what was thought they actually do. Relevance and applicability of content was described based on perceptions of the reality of nursing practice. The findings are consistent with other reports regarding the fact that selection and depth of the content taught to the students is very much influenced by the beliefs of the educators (Walhout and Heinschel, 1992) . Students indicated they learn practical knowledge easier than theoretical knowledge and if the material is not relevant to practice why even teach it. Nursing students perceive nursing as “a very practical and skill-focused career.” The students surveyed expected that courses provide detail about the nursing skills important in the hospital setting. Some instructors expressed their concern regarding the recommendation of reducing the amount of details to simply teaching nursing application. Both the nursing and the science instructors expressed the opinion that the tendency of making all subjects “relevant” to nursing practice has the potential to limit the students’ general knowledge, and the basic knowledge is important in the understanding of the bigger picture. Nursing students are exposed to subjects such as psychology, philosophy, ethics, and sociology in an attempt to broaden their knowledge and understanding of life in general and also with the intention to develop a better-informed nurse. Thornton (1996) concluded, based on the opinion of the several instructors interviewed, that studying an area in general will help the nursing students to develop critical thinking and problem solving skills rather than just technical skills. The study brought to light the fact that both the students and the instructors perceive nursing

as being primarily a technical, skill-focused profession which influences them in the consideration for certain content and in some cases a devaluation of the content.

The study by Friedel and Treagust (2005) of nurses' attitudes and self-efficacy toward biosciences concluded that according to the nurse educators and nursing students, biosciences are important; both of the groups would like to have more bioscience knowledge. Their study reported that nurse educators lack knowledge in bioscience and have even lower self-efficacy in bioscience than the students. Because of this situation, it was suggested that nursing students might not be getting enough support to apply bioscience knowledge to the clinical practice.

Despite the fact that different research has pointed out the lack of bioscience knowledge among the nursing students and nurses, there is no clear consensus regarding the relevant content that should be taught in the biological sciences or the depth of knowledge required for competent nursing practice (Caon and Treagust, 1993, Jordan et al., 1999, Blais and Bath, 1992, Gretsy and Cotton, 2003). A recent UK study with surgical care nurses showed that experience was perceived as most important in learning biosciences; nurses self-rated their bioscience knowledge as weak (McVicar et al., 2010). The study showed that the dichotomy in expectation and reality of bioscience learning persists. It was suggested that post-qualifying education might help resolve some of the identified difficulties.

In the context of the theory practice gap, research has revealed disagreement as to whom should teach the bioscience courses to nursing students. Some research suggests that the academic scientists are the most qualified to teach the biosciences for nurses. Other studies argue that nurse educators should teach these courses since they are more

connected and aware of the needs in clinical practice (Thornton, 1997, Chapple et al., 1993). Larcombe and Dick (2003) presented the advantages of having teams of academic scientists and nurse educators teaching the biosciences in the context of laboratory settings.

Another aspect researched in order to improve the theory practice gap has been the area of teaching strategies to facilitate the learning and understanding of such a difficult area of the curriculum. In this study (Thornton, 1997), students found lecture, tutorials, and laboratory sessions of approximately equal value. Also it was discovered that nursing students prefer information to be given by the lecturer and feel insecure with a self-directed approach to learning. It was suggested that a specifically designed tutorial would be a major improvement for this, and students view them as supplements to learning rather than lecture replacement. Several studies show that nursing students found the studying of biological sciences to be easier when practical and discovery-teaching methods were used. The relevance of the information based on the connection of the presented material to practical applications will better help the nursing students to study and learn bioscience (Jordan et al., 1999, Thornton, 1997, Caon and Treagust, 1993).

Currently the call to improve the structure and planning of the biosciences courses in nursing education continues and scientists (biologists, chemists) have joined the nurse educators in sharing the same concern and desire to improve the learning of the pre-nursing students in the area of biosciences. The combination of graduating more students in a short time, since there is a shortage of nurses, with the increasing volume and complexity of information creates pressure on nurse educators and other instructors to teach more content in less time. Because of the reality of this situation, there is a

significant need for prioritization and focus in curriculum, teaching, and assessment methods development (Wright, 2006)

Chemistry in Nursing

The importance of chemistry in nursing was acknowledged from the beginning with the first nursing licensure test. Nursing licensure legislation was initiated in 1923 (Bullough, 1976). The first year of testing with a national exam, in order to offer the licensure for nursing, was 1944. The first state board test pool exam (SBTPE), the equivalent of the current National Council Licensure Examination (NCLEX), included tests from thirteen subject areas, one of them being chemistry (Department of Measurement and Guidance and National League of Nursing Education, 1952).

In her presentation, Timmer (2006), president of the American Nurses Association of California, emphasized the importance of chemistry and the multitude of applications of chemistry in nursing practice. She suggested that an integrated GOB chemistry course would provide nursing students with a foundation for pathophysiology of diseases, treatment, and recovery. Studies indicate that patient care is enhanced when nurses apply their knowledge of physiology to practice (Jordan and Reid, 1997). Nurses can recognize signs but lack the understanding of the cause, which is very important in assessing the physiological status of the patient as well as effectiveness of medical therapy.

In their case study of student nurses, Scalise et al. (2006) proposed that chemistry is an essential foundation for all healthcare professionals. Biochemistry is foundational for understanding disciplines such as pathophysiology, nutrition, pharmacology, and other biology- and chemistry-related subjects. Biochemistry provides information about

normal structure, function, and metabolism; without an understanding of the normal, it would be difficult to explain the abnormal (Ouyang et al., 2007). General, organic, and biological chemistry can potentially impact the understanding of all science-based subjects important in nursing education as indicated in Figure 1.

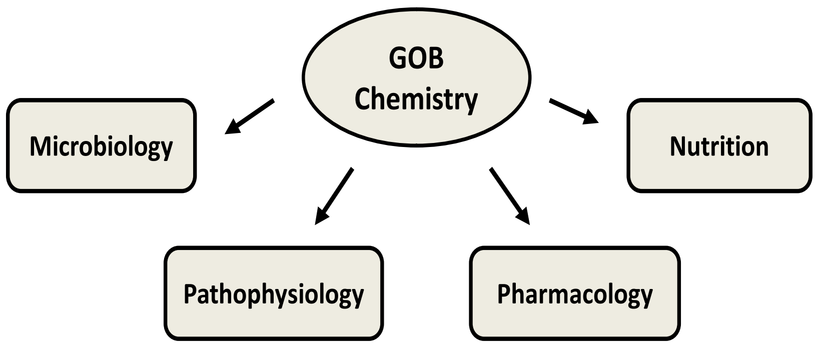

Figure 1: A sampling of disciplines in which understanding is impacted by general, organic, and biological chemistry knowledge.

Several reports have indicated that nurses' understanding of topics in physical science is inadequate for professional practice. The study presented by Wilkes and Batts (1996) explored registered nurses' conceptions of physical science in clinical practice. The nurses were able to pair terms used in physical science and their nursing activities. For example, "isotonic and blood" were given. In the context of interviews, their explanations of a hypertonic solution appeared to show that nurses had ideas of the physical principle but were unable to relate those ideas to a slightly different situation. This inability to transfer topics across contexts is also apparent in the data related to the nurses' definitions of pressure and pH. The nurses' conceptions are not always the same

as those of the scientists. Often nurses act as observers and doers rather than decision makers. It is imperative that nurses question, analyze, and make decisions based on appropriate scientific principles (Scalise et al., 2006).

In their case study, Scalise et al. (2006) assessed and compared the chemistry knowledge of a group of nursing students at the completion of their required general chemistry coursework for the Bachelor of Science degree in Nursing with a group of high school students at the completion of their chemistry course. In the study, basic ideas regarding understanding of matter, composition, structure, quantities, and properties were examined. According to the authors, a good understanding of general chemistry for the nursing students is a foundation for more advanced work in organic and biochemistry, which were another requirement of the program. Chemistry supports learning in physiology and microbiology courses. The study highlighted the contrast between what chemistry knowledge is expected of nurses and the level they actually achieve, and what this may mean for their future professional performance. It was found that the nursing students demonstrated at the end of the course a lower level of comprehension and more common misconceptions regarding basic characteristics of matter and of reactivity than the first-term high school students used as reference in the study. Furthermore, it was discovered that most of the nursing students demonstrate a “prechemistry” reasoning; reasoning based on logical patterning or real-world experience without involving any models or topics of general chemistry. The students experienced anxiety when confronted with material beyond their mastery. The authors concluded that there was conflict between the need of developing a working knowledge of the chemistry needed for clinical practice and the amount of time (in this research 10 weeks) they were studying

general chemistry. Also, according to the authors, it is difficult for students to make discoveries of topics or scientific entities based on their own empirical inquiry; learning science involves initiation into ideas and practice of science. As a possible solution to more successful courses for the nursing students, the authors suggested that curricula appropriate to the practice would better support the needs of the students. For example, the valence electron is a typical concept for general chemistry but nurses will not need to know this for their professional career. The authors suggested that chemistry should be taught in the context of practical examples relevant to nursing. This would be more appropriate to the working knowledge of the nursing practice and also offer nurses some ways of connecting the chemistry they are learning to their prior knowledge.

In the desire to make GOB chemistry more accessible to the nursing students, the area of chemistry content has been under exploration. Price (1976) presented the innovation in terms of the content and philosophy of an organic and biological chemistry course for nursing students. The article presented a table in the form of a syllabus of the topics of organic and biological chemistry taught in the course along with the additional material used in the course. According to the author, nurses do not need to be experts in bio-organic chemistry; they should know the general principles of biochemical structure and function. The course covered most areas of traditional biochemistry in a superficial but moderate way. The material selected for the course was based on the instructor’s judgment of being important to the student’s career. At the end of the course, the students were surveyed on several aspects of the course and 90% of the students enjoyed the course and considered it relevant to nursing.

The Task Force on Chemical Education for Health Professions was established by the American Chemical Society in 1979 with the role of developing curricula for chemistry courses for the allied-health majors. The group published a one-semester and a two-semester curriculum (Treblow et al., 1984, Daly and Sarquis, 1987). Although the intent of this committee was to develop a curriculum in consultation with health professionals, it was difficult to have their involvement because they “are caught up in their own problems and agendas” (Treblow et al., 1984). The curriculum developed by the task force contains topics viewed as major by chemical instructors with experience in the course. However, interaction of chemistry instructors with health professionals was recommended in order to inform the chemistry instructors about the reality and the needs of the nursing practice and in this way to be able to better prepare the nursing students for their careers (Doran, 1980).

Walhout and Heinschel (1992) surveyed the perspective of nursing department chairs and registered nurses with regard to the chemistry course taught to nursing students, with a curriculum determined by chemists. The nursing professionals were asked to rank, in order of their importance, the topics included in an allied-health chemistry course. The topics of salts/buffers; acids/bases/pH, and general metabolism were the three most important groups of topics. The organic chemistry topics were ranked the lowest. The authors reported that even though the nursing professionals do not see the relevance of some of the topics taught, there is a relationship between understanding the structure and understanding the function of different compounds that should be considered in teaching. The authors suggested that chemistry instructors should find the

right balance of how much is taught in this course, sometimes too much, and the appropriate foundation for other courses in the allied-health program.

Depending on the specific nursing school and its requirements, many pre-nursing students are required to take a GOB chemistry course to fulfill their chemistry requirement. Many of the nursing programs are forced to reduce the two-semester chemistry requirement to one semester (Frost, 2010, Frost and Deal, 2006). This is a challenging task since even with the two-semester course the excessive amount of information presented in the course brought student criticism (Tracy, 1998). In this context, Tracy (1998) presented the research in the area of restructuring a two-semester course to one semester. The chemistry and nursing faculty, based on the ranking of topics from the Walhout and Heinschel (1992) study, condensed the course into four categories: measurement, molecular structure, acid-base chemistry, and biochemistry. Also they proposed to "tie" the material together through a modeling project that counted for one-third of the course grade. The author recommended as a major revision to the course the idea of moving the measurements and mathematical topics into the laboratory portion of the course.

An innovative GOB chemistry course at Georgia Southern University (Frost and Deal, 2006) integrates the biochemical topics throughout the syllabus. Here, the organic topics are presented in the context of biochemistry. The course emphasizes biochemical aspects rather than organic aspects, as it was previously taught at that university. The chapter on measurement and unit conversion is covered in the laboratory portion of the course, as suggested by Tracy (1998). Each laboratory session starts with a recitation session, with the intent that the students can receive better assistance with the topics.

Also the laboratory experiments were revised to make them more relevant to the allied-health profession. Another part of the innovation was the adoption of the molecule project (Tracy, 1998). At the beginning of the semester, students receive the name of a biologically-active molecule. By the end of the semester they must generate a report that describes the molecule in terms of: the Lewis structure, organic functional group(s) and chiral centers, a three-dimensional computer-generated ball-and-stick model of the molecule, a statement predicting the molecule's solubility in water, and a summary of the molecule's biological function including at least one chemical reaction in which the molecule is involved. It was reported that the molecule project enhanced learning of topics and helped students to understand the relevance of chemistry to life. At the end of the course, the attitude of the students that took the innovative course was compared with the attitude of the students of a control group that took the traditional course. Based on students' evaluations at the end of the semester, students involved in the innovative course had a significantly improved attitude toward the course, reflected in the Chi-square value calculated for the two groups. According to the authors, data reflected that the improved attitudes were due to the integrated curriculum not the instructor. Also, the withdrawal rates in the course taught with the integrated curriculum were lower than the ones in the traditional GOB curriculum.

While many studies document the importance of science content within undergraduate programs, the depth and breadth of the content to be taught remains unclear (Friedel and Treagust, 2005). As with many areas of biosciences, there has been a long history of concerns and debate regarding content in the GOB chemistry course taken by the pre-nursing students. The struggle is reflected in the presentations at the American

Chemical Society (ACS) meetings and the Biennial Conference on Chemical Education (BCCE). For several years, symposia at the ACS and the BCCE meetings have been devoted to the topic of GOB chemistry for the allied-health majors. Presentations have expressed the confusion regarding how the content of this course should be taught combined with the chemistry instructors' desire of making this course relevant, more enjoyable, and better appreciated in the future profession by the pre-nursing students. For example, at the 2012 BCCE section entitled “Trends in GOB Chemistry,” the thirteen abstracts submitted pertained to research in the area of content innovation of this course.

Similarities among the GOB chemistry textbooks indicate that there is some consensus among the chemistry culture regarding the content of this type of course. However, there are a limited number of studies regarding the opinion of the nursing culture toward the chemistry knowledge of nursing students (Wilkes and Batts, 1996, Scalise et al., 2006). In the two decades since the Walhout and Heinschel (1992) survey of nursing professional opinion, there have been no published studies pertaining to the main chemistry topics relevant to the nursing clinical practice. Also, there is no published research regarding the combined opinion of chemistry and nursing instructors regarding the content of a GOB chemistry course for the nursing students.

Some chemistry instructors feel they have to “lower their standards” in order to avoid students’ low performance (Davies et al., 2000, Thornton, 1997, Davis, 2010). It is documented that often the content selection is based on the science instructor’s expertise. Despite similarities in GOB chemistry textbooks, there appears to be no consistency or standardization of topics or topics taught in a GOB chemistry course. Attempts to condense one’s own area of expertise into a one-semester course is a “daunting prospect”

(Thornton, 1997). The lack of standardization of the GOB chemistry topics taught in the nursing program raises questions that demand research on how much chemistry nurses need, what chemistry topics should be taught, and what guides the selection of the various topics within the content area.

Nursing Students' Perceptions of Biosciences

Research in nursing education has revealed various potential factors that contribute to the nursing students' perception that bioscience courses are difficult (Caon and Treagust, 1993, Nicoll and Butler, 1996). Studies concerning science courses in nursing programs have suggested that nursing students have not only inadequate preparation for bioscience courses and a negative attitude toward the relevance of science in nursing, but also lack the confidence necessary to study these subjects. Some pre-nursing courses are sometimes viewed as gatekeepers, thus determining who has access to the profession (Scalise et al., 2006). Some factors that present challenges and consequently successful performance in a GOB chemistry course include the cognitive load of the courses, academic skills of the students, science background of the students, mathematical abilities of the students, the anxiety of failure, and the instructor's approach (Caon and Treagust, 1993, Chapple et al., 1993, Clancy et al., 2000, Gretsy and Cotton, 2003, Wright, 2007, Courtenay, 1991). These factors are summarized in Figure 2.

The teaching of biosciences in the nursing curriculum has long been identified as problematic and a source of anxiety by teachers, students, and even practicing nurses (Nicoll and Butler, 1996, Larcombe and Dick, 2003, Gretsy and Cotton, 2003, McCabe, 2007). Undergraduate nursing students feel stressed by the cognitive load and content details in their program. Often the students take several science courses in the same

semester which greatly increases the cognitive load and the working memory of the students (Nicoll and Butler, 1996). Scalise et al. (2006) state that nursing students are confronted with anxiety to achieve passing grades in the chemistry courses required in the nursing programs.

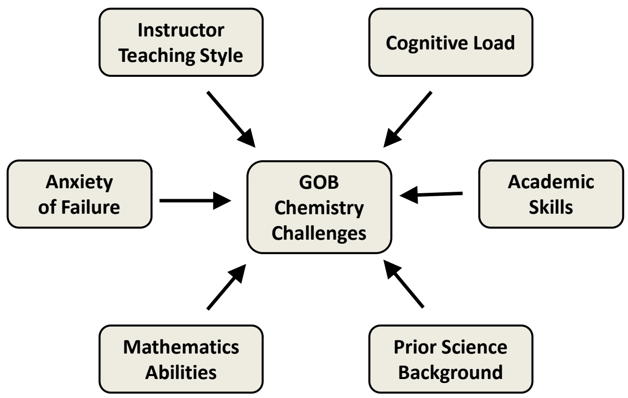

Figure 2: Factors affecting success in a general, organic, and biological chemistry course.

Another cause of anxiety in the science courses is the lack of knowledge and preparation. Often, nursing students have difficulty understanding the relevance of their science courses and perceive the relevancy of a course based on personal beliefs and their image about nursing. They discount information that seems irrelevant to their perception of nursing; finding relevance is a key to success (Caon and Treagust, 1993, Thornton, 1997).

Nursing students, and allied-health students in general, feel anxiety in chemistry due to the math and science skills required (McMullan, 2012, Tobias, 1988). “Chemistry anxiety” is attributed to three factors: (1) chemistry is perceived as difficult, (2) it

involves a multitude of facts, and (3) it does not relate to real-life situations" (Dori, 1994).

Students perceive biosciences as being "difficult" based on their previous experiences or due to negative experiences earlier in their school careers (Clancy et al., 2000). Yager and Penick (1986) concluded in their study that there has been a decline in positive attitude toward science throughout junior high and high school. Thornton (1997) presented that one of the concerns of science instructors is the students' poor understanding of fundamental topics taught in secondary school. Instructors expressed concern regarding students' superficial approaches to learning in response to certain teaching and assessment methods used. It was found that students' learning was very much based on rote memorization. Subjects that present more abstract topics and challenging ideas were seen by students as less popular and as "lacking relevance."

In order to address this deficit, college instructors are faced with spending additional time revisiting basic principles. Pre-nursing students describe the relevance of certain topics based on their assumption about the practical applicability of the information and their perspective on the requirements of clinical practice (Tallmadge and Chitester, 2010). Based on their negative feelings and attitudes developed in previous encounters with sciences, nonscience majors do not feel motivated to explore the sciences (Gogolin and Swartz, 1992).

McKee (2002) analyzed some factors that contribute to the poor performance of pre-nursing students in biological sciences. Based on interviews with students that had previously failed the course, a questionnaire was constructed and used in data collection. The questionnaire addressed the following areas: study patterns, attendance, work

patterns, and previous theoretical biological science knowledge. The study found that poor study skills and poor attendance contributed significantly to low performance in biological sciences. The study also discovered that the high school science background of the students or previous exposure and experience with the biosciences would influence the student's performance; in some cases, the students may feel unmotivated due to a previous negative experience. There were no significant differences in performance between the students that had a job during the semester and the ones that did not work during the semester. McKee (2002) recommended some type of prerequisite courses that could influence both the theoretical knowledge and the study skills of the nursing students prior to the bioscience courses. Non-traditional students were clearly at a disadvantage in the course, since many years may have passed since their high school experience; however, many traditional students were not well-prepared either (Tallmadge and Chitester, 2010).

The academic skills and learning styles of the nursing students have also been factors that contribute to their perception that biosciences are difficult (Thornton, 1997, McKee, 2002). Thornton (1997) reported that most nursing students demonstrate superficial learning and study techniques. The same study mentioned that students are reluctant to experience different ways of teaching and assessment, and students especially in their first year in the program preferred courses that are highly structured with prescribed reading and assessment.

Learning style is defined as "the learner's preference for different types of learning and instructional activities" (Jonassen and Grabowski, 1993). There has been a variety of studies that assess the learning style preference of allied-health students in

general and some specific to nursing students (Hauer et al., 2005). One of the reasons for understanding the learning style of nursing students is to inform and guide faculty in communicating knowledge to students in the most efficient way (Hauer et al., 2005, Rassool and Rawaf, 2007). Kolb's Learning Style Inventory (Kolb, 1985) has been one of the most widely used instruments in determining the learning style of the allied-health professionals (Cavanagh et al., 1995, DeCoux, 1990). The findings of Cavanagh et al. (1995) showed that 53.7% of the nursing students expressed preference for the concrete learning style, while 46.3% were predominantly reflective. Also by using a Chi-squared test, no statistically significant associations were found between the respondents' learning styles and the connection with age, gender, or having been in employment prior to becoming a nursing student. The concrete learning style emphasizes involvement with people in everyday situations. The individuals in this category tend to rely on feelings, to be open-minded, and adaptable to change (Kolb, 1985). Similar results were found in the study conducted by Hauer et al. (2005). A study conducted by Rassool and Rawaf (2007) using the Honey and Mumford (1992) learning style questionnaire found that besides a predominant reflective style, which is the equivalent of concrete style on Kolb's Learning Style Inventory, a "dual" learning style was discovered and explained by the fact that non-traditional students may have learned to be adaptive in their learning experience and develop skills to meet the requirements of the course. In all the studies mentioned, the authors suggested the need for using a variety of delivery styles with the allied-health students with an emphasis on participation and experiential learning.

Another interesting perspective that has not been researched to a great extent but should be considered in the teaching and learning approaches of the nursing students is

the generational diversity. The nursing majors are composed of a diverse population that represents multiple generations such as Baby Boomers, Generation X, and the Millennials. Each generation is characterized by its own set of values, ideas, ethics, beliefs, and learning styles. Johnson and Romanello (2005) provided suggestions and teaching tools for enhancing teaching and learning across the multiple generations. Generational diversity itself can be used as a tool to support learning in the classroom.

Mathematical proficiency is required for the performance of many nursing functions (Bindler and Bayne, 1984) and competence in calculations is important for patient safety (Jukes and Gilchrist, 2006). Studies have shown that nurses do not always have the necessary skills to calculate correct drug dosages, and there is need for improvement of both mathematical skills and conceptual skills of nursing students (Hutton, 1998, Chrisensen and Miller, 2008, Wilson, 2003). Pozehl (1996) provided evidence for a reduced level of mathematical abilities of nursing students in comparison to non-nursing majors. Huse (2010) reported in her dissertation that one of the reasons for errors in drug dosage calculations is due to the lack of math skills of the nursing students. Blais and Bath (1992) reported on the difficulty nursing students have with basic math operations such as multiplication, division, and decimal points. They also found that, in addition to computational error, conceptual error accounted for 68% of all errors and that students were unable to judge unrealistic results such as the administration of 20 tablets instead of 2. Jukes and Gilchrist (2006) surveyed the math abilities of a convenience sample of thirty-seven nursing students. The students answered ten pencil-and-paper questions regarding drug dosage, dosages for tablets and mixtures, dilutions, and intravenous infusions. The mathematical skills tested were those used daily or on a

frequent basis and involved division and multiplication, percentages, and ratios and proportions; one of the problems involved conversion of units requiring multiple steps. Only 35% of the students achieved a score of seven or above and no student answered all questions correctly. Students achieved the most correct answers to the questions that involved percentage. Problems that necessitate ratios/proportions and unit conversions seem to be the most difficult for the nursing students. Nursing students demonstrate math anxiety (Glaister, 2007) and low self-efficacy (Maag, 2004) when presented with medication calculations due to the poor experience or failure of math during school years (Andrew et al., 2009). An inventory of self-efficacy for mathematics (NSE-Math) was specifically designed for second-year nursing students. The instrument contains 12 items loaded on two factors: "confidence in application of mathematic topics to nursing practice" and "confidence in arithmetic topics." The instrument was used with 123 students. The value of Cronbach's alpha reported for the scale was 0.90, which indicates a high reliability. The NSE-Math demonstrated predictive validity with the medication calculation examination results ($p = 0.009$). The psychometric analysis suggested the NSE-Math is a valid measure of mathematics self-efficacy of second-year nursing students (Andrew et al., 2009).

Among the factors mentioned regarding success in a GOB chemistry course (Figure 2), the instructor's approach is very important. Several studies reported that many chemistry instructors teach based on their perception of how chemistry topics may relate to the nursing profession (Friedel and Treagust, 2005, Larcombe and Dick, 2003, Clancy et al., 2000). Courtenay (1991) reported that lack of science background in nursing instructors has contributed to the perception that science content is not important in their

practice. On the other hand, lack of nursing connection and background from science instructors contributed to students' perceptions that content was more in depth than needed for their clinical practice (Nicoll and Butler, 1996, Clarke, 1995).

The instructor's approach and the cognitive load of the course (Figure 2) are two very important factors that can be controlled or modified by chemistry instructors. GOB chemistry instructors are typically chemists and often present the material as they would to chemistry majors. Science instructors tend to teach from a rather discipline-based approach (Courtenay, 1991). An appropriate example of how the approach taken by chemistry instructors differs from what nurse educators think is important for the profession can be illustrated using the concept of *pH* as outlined below.

Chemistry Instructors' Perspective

From the perspective of chemistry instructors, *pH* is typically introduced in connection with the self-ionization of water. This is often followed by a derivation of the K_w expression. Students are told that the concentration of hydronium ion $[H_3O^+]$ in an aqueous solution can range from about 18 M to $1x10^{-15}$ M. Because it is inconvenient to work with such a large range of concentrations, the calculations are simplified by introducing the logarithmic mathematical function. Things can become even more challenging for nursing students when the relationships among *pH*, pK_a, and the concentrations of a weak acid and its conjugate base are introduced and described by the Henderson-Hasselbalch equation in relation to a buffer solution. It is often difficult for non-chemistry majors to see the relationship between $[H_3O^+]$ and *pH*, making the concept of *pH* difficult to understand as well as to apply.

Nursing Educators' Perspective

From the perspective of nurse educators, the *pH* concept should be considered in the context of homeostasis. It should be explained that there is an inverse relationship between the value of *pH* and the concentration of hydronium ions. It should be mentioned that many compounds in the body contain functional groups that can act as acids or bases by donating or accepting hydrogen ions, respectively, and that the concentration of hydronium ions determines the acidity of the solution, which consequently affects many biological reactions. As a connection to clinical practice, the *pH* range of blood should be mentioned (as illustrated in Figure 3); the normal blood *pH* range is 7.35-7.45. The range 7.35-6.80 is an indication of metabolic acidosis and the range 7.45-8.00 is an indication of metabolic alkalosis. This type of introduction to the *pH* scale offers a direct opportunity to connect *pH* to metabolism.

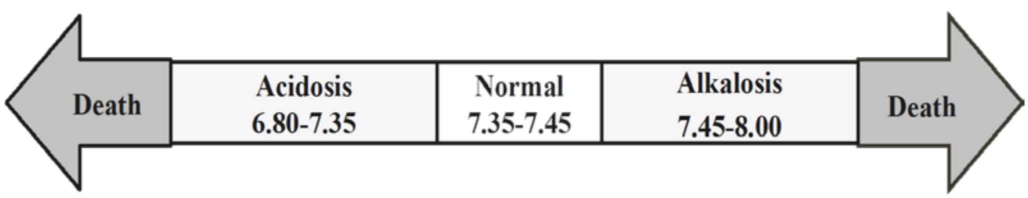

Figure 3: Normal and abnormal *pH* of blood.

Some of the main factors that affect the success of the pre-nursing students in a GOB chemistry course were presented in this section. Studies show that nursing students will be more motivated if they see the relevance of the content to the clinical practice. Nursing students perceive biosciences as being an important part of the curriculum, but most of them feel they do not have an adequate level of knowledge (Oliveira et al., 2003).

Davies et al. (2000) discovered that despite the difficulty of the bioscience courses in the nursing program, students found the information relevant to nursing and felt motivated to spend more of their time studying bioscience than other subjects.

Teaching Strategies Used in Nursing Education

Teaching Strategies Used in Biosciences for Nursing Programs

For many years, the lecture format has been the primary format for delivering new information. The study conducted by Gibbs et al. (1997) found that nursing students do not perform very well in large enrollment modules. More students adopted a surface approach (attempting to memorize material) in comparison with the number of students that presented a deep approach (attempting to understand material) in large enrollment modules where biosciences were being taught. Also, it was found that nursing students performed better when there was more coursework assessment.

Recently in nurse education, there has been a change from a teacher-centered to a student-centered approach. This change has the role of developing critical thinking of the nursing students, helping the students be better prepared for the continuous changes that the health care system is experiencing (Walton, 1996). Studies have suggested that improved teaching techniques are needed in order to improve nursing students' outcomes in science courses, including the techniques used in self-regulation (Andrew et al., 2009).

In subjects such as anatomy and physiology, there has been an abundance of research in the area of innovative teaching methods (Green et al., 2000, Larcombe and Dick, 2003, Gretsy and Cotton, 2003, Davies et al., 2000). Larcombe and Dick (2003) developed an anatomy and physiology course taught in collaboration between a science instructor and a nurse instructor. The science instructor developed the content of the

course and experiments for the main topics and systems. The role of the nursing instructor was to link the content to clinical practice.

Computer-assisted learning has been successfully used in nurse education. Gretsky and Cotton (2003) developed and evaluated an on-line program designed to improve bioscience knowledge of the students. The development of the “Headstart package” was guided by the need for help expressed by students in focused groups. Nursing students indicated the need for help in the area of scientific measurement, chemical and physical topics, biomolecules, and body anatomy and physiology. The value of the program consisted of a good support system for student-centered learning in biosciences; students could access information tailored to their studies in an easy manner and could take quizzes on-line with instant feedback. Different units (galleries) presented an integration of bioscience topics within a nursing context, which was very helpful for the students regarding the relevance of theoretical topics and application to clinical practice. Another positive aspect of the on-line program was that students could access it even before the class started; thus the students could review and test their bioscience knowledge, which allows them to seek help if necessary. Students in general were satisfied with the program and the enhancement of their education. A negative aspect of the program, mentioned by the authors, was the lack of experience especially of the non-traditional students with information technology. Students indicated navigation problems such as logon passwords.

The effect of problem-based learning (PBL) on nursing students' approaches to learning has received special attention in nursing education. Tiwari et al. (2005) evaluated the effect of PBL on students' approaches to learning in clinical nursing

education. Significant changes were observed between pre- and post-test scores for the students that participated in the PBL. Also, it was observed that students adopted a deep approach to learning during a period of clinical education in which PBL was implemented.

Smith and Coleman (2008) surveyed the opinion of nursing students regarding the problem-based learning (PBL) used in the nursing program. The methodology used was based on focus group interviews at the end of the program (first groups) and six months post-qualification (second group) in order to capture the students' perceptions of how they experienced learning in this type of program and how it helped them in their clinical practice. Students from the first focus group expressed negative perception toward this methodology. The students from the second focus group had time to reflect on their experience and the impact of this type of learning. They presented a positive view of their experience and indicated that this type of course increased their confidence, assertiveness, and helped them to be more questioning of the practice. The study concluded by recommending a blended approach rather than curricula wholly delivered by PBL with consideration toward students' concerns. This research indicated that, although the students experienced difficulties in the process, the outcome did meet students' needs in the longer term.

Teaching Strategies Used in General, Organic, and Biological Chemistry for Nursing Programs

There is a lack of published research regarding teaching styles in the GOB chemistry courses for allied-health majors. Tallmadge and Chitester (2010) developed several on-line tutorials with the intent of enhancing general chemistry knowledge of

nursing students, reducing the cognitive load, and reducing the frustration of students with the course. General chemistry is a prerequisite for the one-semester GOB chemistry course at the university at which the research was conducted. The students had difficulty in organizing the information. The instructor often had to re-teach some of the topics resulting in less time for the biological chemistry portion of the course. Students also had difficulty in integrating general chemistry principles with the organic and biological chemistry content of the course. The tutorials were designed based on the instructor's experience with the course. Tutorials addressed six general topics that the majority of students struggled to integrate into the organic/biochemistry portion of the course. The topics included atomic structure, chemical bonding, intermolecular forces, acids and bases, oxidation and reduction, and solutions. Measurable objectives were assigned to each of these topics. Students could work at their own pace on the tutorials, although each had a specific due date. Also, students could work with a colleague. Students received the graded tutorial prior to the reviewed objectives being integrated into the new course material. A negative aspect of the innovation was the increased instructor load created by grading the tutorials. An option was to use multiple-choice questions that could be graded on-line immediately. The students responded positively to this initiative: "50% responded that they had worked with another (or other) student(s) to complete the tutorials, 91% of those that had 'worked with others' said it was helpful for them to do so, and 77% responded 'yes' to 'Would you recommend using the tutorials in future classes?'" The on-line tutorials allowed the class to progress faster into the biological chemistry topics. While other approaches may accomplish the same goal, this approach

minimized the in-class time needed for review of background material and increased feedback to students.

Frost (2010) described research in the area of active learning in a GOB chemistry course by using Process Oriented Guided Inquiry Learning (POGIL). POGIL is a guided inquiry, non-lecture-based, cooperative-learning approach rooted in constructivist learning theory. Based on this teaching method, students construct new knowledge through a learning cycle that allows them to explore a model, construct topics, and apply these topics to new situations (Piaget, 1964, Karplus and Their, 1967). According to Frost, POGIL helped students develop critical thinking, a very important aspect for allied-health students as they move through their programs and provide diagnoses for patients. Students, in groups of three to five, worked on specially designed guided inquiry materials (Garoutte, 2007). Students were provided with a worksheet with a table of sample data and were guided to explore the data based on some critical thinking questions. Students formulated their own conclusions that must apply to similar data. The instructor did not provide direct answers to the critical thinking questions. In the POGIL setting, the instructor served as a facilitator rather than as an information source as in the lecture format. The method was assessed by comparing the performance of the students taught through a POGIL method with a group of students taught through the traditional lecture format. By using a pre- and post-test, the author concluded that the students in the POGIL group learned more chemistry at a higher learning level and their perception of learning gains was higher than that of the students in the traditional lecture format.

Assessment of Student's Learning of Biosciences

"Teaching and assessing are two dimensions within the learning process. Neither assessing can stand alone nor teaching can be considered comprehensive if evaluation has not taken place" (Halarie, 2007). Teaching and assessment strategies for nursing students must be considered carefully and must be combined with methods that facilitate the development of a deeper understanding rather than simple recall or recognition. Nursing students expressed a preference for what they described "multi-guess" (multiple-choice) questions rather than written assessments (Thornton, 1997).

Assessments are used for three broad purposes: to assist learning, to measure individual achievement, and to evaluate programs (Pellegrino et al., 2001). Among the assessment tools, concept inventories have been used successfully in different areas of science.

Concept Inventories

This section of Chapter II introduces assessment in the form of concept inventories. The section presents an overview of the design, analysis, and examples of concept inventories in general. This presentation facilitates a comparison in terms of design and psychometric analysis between the existent concept inventories and the proposed GOB-CTI.

Psychometric Analysis

Psychometrics is the field of study concerned with the theory and techniques of educational and psychological measurement. Psychometric analysis has an important role in educational testing in the construction of instruments and procedures for measurement and in the development and refinement of theoretical approaches to measurement

(Mislevy et al., 2002). The purpose of any assessment is to provide data from which inferences about the ability or competency of an examinee can be obtained.

Any type of study is guided by a theoretical framework that influences the type of data collected. In a typical experiment performed by a chemist, different aspects of a sample can be examined based on the instrument chosen. Analogous to the chemistry lab, educators and education researchers use certain instruments to collect data. Instruments such as a concept inventory or a survey are used to make interferences about examinee abilities. The two major theoretical frameworks that allow one to explore and address measurement problems in psychometrics will be presented with their particularities. The two most frequently used theoretical frameworks in psychometric analysis are Item Response Theory (IRT) and Classical Test Theory (CTT) (Furr and Baharach, 2008, Crocker and Algina, 2008). These two measurement theories are employed by researchers to construct measures of latent traits. Latent traits are unobservable characteristics such as student abilities, self-efficacy, and motivation, which are assumed to influence the way people respond to tests or surveys. Latent traits are measured indirectly through some form of assessment such as a test or survey. By examining how a person responds to a set of items related to a single underlying dimension, researchers can create scores that approximate a person's ‘‘level’’ of the latent trait; however, there are no perfect measure of a latent variable. The tow mentioned theories are tools that can be used to approximate a person's ‘‘level’’ of the latent trait, but beyond their common purpose, the two measurement systems differ significantly in their modeling processes and assumptions about the nature of the construct being measured as well as about how individuals respond to test items (Cavanagh et al., 1995, Hogan, 2007).

Item Response Theory

The purpose of Item Response Theory (IRT) or latent trait models is to explore the underlying ability (latent traits) which are producing the test performance rather than measuring performance (DeMars, 2010). In contrast with Classical Test Theory (CTT), the analysis takes place at the item level and the statistics of this type of analysis is not dependent on the test situation which generated them (Lord, 1980). The theory is based on the idea that the probability of getting an item correct is a function of a latent trait or ability of the test-taker and the difficulty of the item (Hambleton et al., 1991).

Classical Test Theory

Classical test analysis assumes that any individual's test score or observed value (x_{obs}) is comprised of a "true" (x_{true}) value plus randomised error (x_{error}) as illustrated by the equation: $x_{obs} = x_{true} + x_{error}$. The true value cannot be directly measured; the observed value gives an estimate of this value. This theory assumes that the randomised error is normally distributed, uncorrelated with the true score, and that the mean of the error is zero. Some of the potential factors that create error in a score include for example, the test taker - it is possible that the subject is having a bad day, the test itself - it is possible that the questions on the instrument may be unclear, the testing conditions - the existence of distractions during the testing that detract the subject, and the test scoring - scorers may be applying different standards when evaluating the subjects' responses (Bresnock et al., 1989).

Classical Test Theory evaluates outcomes of a test such as the difficulty of items, item discrimination, and the probability of the test-taker to pass an item. These outcomes are a function based only on the ability of a test-taker, in contrast with IRT. In IRT, the

probability for a test-taker to pass an item is a function of both the ability of a test-taker and the item difficulty. Classical Test Theory predicts item statistics of a test such as item difficulty and item discrimination and test statistics such as test validity and reliability. These elements of test statistics depend on the examinee sample in which they are obtained (Hambelton and Jones, 1993). Although the statistics apply only to those students taking the test, the results are often generalized to similar students taking the same test.

Important topics in CTT are reliability and validity. Most tests are designed to measure skills, abilities, or traits that are not always directly observable. If test scores are to be used to make accurate inferences about an examinee's ability, they must be both reliable and valid.

Reliability

Reliability is defined as the amount of the total test variation that is attributed to the variation in the true scores versus how much is due to measurement error. Based on this definition, reliability represents the degree to which scores are consistent. A reliable measure is one that measures a construct consistently across time, individuals, and situations (Nunnally, 1978). Spearman (1904) first proposed the concept of reliability and ways to evaluate the degree of score reliability. There are several types of reliability measures that differ in the way they try to account for the variation between an individual’s observed score (x_{obs}) and true score (x_{true}) on an assessment (Crocker and Algina, 1986, Crocker and Algina, 2008, Furr and Baharach, 2008). The reliability index has values measured between 0.0 to 1.0. A value of 0.0 indicates no relationship among the items of a construct while a value of 1.0 indicates a perfect intercorrelation among

test items of a single construct (Kuder and Richardson, 1937). Reliability can be estimated through methods such as: *alternate form reliability (parallel form), test-retest, internal consistency*, and *inter-rater reliability.*

Alternate form reliability (parallel form reliability) is a measure of consistency between different items of the same construct. The items of the instrument are randomly divided into two alternate forms. In practice, this method of evaluation of reliability raises serious concerns since it is difficult to know that alternate forms of a test are truly parallel. The two alternate forms have to measure the same set of true scores, and they must have the same amount of error variance. It is used to assess the consistency of the results of two tests constructed in the same way from the same content domain; however, other methods of evaluating the reliability of the construct are recommended (Furr and Baharach, 2008).

Test-retest reliability is a measure of consistency between two measurements of the same construct administered to the same sample at two different times. The correlation coefficient between results is an estimate of the instrument reproducibility (Trochim and Donnelly, 2007). The reliability is dependent on the assumption that true scores remain stable across the test-retest interval. The lower the test-retest correlation, the greater the effect of measurement error and, consequently, the lower the reliability of the test (Furr and Baharach, 2008). The problem with estimating the reliability through this method is in the period of time between the two administrations of the test and also the fact that it takes two administrations. If the time is too short, the participants may be able to remember their answers from the first administration; if the time is too long, the results may be affected by significant changes in the variable being measured. For

example, the participants may get more practice with a certain concept and truly change their score (Furr and Baharach, 2008).

Internal consistency reliability offers a useful, practical alternative to the previous two methods of estimating reliability. The respondents are required to take the test only one time and there is no need to create more than one form of a test to measure the consistency among the instrument's items (Furr and Baharach, 2008). Cronbach's alpha is the mostly frequently reported reliability estimate because of its convenience of single administration and thus eliminates the possibility of students gaining knowledge between test administrations, which is a concern in the test-retest method. Cronbach's alpha (Paas et al., 1993) is a generalized form of the Kuder-Richardson Formula 20 (KR-20) (Kuder and Richardson, 1937). Kuder-Richardson Formula 20 is used for dichotomous data (Cortina, 1993). The Cronbach's alpha reliability coefficient normally ranges between 0.0 and 1.0. A low value of Cronbach's alpha indicates a weak or no correlation among the items. The closer Cronbach's alpha coefficient is to 1.0, the greater the internal consistency of the items in the scale. Acceptable values of alpha for classroom tests are between 0.6 and 0.8 (Fan, 1998); higher values imply "redundancy" in the test rather than "homogeneity" (Jacobi et al., 2003). The intercorrelation among test items increases when all items measure the same construct. The internal consistency of a concept inventory increases if the inventory contains multiple questions examining the same concept. This will avoid the situation in which a student possibly knows the concept but for some reason misinterprets the question or the student may not know the concept and is just guessing. To determine how an item contributes to the reliability of the scale, each item is successively removed, and the reliability coefficient is computed. An item that

decreases the reliability coefficient is eliminated or examined for improvement (Ebel and Frisbie, 1991).

Inter-rater reliability (inter-observer reliability) is used in qualitative studies in order to evaluate the accuracy of a coding scheme for free response items. Inter-rater reliability refers to the agreement among two or more raters and is connected to the reproducibility; whether scores coded by one rater are the same as scores coded by a different rater. It is a measure of consistency between two or more independent raters of the same construct (Trochim and Donnelly, 2007). The consistency among the raters is calculated by using the kappa statistic or percentage of agreement among the raters. The categories of reliability are summarized in Figure 4.

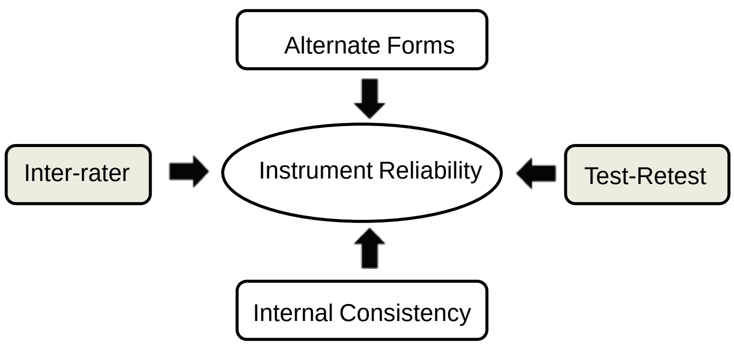

Figure 4: Map of the main categories of reliability.

Reliability is one part of instrument evaluation but not sufficient in itself (Moss, 1994). A measure may produce reliable data without producing valid data. However, reliability is necessary but not sufficient for validity.

Validity

Validity is the extent to which a test measures what it claims to measure and represents how well an instrument measures the construct it is attempting to measure. Validity can be viewed as the accuracy of the instrument (Stangor, 2010). Validity is not determined by a single measure but by a body of research that demonstrates the relationship between the test and the trait it is intended to measure. There are several different methods that can be used to evaluate the validity of a test, each providing a unique set of data about the instrument. Barbera and VandenPlas (2011) described two major types of validity studies: construct validity and criterion validity. The subcategories of the two main types of validity along with their respective subcategories are presented in Figure 5. Each will be discussed below.

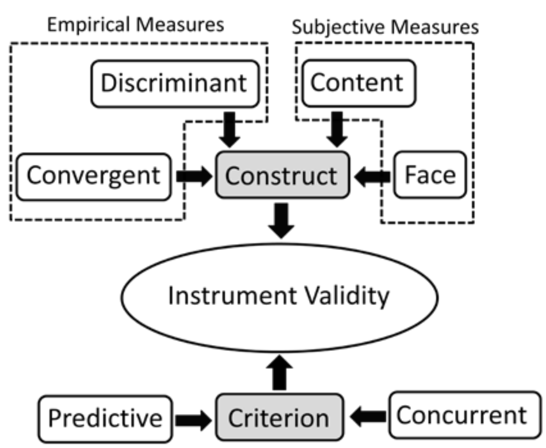

Figure 5: Map of the main categories of instrument validity (Barbera and VandenPlas, 2011).

Construct validity is the most commonly reported form of instrument validity and refers to the degree an instrument's measure matches or is correlated to the conceptual or theoretical variable it is designed to measure. For the *construct validity* of a test, both

subjective measures (such as *face* and *content validity*) and empirical measures (such as *discriminant* and *convergent validity*) are used. Evidence from the two types of measures can be used to establish construct validity.

Face validity is a simple form of validity in which researchers determine if the test seems to measure what it is intended to measure. Face validity assesses whether the test "looks valid" to experts and novices (Barbera and VandenPlas, 2011). This is a weak method for demonstrating construct validity. *Content validity,* sometimes called logical or rational validity, is based on the extent to which a measurement reflects every single element of a construct (Carmines and Zeller, 1979) as well as the importance and utility of the instrument (Barbera and VandenPlas, 2011). According to Barbera and VandenPlas (2011), these two types of validity are important to be established for a developed instrument, but they should be strengthened by using one of the empirical measures.

Convergent validity and *discriminant validity* are empirical measures of a construct and they contrast each other. *Convergent validity* is used to evaluate the degree to which two or more measures that theoretically should be related to each other are, in fact, observed to be related to each other. In contrast, d*iscriminant validity* would be established by showing that measures that should not be related in fact do not relate.

Criterion validity (sometimes called concrete validity) represents the extent to which an instrument's measure is related to some concrete criterion in the "real world." As an example, research has shown that ACT scores accurately predict and can be correlated with success in college. Thus, there is high criterion-related validity between the ACT scores and success in college. These types of validity studies include, and

sometimes employ, additional topics of validity. In order to establish *criterion validity*, either a *predictive validity* or a *concurrent validity* study can be used. *Predictive validity* is a measurement of how well a test predicts future performance. The validity of a test is established by measuring it against known criteria. In order for a test to have predictive validity, there must be a statistically significant correlation between test scores and the criterion being used to measure validity. This type of validity is the foundation for the assumption that the test scores from an ACT or SAT can predict how well a student will perform in college. *Concurrent validity* of an instrument is its ability to distinguish between groups that it should theoretically be able to distinguish (Trochim and Donnelly, 2007). Barbera and VandenPlas (2011) used the following example to illustrate this type of validity: if an instrument is designed to measure student's chemistry content knowledge, it should be able to discriminate between introductory chemistry students and graduating chemistry majors.

Since test validity means validating the use of a test in a specific context, it is important to study the test results in the setting in which it is used. The results of a test must be valid in order for the results to be accurately applied and interpreted. As the uses and the needs of the instrument evolve, the instrument should constantly be evaluated, which makes the process of validation an on-going process (Nunnally, 1978).

Item Analysis

A question on a concept inventory should be designed to test only one concept. Often the questions of a quiz or a test in a course attempt to test more than one concept, in which case it is difficult to determine from the student's incorrect answer which concept was misunderstood. Distracters are often written based on student alternative

conceptions (Osterlind, 1998). Different statistical procedures, under the generic term "item analysis," are used in order to evaluate the quality of an item. The statistical procedures used in item analysis are designed to explore how the individual items of a test compare with other items in the test or in the context of the whole test. Item analysis is conducted to explore the level of difficulty, level of discrimination, and distracter quality of a test item.

Item difficulty (difficulty index) is a measure of the proportion of examinees who responded correctly to an item. Item difficulty (*p*) can range between 0.0 and 1.0, with a higher value indicating that a greater proportion of examinees responded to the item correctly, and the item was thus an easier item. Items of moderate difficulty (0.40 - 0.80) are preferable (Osterlind, 1998). Based on the type of test, different values of difficulty index are considered acceptable. For a test with the emphasis on mastery-testing, such as the criterion-reference tests that are intended to measure how well a person has learned a specific body of knowledge and skills, it is expected that many items on the test will have *p*-values of 0.9 or above. The tests that are designed to compare test takers to one another, such as norm-reference tests, are designed to be harder overall and to have a broader range of the examinees' scores (Oosterhoh, 2001). Based on the difficulty index, items can be interpreted as indicated in Table 1.

Table 1. Item Interpretation Based on Difficulty Index

Difficulty Index (p)	Item Interpretation, Action
$p < 0.3$	Too Difficult, Modify.
$0.3 < p < 0.8$	Moderate, Accept.
$p > 0.8$	Too easy, Modify.

According to the information presented by Abdullah (2006), an acceptable difficulty index for a norm-reference test lies between 0.3 to 0.8. In general, items answered correctly by more than 80% of respondents are considered too easy, and items answered correctly by less than 30% of respondents are considered too difficult.

tem discrimination refers to a test’s ability to produce a wide range of scores and is a measure of how well the item discriminates between examinees who are knowledgeable in the content area and those who are not (Oosterhoh, 2001). Item discrimination is measured by the discrimination index (D), which compares the examinees having higher scores with the examinees having lower scores. The values of discrimination index can range from -1.0 to 1.0; a discrimination index below 0.0 suggests a problem in which overall the most knowledgeable examinees are responding to the item incorrectly and the least knowledgeable examinees are responding to the item correctly (Doran, 1980). The discrimination index can be computed by using the point-biserial correlation coefficient, which is the correlation between the item and total score. A simpler way to calculate the discrimination index is based on the difference in the proportion of responses between the upper and lower 27% of examinees. According to Kelley (1939), the optimal split for a population with more than 200 people is considered to be 27%, because at this point the difference between the means of upper and lower groups divided by the standard deviation of this difference is maximized. For smaller

populations, the split will be 50%. The two ways of calculating the discrimination index are correlated and the discrepancies between the two statistics are very small or nonexistent (Jacobi et al., 2003, Oosterhoh, 2001). Items that fail to discriminate the high-group from the low-group should be eliminated from the item pool or improved (Hogan, 2007). Popham (2000) proposed some criteria for item selection based on the discrimination index value, which are listed in Table 2.

Table 2. Item Interpretation Based on Discrimination Index

Discrimination Index (D)	Item Interpretation, Action
0.4 or higher	Very good items.
0.3 to 0.39	Reasonably good, but possibly subjected to improvement.
0.2 to 0.29	Marginal items, usually needing and being subject to improvement.
0.19 and below	Poor items, Either rejected or improve by revision.

In the interpretation of results from item analysis, it is important to consider the relationship between an item's difficulty index and its discrimination index. Items with very high or very low difficulty indices, items that are either very easy or very hard, respectively, are not likely to provide clear discrimination between high ability and low ability examinees (Ebel and Frisbie, 1991).

Item difficulty and item discrimination indices can be calculated according to the following formulas:

Item difficulty index: $p = (Up + Lp) / (U + L)$

Item discrimination index: $D = (Up – Lp) / U$

where Up = number of high performers who answer the question correctly; Lp = number of low performers who answered the question correctly; U = number of high performers; L = number of low performers.

Upper (U) and Lower (L) criterion groups are selected from the extremes of distribution of test scores. Kelley (1939) proposed that the upper and lower 27% could lead to the optimal point when the total test scores are normally distributed.

In addition to using item difficulty and item discrimination in order to be able to accept or reject an item, an additional analysis needs to be performed that consists of distracter analysis. Distracter analysis is required in order to ensure that the responses are randomly distributed among the distracters. The distracter analysis provides a measure of how well each of the incorrect options contributes to the quality of a multiple-choice item. Based on the item analysis and distracter analysis information, an item review is conducted and the questions that are not efficient are improved or eliminated; some distracters may be changed or discarded. Any of the modified items must be retested again (Allen, 2006).

Distracter Analysis

The quality of a multiple-choice item depends very much on the quality of the item's distracters. Neither the item difficulty nor the item discrimination index considers the performance of the incorrect response options (distracters). Distracter analysis explores the performance of the incorrect response by analyzing the proportion of examinees who selected each of the response options (Hogan, 2007). A distracter should be plausible, that is, the distracters should look reasonable to an examinee that is not sufficiently knowledgeable in the content area. A distracter must be clearly incorrect in

order to avoid confusion with the correct answer. If the proportion of a distracter chosen by the examinees is low, the distracter is either implausible or too easy (Osterlind, 1998). These are some characteristics of the distracters that should be considered in the design of a multiple-choice item.

The Effect of the Number and Position of Options on a Multiple-Choice Instrument

Another important aspect of an item on a multiple-choice test is the number of options per multiple-choice item. Rodriguez (2005) presented a meta-analysis of research regarding the optimal number of options for multiple-choice items. In his analysis, 27 studies were considered based on the analysis provided by the study regarding the effect of changing the number of options per multiple-choice item on item difficulty, item discrimination, test score reliability, and test validity. Among the studies considered in the meta-analysis, Rogers and Harley (1999) and Costin (1972) investigated the difference between three- and four-choice items in terms of discrimination, reliability, and difficulty; Ramos and Stern (1973) analyzed the effect of four- and five-option multiple-choice items. According to the evidence synthesized in this meta-analysis, more three-option items can be administered within the same time limit than four- or five-option items, improving content coverage without significantly affecting the reliability of the instrument. The meta-analysis concluded by presenting the positive side of using fewer options. Fewer options reduce the cognitive load of the instrument and possibly provide fewer clues to the correct answer. Evidence from the meta-analysis, along with the Budescu and Nevo (Budescu and Nevo, 1985) study, suggest that in some cases the impact of changing the number of options per item depends on the method used to delete

options (distracter functioning and random deletion). Halaydna (2004) mention that there is no reason, psychometrically, to have the same number of options for every item.

Other considerations for item performance within a multiple-choice test is the item-order effect (Meyers et al., 2009) and answer-order effect (Bresnock et al., 1989). Several studies have suggested that changing the position of an item on the final exam relative to its position during trial testing development changes the difficulty of the item. Item-order effects have a higher impact on the low-proficiency students' scores than high-proficiency students (Huntley and Welch, 1988). The answer-order effect was analyzed by creating two versions of the same exam. One of the versions of the exam had a significant number of correct answers in the first position, while the other version had a significant number of correct answers in the last position. Students who see the correct answer first may take less time looking at the other possible options for those items. Students that take the exam version with a significant number of "first-answer" items essentially have more time for other items (Bresnock et al., 1989). It was also noticed the effect of answer order on the item performance on ACS exams. On different versions of the ACS exam the answer order is different (Schroeder et al., 2012). Furthermore, the cognitive load of the test should be considered in a test design. According to the cognitive load theory (Paas and van Merrienboër, 1993), a limit is reached in the capacity of the working memory when working on a cognitive task. Conceptual items present a higher cognitive load than a quantitative or definition question. During a timed test as students move from item to item, there is a variation in the cognitive load which explains the role of cognitive fatigue in test taking and also the item-order and answer-order effect (Paas et al., 2003).

Selected Concept Inventories

A selection of concept inventories are presented in terms of design and psychometric analysis. These are outlined below.

Force Concept Inventory

One of the first successful concept inventories was pioneered in physics education. The Force Concept Inventory (FCI) (Hestenes et al., 1992, Halloun and Hestenes, 1985) was designed to test students' knowledge and beliefs regarding the concept of force, which is a central concept of Newtonian mechanics. Mechanics cannot be understood without an understanding of force. The FCI is different from a traditional test in physics by the fact that it assesses conceptual understanding of fundamental force topics. This instrument contains 29 multiple-choice questions in which the students need to choose between the correct Newtonian concept and common sense beliefs. It is a qualitative test and does not require any computation in order to solve the problems. The incorrect answers diagnose the misconceptions held by students about particular topics. The instrument is usually administered at the beginning and the end of the course. A study employing the inventory (Hake, 1998) compared the gain in students' performance between a traditional physics lecture course and a course taught through interactive-engagement, such as problem-based learning. The FCI was administered in introductory physics courses with a total sample size of 6000 students for the study. The results of the study showed that courses taught through interactive-engagement methods generated a significantly higher gain in understanding, more than twice, on average, in comparison with the traditional methods courses. Based on these results, new methods of instruction were developed in physics education in which the focus on routine problem solving

shifted toward conceptual understanding. In addition, assessments became more of a qualitative understanding of topics rather than just algorithmic problem-based (Mazur, 1992).

The creation of the FCI paved the way for the development of concept inventories (CIs) in almost every scientific discipline. CIs are now available or under development in many different areas of science and engineering. For example, CIs have been developed during the last decade in chemistry (Mulford and Robinson, 2002), biology (Garvin-Doxas and Klymkowsky, 2008, Geiger, 2009), geology (Libarkin and Anderson, 2007), oceanography (Arthurs and Marchitto, 2011), and astronomy (Sadler et al., 2010). The Foundation Coalition, a National Science Foundation group, developed concept inventories in engineering: thermal and transport science concept inventory (TTCI) (Streveler et al., 2011), electric circuits (Evans et al., 2003), electromagnetic waves (Rhoads and Roedel, 1999), fluid mechanics (Jacobi et al., 2003, Martin et al., 2004) materials engineering (Krause et al., 2003), signals and systems (Wage et al., 2005), statics (Steif and Dantzler, 2005, Allen, 2006), strength of materials (Richardson et al., 2003), thermodynamics (Midkiff et al., 2001), and chemistry (Krause et al., 2004).

Despite the abundance of concept inventories, there is not a “concise definition” of what they measure nor a “concise methodology” for their design (Lindell et al., 2006). Since there is not a unified definition of what it means for an instrument to be a concept inventory, some of the definitions for a CI are presented. A concept inventory is an outline of core knowledge and topics for a given field and a collection of multiple-choice questions designed to probe student understanding of these fundamental topics (Redish, 1999). According to Savinainen and Scott (2002), concept inventories are multiple-choice

instruments designed to evaluate if a person has an accurate working knowledge of a specific set of topics. “Concept inventories are multiple-choice instruments that explore students' conceptual understanding in a given subject area, providing researchers with a map of their students' conceptual landscape, which can be used to inform instruction in that area” (Klymkowsky and Garvin-Doxas, 2008). Concept inventories are different from standard classroom multiple-choice tests since they assess conceptual understanding of material rather than problem-solving algorithms, which are the typical test format. Furthermore, unlike classroom tests, the design of a concept inventory is based on research about student learning in the concept area. The distracters (“incorrect” answers) typically reflect common alternative conceptions or incorrect ideas held by the students. Concept inventories differ from standardized tests in the intended use and the way they are constructed. Standardized tests typically are designed to rank students with respect to subject area knowledge. Concept inventories in their design use distracters constructed from students’ common alternative conceptions of the target topics. Based on the students’ answers, a CI reveals the probability that the students are using a particular conceptual model when working on problems in a specific area (Klymkowsky and Garvin-Doxas, 2008). Distracters are provided by the students during interviews using open-ended questions or may be gathered through free response items and from literature prior to the development of the CI. A concept inventory can be used for measuring conceptual understanding of students or to compare different types of instructional strategies. Selected items can be used by the instructor as a class discussion to supplement learning (Hestenes et al., 1992). In order to provide an understanding of the design and level of analysis required in the development of a CI, the following section

will provide an overview of several CIs developed in the area of chemistry, biochemistry, and biology education. These examples were chosen based on their relation in content and purpose to the General, Organic, and Biological Chemistry Concept Inventory (GOB-CTI) and will be discussed in terms of validity, reliability and item analysis.

Chemical Concepts Inventory

The Chemical Concepts Inventory (CCI) (Mulford and Robinson, 2002) is a multiple-choice instrument containing one- and two-tiered questions. It contains 22 conceptual questions that cover several topics of first-semester general chemistry. The instrument has been used with students in general chemistry courses for science and engineering majors, and it reveals the level of chemistry misconceptions held by students. According to the authors, the inventory was administered to students in a general chemistry course for science and engineering majors during the first week of a Fall semester and repeated during the first week of the following Spring semester. The average grade on the inventory was 45% (10 of 22) in the Fall and 50% (11 of 22) the following Spring. The average normalized gain <g> calculated for students in this course with the formula below was approximately

$$\langle g \rangle = [\%post - \%pre] / [100\% - \%pre] = 5\%/95\% = 0.05.$$

According to the Force Concept Inventory standards, which presented a gain of 0.2 for the traditional lecture, the gain indicated by this inventory is very low (Hake, 1998). The results of the CCI show that the students have difficulty with fundamental topics in general chemistry such as properties of atoms and molecules. According to the authors, “after at least two semesters of high school chemistry and one semester of general chemistry, 47% of students believe that the rust from a completely rusted iron nail weighs

less than the nail it came from; 75% cannot distinguish between the properties of a single atom of sulfur and a sample of solid sulfur; and 65% believe that breaking chemical bonds gives off energy." Validity and item analysis data were not reported. The internal consistency was determined to be 0.704 and 0.716 for the pre-test and post-test, respectively. Both of the values are acceptable for Cronbach's alpha.

The Genetics Concept Assessment: A New Concept Inventory for Gauging Student Understanding of Genetics

The Genetics Concept Assessment: A New Concept Inventory for Gauging Student Understanding of Genetics (Smith et al., 2008) consists of 25 multiple-choice questions on nine different topics. It was designed to assess conceptual understanding of a set of basic genetics topics taught in courses for both majors and nonmajors and has been used in the evaluation of a course taught through interactive methods. This instrument is designed to measure students' gains (Hake, 1998) by being administered as a pre- and post-test. The learning goals of the course that were chosen as being the main topics in the design of the instrument were established by interviewing course instructors and other genetics experts and by consulting the literature regarding the most common misconceptions in genetics. Experts were also consulted in the development of the multiple-choice questions. The distracters were provided by interviewing students and consulting the literature regarding common misconceptions in genetics. The assessment was statistically evaluated for several attributes: item difficulty, item discrimination, and reliability. The inventory questions were validated through experts (10 genetics faculty experts at several institutions) and students' interviews. The instrument was validated through think-aloud protocols with students based on explanations of the elected choice.

The students’ explanations were helpful in determining if the students were choosing the correct answer for the right reason. Data were collected from five different institutions and the mean pre-test scores, post-test scores, and normalized learning gain, were calculated and correlated with average exam scores in a large course that was taught using predominantly interactive methods. The researchers assessed the test-retest reliability of the instrument in two subsequent semesters. The test-retest method was used to calculate the reliability of the test by comparing the range of all correct and incorrect answer choices from two different courses at the same level. Coefficient of stability was calculated to be 0.93; the closer the coefficient of stability is to 1, the greater the reliability of the assessment.

Test to Identify Students’ Conceptualization

The test to Identify Students’ Conceptualization (TISC) (Voska and Heikkinen, 2000) contains ten, two-tier multiple-choice questions designed with the purpose of identifying topics used in solving equilibrium problems based on Le Chatelier’s principle. The first tier of each item is a multiple-choice question that relates to a problem statement. The second tier requires the student to explain the reasoning for their choice in the first tier. The literature and experts were consulted in the development of the instrument. The development of the distracters was based on the authors’ experience with the subject and class experience. Chemistry educators knowledgeable in chemical equilibria were consulted in order to determine the face and content validity of the instrument. Construct validity was established by comparing answers and reasons identified by the TISC for a particular student with comparable responses subsequently identified in student interviews. Reliability was analyzed through internal consistency;

the Kuder-Richardson (KR-20) reliability for the instrument was reported to be 0.79. The probability that the instrument correctly identified an answer given by a student in the interview was 0.64, and the probability that the instrument correctly identified a reason given by a student in the interview was 0.49. It was also reported that the students selected correct answers more frequently (53% of the time) than they provided correct reasons for their answers (33% of the time). The use of the test also facilitated the identification of eleven prevalent incorrect conceptions of students about chemical equilibria.

Osmosis and Diffusion Conceptual Assessment

This assessment (Geiger, 2009) *i*ncludes 18 two-tiered items. The instrument adopted or modified items from the previously published Diffusion and Osmosis Diagnosis Test (DODT) (Odom and Barrow, 1995), some newly developed items were added. The new instrument aligns better with the current curriculum requests. The items on the instrument are paired. The first-tier item sets the content through the general question “what happens?” and the second-tier item presents the possibility for a reason “Why does this happen?” The items contain two or three responses in the first tier and three or four answers in the second tier. It was observed that a correct answer on the first-tier item did not predict the performance on the second tier. It was also noticed that students generally performed better on the first tier indicating they can predict the outcome but have less understanding of the underlying cause or explanation. The items were tested and modified over the course of several semesters based on review by experts and interviews with students and faculty. From the interviews with students, the researchers noticed the students answered certain questions based on recognition of terms

or recall of definitions. The questions were modified to a more conceptual format. The instrument was administered for several semesters for validity reasons. Incremental changes were made to increase clarity of items and the distracters were improved in wording to look more attractive. Face validity was performed with biology instructors. Semi-structured interviews with undergraduate students provided insight in students' thought processes on the certain items. A difficulty index (with values varying from 0.27 to 0.98) and a discrimination index (with values varying from 0.07 to 0.67) were determined for each item. For the reliability of the instrument, Cronbach's alpha was reported to be from 0.70 to 0.74 for each semester the instrument was administered.

Development and Analysis of an Instrument to Assess Student Understanding of Foundational Topics before Biochemistry Coursework

Topic coverage of this instrument is weighted toward what a student is expected to know from general chemistry and biology upon entering a biochemistry course (Villafañe et al., 2011). The instrument measures five topics from general chemistry and three from biology. The instrument was designed to include three multiple-choice items for each concept. This creates the opportunity to have replicate trials measuring the same concept. The distracters were based on students' "incorrect ideas" that students develop in general chemistry and general biology. It can be used as a pre-test to identify students' incorrect ideas on the specific topics. It can be used as a post-test to determine the efficacy of instruction to help students overcome the incorrect ideas identified at the beginning of the course. The important topics for the instrument were determined by a group of experienced biochemistry faculty, some of who also teach general chemistry, and reviewed by a panel of experts. In their review, the panel considered relevance of

each statement to biochemistry as well as for its clarity and correctness. After the modification of each statement, the distracters were formulated based on incorrect ideas students have, identified from literature and from the authors' and experts' teaching experience. From a pool of 85 questions written by experts, a total of 24 multiple-choice questions, each with four options, were chosen as the final set to be tested. The instrument was analyzed for construct validity through a confirmatory factor analysis (CFA), which supports a good fit for an eight-factor solution. The instrument was proposed to have five general chemistry and three biochemistry topics or factors. CFA was performed to determine how well the instrument data fit the proposed eight-factor model. A Weighted Root Mean Square Residual (WRMR) value of 0.803 and a Comparative Fit Index (CFI) of 0.988 were reported. The results indicate the model fit is very good for the eight-factor solution. A Cronbach's alpha coefficient, as a measure of internal consistency, with values varying from 0.308 to 0.878 is reported for each of the eight topics in the test.

General Steps in the Development of a Concept Inventory

As presented in the preceding section, several concept inventories from the area of chemistry and biology were chosen in this review and discussed in terms of instrument design: the way the topics of the instrument were selected, the process of formulation of distracters, and the reported statistics such as instrument validity, reliability and item analysis. Though there is not a unified methodology in the design of a CI, it can be noticed from the reviews of the several CIs presented, there are some general characteristics regarding the development of a CI. A summary of the main steps involved in the design of a CI is presented (Richardson, 2004, Thornton, 1997):

(A) Determination of the topics to be included in the inventory. The number of topics examined by an inventory is limited due to time constraints. A list of topics is typically formulated based on interviews with experts regarding the topics that are important for the certain course especially those course topics with which students struggle. Based on the topics identified, a pool of open-ended questions is formulated by the researcher or a group of experts. The recommendation is for each item to test only one concept; otherwise it is difficult to determine which concept the students did not understand if the question is answered incorrectly.

(B) Item development. As presented in the review of the concept inventories, there are several ways in which distracters can be formulated. Some of the distracters can be developed based on students' alternative conceptions or incorrect ideas identified during interviews using think-aloud protocols or by discussing open-ended items in focus groups. Distracters can also be selected from published misconceptions or can be based on an instructors' experience in class or with the concept covered (Mazur, 1992).

(C) Data collection and data analysis. Administer a beta version (an "in progress") of the inventory to as many students as possible and perform statistical analyses on the results to establish validity and reliability. Validity is established from different perspectives. For example, face validity is established by consulting experts in the field during the developmental process; content validity can be determined by comparing students' scores with their ability to use topics on traditional exam-style problems. Different types of reliability determine if a test produces the same results if students take it in similar conditions.

(D) Revision of the inventory to improve validity, reliability, and readability. The items are refined based on the analysis of the data collected from the administration of the instrument to students over multiple semesters. The revised concept inventory needs to be reanalyzed and retested. The refinement of an instrument is a continuous process.

Conclusion

Nursing is an ever evolving and exciting field that integrates knowledge of science, compassion, and the means to serve others. Nurses are professionals who are becoming more and more independent in their daily practice. The literature review presented in this chapter brings some understanding of the progress of nursing as a profession, a portrait of the pre-nursing students as learners and pre-nursing students' journey in biosciences. As science instructors, it is important to understand the background of these types of students in order to be able to help them succeed. The literature review shows the importance of biosciences in nursing, the need for reductions in the cognitive load of these courses, and the need for teaching and assessment tools especially in the area of chemistry. The second part of the chapter presented the successful use of concept inventories as assessment tools in different areas of science along with the psychometric elements of design and development of a these types of assessments.

CHAPTER III

METHODOLOGY

This chapter presents the methods employed in conducting the study, including the research questions, research design, data collection procedures, and instrumentation. A multi-methods approach to data collection was used and the research was conducted in several stages.

It is well documented in nursing education publications that bioscience courses have a high cognitive load which creates anxiety (Nicoll and Butler, 1996) and difficulty (Wharrad et al., 1994) for many pre-nursing students. McKee (2002) recommended that, in order to achieve certain standards in these courses and to reduce the cognitive load of the course, it is important to establish a level of base knowledge required before starting the course. Regarding the GOB chemistry course for allied-health majors, there are no national guidelines or minimum standards for course content. Therefore, there is a need for exploration of different teaching approaches and assessment for such a high cognitive load and time-demanding course as GOB chemistry. One of the main purposes of this study was to identify the GOB chemistry topics pertinent to clinical practice. After identifying the main topics, the next phase of this research was the design and development of a GOB chemistry concept inventory. It is anticipated that the instrument will provide a tool to measure students' learning of the selected topics and determine

whether students have the required knowledge to successfully manage other courses in the nursing program that require the fundamental knowledge of GOB chemistry.

As presented in Chapter I, this study investigated the main topics of a GOB chemistry course and assessment of the pre-nursing students' conceptual understanding of the main GOB chemistry topics relevant to nursing clinical practice taught in the course as framed by the following questions:

Q1 What are the topics in a GOB chemistry course that are perceived by experts to be relevant to nursing clinical practice?

Q2 Is there a consensus among the nursing educators and GOB chemistry instructors and between the two cultures regarding the topics perceived to be relevant?

Q3 How does one appropriately measure pre-nursing students' conceptual understanding of the topics perceived by the experts to be relevant to clinical practice?

The project consisted of three major parts. The first part sought to identify the main GOB chemistry topics perceived by experts to be relevant to nursing clinical practice. The second part of the project assessed the consensus among experts. The third part addressed the design and the development of an inventory based on the GOB chemistry topics deemed important and foundational to the nursing clinical practice. In order to address the research questions, the study employed an array of statistical methodology including qualitative, quantitative, survey, and psychometrics.

Protection of Human Subjects

Various aspects of this study were submitted to the University of Northern Colorado Institutional Review Board (IRB) for projects involving human subjects. Institutional Review Board approval was submitted and approved prior to starting any fieldwork, and all participants were asked for consent to use their data before being used

in the project. An appropriate IRB request was submitted for each phase of the project (see Appendix A). The participants solicited in this research were a minimum of 18 years of age. All ethical considerations common to research with human subjects were used in the development of this study. Invitations to participate in the different stages of the project were presented to the experts and to the students (see Appendix B). All participation in the study was voluntary. Names were not associated with responses. Individuals received a code as to whether they were chemistry instructors, nurse educators, nursing graduate students or GOB students participating either in interviews, a pilot study, or final data collection. All data were stored in personal files of the researcher. Computer files were password-protected and paper files locked. Only the researcher had access to the raw data. In all cases, the anonymity of information collected from experts and students was maintained, confidentiality respected, and voluntary participation in the study emphasized. For each stage of the project, demographic data were collected (see Appendix C).

Part I: Identification of the Main General, Organic, and Biological Chemistry Topics Relevant to Nursing Clinical Practice

The first part of the study addressed RQ1: What are the topics in a GOB chemistry course that are perceived by experts to be relevant to nursing clinical practice? It was based on qualitative methodology to acquire descriptive, detailed data collected directly from the expert participants. Qualitative research and analysis give the most relevant and problematic details of the phenomenon that can then be used to formulate questionnaires or surveys for use in quantitative research (Creswell, 2001). In this study, the phenomenon being examined was the perceived relevance of topics presented in a GOB chemistry

course to the clinical practice of nursing from the perspective of GOB chemistry instructors, nurse educators, and nursing graduate students.

Theoretical Framework

In order to understand and formulate conclusions on the experience of the experts regarding the different chemistry topics perceived to be relevant to clinical practice, a qualitative research inquiry was conducted. Methods for qualitative inquiry are grouped in methods that attend to the behavior of the phenomena and methods that explore the human experience. The theoretical framework chosen to guide this qualitative inquiry research was phenomenography. Even though both aim to reveal human experience and awareness as object of study, phenomenology and phenomenography differ in purpose. There are some fine distinctions between the two methodologies (Barnard, 1999). In phenomenology, the search for essences or the most invariant meaning of phenomena is central, while in phenomenography the aim is not to find the singular essence but the variation of the world as experienced. The focus of the two methodologies makes them distinct. Phenomenography focuses on differences while phenomenology is focused on similarities in order to permit a description of the essence of a phenomenon (Giorgi, 1985, Giorgi, 2000). Phenomenography is an exploration and analytical approach to qualitative research that is interested in the content of thinking rather than the process of thought or perception. Phenomenography “is a research method adapted to mapping the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of phenomena in the world around them” (Marton, 1986).

Phenomenographic research aims to identify and describe qualitative variation in people's experience of phenomena, which is a suitable approach for description of differences and similarities in participants' opinions.

Participants

Participants were chosen based on either their academic expertise in the field of nursing, experience in clinical practice, or experience teaching a GOB chemistry course to pre-nursing students. In this study, criterion sampling was used since experienced participants, hereafter referred to as experts, were required to identify the relevance of chemistry topics useful in clinical practice. Diversity in sample selection provided a greater range of opinion and different perspectives on the phenomenon. Experts consisted of GOB chemistry instructors, nurse educators, and nursing graduate students with 2-5 years of clinical experience. The chemistry instructors were current faculty with graduate degrees in biochemistry that have regularly taught a GOB chemistry course. Nurse educators were current faculty in a program granting B.S., M.S., and Ph.D. nursing degrees. All nurse educators that were interviewed had a baccalaureate degree in nursing and experience in clinical practice as one of these types of nurses: RN, FNP, MSN, or CPNP. They have taught courses such as Pharmacology, Pathophysiology, Medical Surgical Nursing, Clinical Nurse Specialist in Oncology and Hematology, Labor & Delivery/Postpartum Nursing, Pediatric Nursing, Health Assessment, Clinical Skills, Therapeutic Interventions, and Women's Health Care Gerontology. Nursing graduate students invited to participate in this study were currently enrolled in either an M.S. or Ph.D. nursing degree program. All nursing graduate students have had 2-5 years experience in clinical practice. The period of 2-5 years of clinical practice for nursing

graduate students was selected based on the rationale that going back more than five years may be too long for people to remember accurately the breadth/depth of their chemistry course(s). As for the lower end being specified as two years, it was assumed that first-year nurses may still be adjusting to their new setting and may not have gained enough experience to understand how some of the chemistry topics relate to their clinical practice. All experts were recruited from a mid-size, western U.S., state university. Chemistry faculty were members of a Department of Chemistry and Biochemistry; nurse educators and nursing graduate students were members of a School of Nursing. There was adequate time spent in data collection such that data became “saturated,” that is, no new information was revealed by additional interviews.

Data Collection

Most phenomenographic research is based on semi-structured interviews though focus group or open-response survey data may be used (Cousin, 2009). The main data collection method for this part of the project consisted of semi-structured interviews with the experts, which used a predetermined set of questions. Qualitative research is designed to “listen to participants and build an understanding based on their ideas” (Creswell, 2001). The format of a semi-structured, person-to-person interview was selected because, although each interviewee was asked the same general set of questions. The interview responses reflected the personal experience and knowledge of the individual expert with the phenomenon. The semi-structured interview “allows the researcher to respond to the situation at hand, to the emerging world view of the respondent, and the new ideas of the topic” (Merriam, 2001). Based on the Stoker (2007) textbook used by the instructors teaching GOB chemistry at this university, a list of topics usually taught in a GOB

chemistry course (seeAppendix D) was developed. The list was compared to the table of contents of several other GOB chemistry textbooks including Denniston et al. (2007), McMurry et al. (2007), Raymond (2008), (Timberlake, 2010).

Using this list of topics along with the Stoker textbook, experts were interviewed about the relevance of the GOB chemistry topics that a nurse should understand. During the interview, the experts were asked to classify the listed topics based on their importance to clinical practice; furthermore, they were asked about chemistry applications within nursing related to the GOB chemistry topics. The purpose of interviewing the experts was to understand their perceptions and interpretations of the main chemistry topics deemed important for safe clinical practice. All interviews were digitally recorded and transcribed verbatim. From these transcribed interviews, a list of topics relevant to clinical nursing practice was generated (see Appendix E). The researcher was the primary instrument for data collection and analysis.

Data Analysis

The initial outcome of a phenomenographic research study was the identification of categories of description. In a phenomenographic study, “there are no algorithms for the analysis of interviews, rather a series of iterations to distill the meaning by repeated reading of the transcripts” (Bowden, 2000). The interviews were transcribed and analyzed by reading through the transcripts several times to look for patterns in the experts’ opinions and for similarities and differences. Based on observed trends in the experts’ responses, an initial coding scheme and categories was developed. The categories developed described different expert’s experience of the given phenomenon. In phenomenography, the only ground rule for category development is internal consistency

and parsimony, that is, identifying an “outcome space” that includes a minimum of categories which explains all the variation in data (Barnard, 1999). Data (excerpts of transcripts) were organized into categories that address the phenomena based on participants’ different views and responses.

Any qualitative study employs several strategies that promote validity and reliability (Merriam, 2001). These will be discussed in the following sections.

Study Rigor

The researcher’s careful design of the qualitative study made it rigorous and trustworthy. The researcher used different strategies to evaluate the study rigor, namely *inter-rater reliability, member checks, expert examination, and triangulation* to obtain a high level of trustworthiness. In order to evaluate the accuracy of a coding scheme in qualitative studies, the *inter-rater reliability* was used which consisted of the agreement between two or more raters. Once a set of codes was developed, additional raters (besides the researcher) were consulted regarding the categories of description and classification of topics. In consultation with a chemistry instructor and a nurse educator, information gathered from the interviews were also clarified in terms of meaning of the words and terminology to produce a list of detailed topics relevant to nursing clinical practice. *Member check* is another step in promoting validity in a qualitative study. Member checks provide credibility by eliminating any misunderstandings and confirming the researcher’s personal understanding. After transcribing each interview, the researcher returned the corresponding transcript to each participant to read the transcriptions and confirm the interpretations of the data. The researcher referred to *expert examination* by soliciting the expertise of the members of her dissertation committee. All phases of the project were

subject to their scrutiny and review including the clarity and accuracy of the open-ended questions, interpretation of interview scripts, and presentation of final data.

Triangulation refers to using multiple sources of data or data collection methods to confirm emerging findings and represents a way of exploration of internal validity of the study. Even though in a phenomenographic study there are no recommendations for triangulation, the researcher sought to accomplish it through the comparison of data from interviews with data from a national survey. The comparison of data collected in the two different ways strengthened the conclusions of the study. All the aforementioned procedures were used in the qualitative study in order to establish the internal validity of the study.

External validity of a qualitative study refers to the extent the findings of one study can be applied to other situations. It is important to provide a good "rich, thick description" of the research including questions, settings, participants, data collection, and findings as well as other details of the research so that other researchers can judge the trustworthiness and generalizability of the results and transferability to their specific cases (Creswell, 2001). Phenomenographical results may not be the "truth" in that they may never accurately describe "ways of experiencing," but they never claimed to be such. They only claim to be useful (Orgill, 2007).

Subjectivity Statement

The human element of research cannot be removed. In qualitative research, "data are mediated through this human instrument, the researcher, rather than through some inanimate inventory, questionnaire or computer" (Merriam, 2001). The researcher has certain experiences and theoretical beliefs that will influence data analysis and

categorization. One of the critiques of the phenomenography research pertains the assumption that the researcher can be a “neutral foil.” Despite this assumption, the readers of phenomenographic research need to be informed about all variables that have potentially affected the study results (Webb, 1997). According to Orgill (2007), this self-examination process may lead to additional insight into the data and an understanding of the way the beliefs of the researcher could have impacted the results of the research.

Personal Stance of the Researcher

The researcher is fascinated with chemistry, especially biochemistry, because of the many applications to living systems. She has a master’s in biochemistry and has been preoccupied by the health aspect and quality of life. In her teaching career, the researcher has had the opportunity to teach the laboratory for the GOB chemistry class for several semesters. As a teaching assistant for several years, she constantly sought to meet the needs of the pre-nursing students. Semester after semester, she has been a spectator watching the pre-nursing students struggle with the “Fundamentals of Biochemistry” - CHEM 281 course. She has noticed the high cognitive load of the course and that students understand a concept much more easily in an applied context since they like to recognize the relevance of the material to their future nursing practice. The researcher likes to use examples of the application of the concept taught, though she has never been exposed or studied in depth the relationship of some of these topics to the clinical practice. She believes that teaching topics with application to the nursing clinical practice will increase the motivation and may offer the students a good experience with the course.

Part II: Consensus Among And Between the Experts

The second part of the study addressed RQ2: Is there a consensus among the nursing educators and GOB chemistry instructors and between the two cultures regarding the topics perceived to be relevant? Data from interviews of the experts at the researcher's university were tabulated and compared for consensus both within each group of experts and between groups of experts.

In addition to the interviews, an on-line survey was designed to explore, at the national level, the nursing and chemistry experts' opinions about the specific GOB chemistry topics perceived to be relevant to nursing clinical practice (Appendix F). The survey was developed by the researcher and administered on-line by using the university survey software Qualtrics. The survey opened with an informed consent statement, a request for acknowledgement of that statement, and an icon 'yes' to designate consent to participate (see Appendix A). The survey consisted of topics taught in a GOB chemistry course and respondents were asked to rate each concept as *important*, *foundational*, or *not important*. The meaning of each of these terms was explained on the first page of the survey. Following each question, the survey presented an open text box for comments. The survey for nursing and chemistry experts concluded with some demographic questions (see Appendix C). The demographic form requested information such as the chemistry instructor's experience with the course, the percentage of each section of chemistry (general, organic, and biological chemistry) they teach in the course, and the use of the General-Organic-Biochemistry Exam (Form 2007) of the American Chemical Society (GOB-ACS) in the course. The demographic form for the nurse educators

requested information regarding their experience in nurse education and their experience with chemistry.

The sample used in the national survey was a random sample, since the nurse experts were identified and recruited from the web site of different nursing schools. The chemistry instructors were identified and recruited from the web site of chemistry departments at universities that have a nursing school. Invitations to participate (Appendix B) were sent by email to the experts. The email informed the experts about the project, the link to the survey, and email addresses by which they can communicate with the researcher or the advisors of the project. Survey results were downloaded and stored in an Excel file. Data were presented in the form of percentage of agreement among the experts based on the different topics.

Part III: Instrument Design and Development

The third part of this study addressed RQ3: How does one appropriately measure pre-nursing students' conceptual understanding of the topics perceived by the experts to be relevant to clinical practice? In this section, the theoretical framework and the steps employed in the development of the GOB chemistry concept inventory (GOB-CTI) are described.

Theoretical Framework

The GOB-CTI was designed and developed in accordance with a framework known as the 'assessment triangle' recommended by the National Research Council report *Knowing What Students Know: The Science and Design of Educational Assessment* (Pellegrino et al., 2001). The assessment triangle is a psychometric model applied in educational assessment. The research in educational assessment seeks to (1) identify the

best evidence of learning, (2) develop accurate means of measuring that evidence, and (3) maximize the interpretation of those measures by applying theories in cognitive and measurement science.

The assessment triangle model, regardless of the type of assessment whether large-scale standardized tests or smaller classroom assessments, consists of three interrelated components of assessment: cognition, observation, and interpretation as illustrated in Figure 6. *Cognition* refers to a model of how students represent knowledge and develop expertise in a content domain. It is recommended that a theory of learning is needed to identify the knowledge and skills that are important to measure for a certain task. In building an assessment, the designer must consider a clear cognitive model of learning. *Observation* represents tasks or activities performed by students by which knowledge and skills are demonstrated that allow an evaluator to observe students' performance. *Interpretation* refers to evaluation methods of the tasks or activities in order to draw conclusions about the learning outcomes. Measurement models are statistical examples of the interpretation corner of the assessment triangle. They provide the statistical tools needed to integrate the information obtained from a task to formulate assessment results. In the design of an assessment instrument, it is important to have 'alignment' of the three corners of the triangle that represent the three components. The beliefs about how students learn the material must be consistent with the type of assessment tasks and with the methods used to analyze the results of the assessment (Pellegrino et al., 2001).

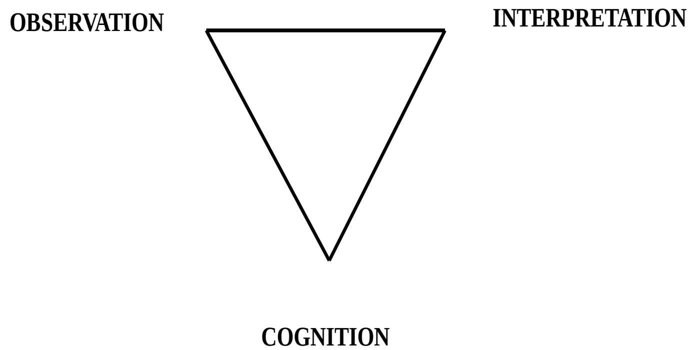

Figure 6. The assessment triangle (Pellegrino et al., 2001).

Concept inventories are among the research-based assessment tests developed using the assessment triangle. The methodology that was involved in the development of the GOB-CTI aligned with the three corners of the assessment triangle: cognition, observation, and interpretation. In the cognition corner, the alternative conceptions or incorrect ideas held by GOB chemistry students were identified by using a think-aloud protocol in conjunction with a chemistry instructor experienced with the course. In the observation corner, items for the GOB-CTI were created and piloted. In the interpretation corner, Classical Test Theory was used to evaluate the performance of the GOB-CTI items and to estimate the instrument validity and reliability of the data.

General Model for Test Design

An overview of the main steps in the development process of the inventory is presented in this section. The GOB-CTI was analyzed from a Classical Test Theory perspective. As part of the ongoing developmental process, individual item analysis was conducted which included item difficulty, item discrimination, and quality of distracters.

The GOB-CTI purports to measure the pre-nursing students' conceptual understanding of the main chemistry topics important in the clinical practice. The test contains 45 items divided into three sections: general (approximately 30% of the questions), organic (approximately 20% of the questions), and biological chemistry (approximately 50% of the questions) based on the significance of the topics from each section of chemistry present in the GOB course. The test instrument was designed with 45 items, which represents a reasonable number of items, which allows the coverage of the amount of topics found relevant and also it is intended to be completed in a 50-minute class period. The multiple-choice format of concept inventories eliminates reliance on the subjective judgments of raters (Osterlind, 1998). The test instrument provided a comparison of the pre-nursing students' knowledge of the main chemistry topics identified (during phases one and two described below) as essential for the nursing clinical practice. The test does not evaluate all the topics taught in a GOB chemistry course, only those deemed most relevant to the nursing clinical practice. The design and development of the test instrument was divided into several phases and followed the reiterative model illustrated in Figure 7.

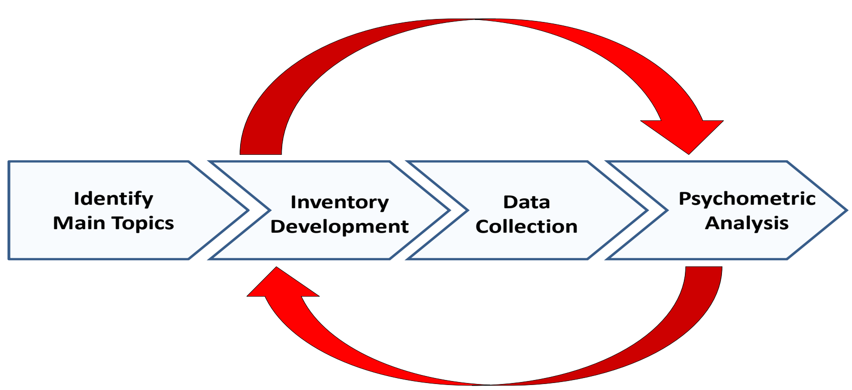

Figure 7: General model for test design of the General, Organic, and Biological Chemistry Concept Inventory.

Phase One: Formulation of a List of Topics

From the interviews with the experts and based on experts' classifications of the topics taught in a GOB chemistry course, a list of topics considered relevant for a nurse's clinical practice was developed (Appendix D). This list of topics served as a blue print in writing open-ended questions. These questions were tested with students in order to formulate the distracters for the multiple-choice items. Data were collected through interviews with the students in the format of think-aloud problem solving and in written form.

Phase Two: Development of Distracters

A variety of research techniques, such as interviews, think-aloud as students are working a problem, and analysis of errors, can be used to "observe" the mental process of examinees. This type of approach can also ensure that the assessment instrument measures what it is intended to measure (Pellegrino et al., 2001). The way the students answer a question and the explanation of how they get to a certain answer is a revelation in students' beliefs, alternative conceptions, and incorrect ideas. The think-aloud protocol allows the researcher to gain an insight in the students' thinking and understanding of terms and topics. Interviews with the students assures novice face validity which is very important since sometimes students understand and interpret a concept in a way very different from an expert (Bowen, 1994).

The think-aloud protocol technique was initially used in cognitive psychology research to investigate problem solving. The protocol allows the researcher to observe the thought process or decision-making of somebody performing a task. Ericsson and Simon

(1993) contributed to the development of the think-aloud protocol. The method has been used in chemical education research to explore the cognitive process of students when solving chemistry problems (Bowen, 1994, Cheung, 2009). With this type of protocol, students are encouraged to verbalize their thinking while solving open-ended questions. The think-aloud process reveals the way of thinking and beliefs of students related to a certain concept. The interviewer will ask the students to explain their answer; however, the researcher must be careful to avoid suggesting students to reason or respond in a certain way. The researcher must be careful in asking students their reasoning; asking *why* or *how* they did something can alter students thinking, thus students may attempt to improve their answer. The interviewer, in addition to having good interviewing skills, must have a good knowledge in the content area in order to properly interpret or identify students' deviation from the expert-like thinking (Adams and Wieman, 2011).

Participants

Students were selected on a voluntary basis. The researcher presented the project in the GOB chemistry classes at a mid-size, western U.S., state university and a form requesting volunteers was circulated among the students. The students had the opportunity to volunteer for a preferred date and time for the interview and provide their contact information. The researcher contacted the volunteers via email to finalize the appointment. Approximately 20 students were invited to participate in this phase of the project. Since each student answered 7-10 questions, this sample size of students allowed the coverage of each question several times, which enabled the researcher to decide if a certain answer reflected an alternative conception or an incorrect idea. Also with this student sample size, a saturation in answers for each question was reached, thus additional interviews were not

conducted since they would probably not have provided new information. As an incentive for students to participate and provide thoughtful responses, the researcher offered a help session at the end of the semester.

All interviews were conducted by the researcher in a private interview room. The interviews were audio recorded and transcribed. At the beginning of the interview, participating students were presented with two consent forms, one for them to keep as a reference of their participation in the study and one to be returned with a signature to the researcher (see Appendix A). The students also completed a demographic form (see Appendix C). Data obtained through the demographics form provided student information such as gender, previous experience with chemistry, math or other science courses, and the effect of time since the student's graduation from high school. This information is available if, following the conclusion of this study, there may be interest in investigating the effect of any of these variables. Students were provided with a pencil, blank paper, and a calculator. Participants received directions about the think-aloud protocol. The interview took 30-45 minutes and each student was presented with a total of 7 to 10 open-ended questions, one question at the time. They were asked to read each question aloud. A few minutes were offered for students to think and write an answer. Students were asked to verbalize their thoughts as they answer each question. In addition, the investigator utilized verbal probes to clarify students' reasoning. Also, students were consulted whether the questions were clear regarding the wording or meaning of certain terms. After each interview, the researcher compiled field notes about the progression of the interview and special aspects that may need to be considered in the analysis of the interview.

Phase Three: Item Development

Cognitive think-aloud interviews with pre-nursing students guided the open-ended item revision and development into a multiple-choice question format. Nunnally's (1978) recommendation is that the initial pool should contain 1.5 to 2 times as many items as the final instrument. Since the number of questions desired for the final instrument was 45, a bank of 67 questions was constructed with distracters utilizing alternative conceptions, incorrect ideas identified among the pre-nursing students in the GOB chemistry course, and plausible but incorrect answers gathered from the experience of one of the chemistry instructors with the course (see Appendix G). Three to five questions per concept were written.

Rodriguez (2005) presented a meta-analysis of research in the area of optimal number of options for multiple-choice items. The study concluded that the optimal number of options is three. The 3-option items present certain advantages in terms of improving content coverage without significantly affecting the reliability of the instrument compared to 4- or 5-option items. Also, fewer options reduce the cognitive load of the instrument and possibly provide fewer clues to the correct answer. In the design of the options per item of the GOB-CTI, consideration was given to the report of Budescu and Nevo (1985) which suggested that in some cases the impact of changing the number of options per item depends on the method used to delete options (distracter functioning and random deletion). Haladyna et al. (1987) mentioned that there is no reason, psychometrically, to have the same number of options for every item. In the initial draft of the GOB-CTI, each item was designed to have four options, a correct answer and three distracters; in case of deletion of one of the options as a result of data analysis, the item will still function well.

Each item was designed to measure knowledge of a single concept. The bank of items was developed and analyzed by the researcher, a GOB chemistry instructor, and a chemical educator, for the topics, wording, and possible confusing or misleading aspects of the questions. When necessary, the multiple-choice items were improved. Once the items were organized into an instrument, data were collected in order to gauge the validity and reliability of the instrument. Furthermore, each item was analyzed in the context of the whole test.

Phase Four: Data Collection and Psychometric Analysis

The draft inventory was pilot tested with pre-nursing students enrolled in a GOB chemistry course at two different universities. The instructors of each course were contacted by the researcher and with permission of the instructor; the test was administered in the last week of the semester. Students were informed about the project and the possibility to take the draft inventory as a practice test for their final exam (see Appendix B). Before they started the test, the students were requested to sign a consent form and complete a demographics form (see Appendices A and C). They received instruction about the scantron answer sheet.

The students recorded responses to questions on scantron sheets. Following scanning, the results were received in the form of a .cvs file which was converted into an Excel spreadsheet. Data were converted in Excel to two working sets of polytomous and dichotomous values. For the polytomous set of data, the items were coded 1, 2, 3, and 4 (the number corresponding to each of the four response options of an item: A, B, C, D) and were presented in the form of tables and histograms for use in distracter analysis. For the dichotomous set of data, values of 1 for correct answers and 0 for incorrect answers

were assigned to each item on the assessment and analyzed with SPSS 17.0 software in order to determine the item difficulty and discrimination. A t-test of the data collected was performed in order to identify any significant differences between each group of students at the different universities. Since there was no significant difference, the data were analyzed collectively.

The GOB-CTI was analyzed through the prism of Classical Test Theory (CTT). The CTT provides information at the test level, not the individual item level, which implies some limitations on the conclusions regarding individual test items. In CTT, detection of poor items is straightforward and is based on item analysis. A poor item is identified by an item difficulty or item discrimination index being either too high or too low (Hambelton and Jones, 1993). Since there is a lack of assessments and no concept inventories in the area of GOB chemistry, the project is considered “ground breaking work” and classical item analysis in conjunction with an analysis of distracters provides the researcher with invaluable information regarding the quality of the item regardless of the measurement model applied in later stages of test development.

The benefits of applying CTT to measurement problems includ: CTT requires smaller sample sizes, simpler mathematical analyses compared to Item Response Theory (IRT), the estimation of model parameters is straight-forward, and the analyses do not require strict goodness-of-fit studies to ensure a good fit of model to the test data (Hambelton and Jones, 1993). Psychometric analyses based on CTT of the data includes item analysis, validity, and reliability studies which will guide item retention, omission, or revision of the items on the inventory. In the case of CTT, the psychometric analysis is

sample dependent, thus generalizations are limited to populations that are similar to the sample from which the statistics are derived.

Item Analysis

Item analysis was conducted to determine the best items to retain in accordance with the purpose of the inventory. Item analysis consisted of determining the item difficulty, item discrimination, and analysis of item distracters (response frequency) and is based on data collected from the students. The item difficulty and item discrimination indices were calculated according to the following formulas:

Item difficulty index: $p = (Up + Lp) / (U + L)$

Item discrimination index: $D = (Up - Lp) / U$

where Up = number of high performers who answered the question correctly; Lp = number of low performers who answered the question correctly; U = number of high performers; L = number of low performers. Upper (U) and lower (L) criterion groups are selected from the extremes of the distribution of test scores.

These calculations were performed in Excel for the 27% upper and lower of the total scores (Kelley, 1939) for a set of data of $n \geq 100$. For a smaller set of data ($n < 100$), the 50% upper and lower limits were considered (Kaplan and Saccuzzo, 1997).

The item difficulty index reflects the proportion of students who responded correctly to an item. The item discrimination index is a measure of how well an item discriminates between examinees who are knowledgeable in the content area and those who are not.

The GOB-CTI is a criterion-referenced test designed to measure students ability to master the GOB chemistry topics deemed relevant to the clinical practice. For this

purpose, items of moderate difficulty (0.29-0.80) and a discrimination index of 0.29-0.8 were considered. The item difficulty and item discrimination indices were presented in tabular format for easier analysis. Items that failed to discriminate the high performers from the low performers were improved or eliminated from the item pool. By including items of varying difficulty, the instrument will be able to differentiate between students with different levels of knowledge (Kline, 2005). Based on the item analysis statistics, each item was reviewed, revised, or eliminated. After the selection and revision of items, the beta version of the instrument containing 47 items (Appendix H) was re-tested. An attachment (Appendix I) provides psychometric information in terms of item difficulty, item discrimination, and "Cronbach's alpha if item deleted" of the beta version of GOB-CTI.

Distracter Analysis

Distracter analysis informs the researcher about how the distracters contribute to the quality of an item. The polytomous set of data in which the items were coded 1, 2, 3, and 4 (the number corresponding to each of the four response options of an item: A, B, C, D) was used in distracter analysis. Data were analyzed in terms of the proportion (expressed in percent) of each option selected by the examinees. When the proportion of examinees choosing a distracter is higher than the proportion of the ones choosing the right answer, it is an indication of a difficult concept or an indication that the item should be reanalyzed in terms of wording or the possibility of a mistake in the key. If a distracter is not chosen or chosen in low proportion, it is an indication that the distracter is too easy or unattractive to the examinee. In this case, the distracter must be reworded or removed from the test.

As the result of the psychometric analysis of the second pilot (beta version) study, two items were eliminated, and the final form of the GOB-CTI contains 45 items. The final form of the inventory and answers are presented in Appendix H.

Assessment of Validity

The validity studies of the GOB-CTI focused on construct validity, which is the most widely reported form of instrument validity. For the construct validity of the GOB-CTI, both subjective measures such as *face validity* and *content validity* and empirical measures such as *convergent validity* were established.

Face validity is a very subjective measure of construct validity. After the instrument was assembled, experienced GOB chemistry instructors reviewed the instrument regarding the instrument's appearance to measure the topics that it is supposed to measure. *Content validity* refers to the coverage of a certain content domain. The content domain was established from the interviews and by soliciting a panel of the experts. After the instrument was assembled, GOB chemistry instructors and nurse educators were invited to revise the content of the instrument for clarity, correctness, and relevance based on the utility of the instrument and also to decide to what degree the items reflect the content domain. The experts were solicited to express their opinions, suggestions, and comments about each item on the instrument to make sure the items reflect each topic of the content domain (Carmines and Zeller, 1979). For this purpose, a blue print in the form of a table of the main GOB chemistry topics relevant to the clinical practice (see Appendix D) was distributed to the experts along with the instrument for review (see Appendix H). In this phase of the project, the experts that participated in the first phase of the project were solicited. Additionally, an invitation letter was sent to

experts from other universities to participate in this phase of the study (see Appendix B). The content domain for the GOB-CTI is presented in Appendix J.

Convergent validity is an empirical measure of a construct and is used to evaluate the degree to which two or more measures that theoretically should be related to each other are actually observed to be related to each other (Barbera and VandenPlas, 2011). Convergent validity was established by comparing the results from the GOB-CTI instrument with the General-Organic-Biochemistry Exam (Form 2007) of the American Chemical Society (GOB-ACS). Students took the GOB-CTI the last week of class of the semester. The scores on the GOB-CTI questionnaire, expressed in percent, were compared with the scores of the GOB-ACS that was administered as the final exam in the course. The comparison between the two tests was performed in two ways. One way was a comparison of the total scores of each test. Since the GOB-ACS covers a broader content area than the GOB-CTI, a low positive correlation was expected. Another way of comparison was at the item level. It was expected that there will be a high positive correlation between similar items among the scores on the two instruments. As the uses and the needs of the instrument evolve, the instrument should constantly be evaluated, which makes the process of validation an on-going process (Nunnally, 1978).

Assessment of Reliability

Reliability of the GOB-CTI was analyzed in terms of internal consistency, which was represented through Cronbach’s alpha. This type of reliability is concerned with the consistency of the data produced by an instrument. Cronbach’s alpha was chosen in the study because it requires only a one-time administration of the instrument which eliminates the concern of students gaining knowledge between administrations as is the

case with test-retest reliability (Trochim and Donnelly, 2007). An instrument that is functioning well will yield scores that are consistent, which is an indication that the items measuring the same concept produce scores that are correlated. Cronbach's alpha depends on several factors: correlation among items, the number of items, and the variance among scores. A high alpha value indicates a high correlation among items measuring the same construct. Based on the purpose of the test, Cronbach's alpha has different accepted values that indicate if the test is reliable or not. An acceptable value for Cronbach's alpha is 0.70 (Nunnally, 1978). The overall reliability of the GOB-CTI instrument was expected to be lower since the instrument covers a wide range of topics in three major areas of chemistry, and the students will more likely guess on some questions (Oosterhoh, 2001). Considering the broad content domain of the GOB-CTI, a modest correlation between inventory items was expected, which will be reflected in a low value of internal consistency.

Construction of a concept inventory involves iteration of the steps outlined in this chapter. In a course such as GOB chemistry applied to nursing, there is a strong emphasis placed on conceptual learning instead of focusing on procedural and computational skills (Tiwari et al., 2005). The GOB-CTI is a multiple-choice instrument that aims to assess conceptual understanding of the main GOB chemistry topics relevant to nursing clinical practice. The final instrument contains 45 questions, which can be administered in a typical class period of 50 minutes.

CHAPTER IV

ARTICLE 1: A BRIDGE BETWEEN TWO CULTURES:
UNCOVERING CHEMISTRY TOPICS RELEVANT
TO NURSING CLINICAL PRACTICE

Abstract

This study focused on the undergraduate course that covers basic topics in General, Organic, and Biological (GOB) chemistry at a mid-size, Western U.S., state university. The central objective of the research was to identify the main topics of GOB chemistry relevant to the clinical practice of nursing. The collection of data was based on open-ended interviews of both nursing and chemistry teaching faculty and nursing graduate students with clinical practice experience. From the resulting interview transcripts, three categories emerged: topics that are Important--have a direct application in nursing clinical practice; topics that are Foundational--facilitate understanding of important topics, but are not directly important in nursing clinical practice; and topics that are Not Important--do not have a direct application and are not significant in nursing clinical practice. Utilizing the data collected, a list of clinically-relevant chemistry topics was developed. The information from this study can assist GOB chemistry instructors to

better understand which topics to emphasize in their teaching. The two cultures, the disciplines of chemistry and nursing, agree that a good understanding of chemistry, with clinical implications, is important for a practicing nurse.

Keywords: Chemical Education Research, Curriculum, General Chemistry, Organic Chemistry, Biochemistry, Non-majors Chemistry Course, Nursing Education.

Introduction

There have been significant changes in nursing and nursing education in recent years. The roles of nurses have changed and are becoming more complex and more demanding. The current expression in the nursing world, "high tech, high touch," reflects the need for nurses to demonstrate the ability to combine humanistic skills with scientific knowledge and technological elements. Nurses should possess a high level of critical thinking skills and positive self-efficacy in the profession, especially in trouble shooting situations (Harvey, 1994, Scheffer and Rubenfeld, 2000, Simpson, 2002). General care nurses must be cognizant of the cytotoxicity of different drugs, dosage and concentration, and waste disposal of byproducts of toxic drugs (Heath, 2002, Scalise et al., 2006). Because of the increased expectations of nursing as a profession, the need for a strong scientific foundation is more demanding. It is important that nurses question, analyze, and make decisions based on appropriate scientific knowledge (Wilkes and Batts, 1996) .

In their case study of student nurses, Scalise et al. (2006) proposed that chemistry is an essential foundation for all healthcare professionals. Biochemistry is foundational for understanding disciplines such as pathophysiology, nutrition, pharmacology, and other biology- and chemistry-related subjects (Ouyang et al., 2007). Studies concerning science courses in nursing programs have suggested that nursing students have not only inadequate preparation for these courses and a negative attitude toward the relevance of science in nursing but also lack the confidence necessary to study these areas (Caon and Treagust, 1993, Chapple et al., 1993, Clancy et al., 2000, Friedel and Treagust, 2005).

Research in nursing education has revealed various potential factors that contribute to the perception by nursing students that bioscience courses are difficult

(Caon and Treagust, 1993, Nicoll and Butler, 1996). Some of these factors include the cognitive load of the courses, academic skills, science background of the students, mathematical abilities of the students, the anxiety of failure, and instructor's approach (Caon and Treagust, 1993, Chapple et al., 1993, Clancy et al., 2000, Gretsy and Cotton, 2003, Wright, 2007, Courtenay, 1991). Depending on the specific nursing school and its requirements, many pre-nursing students are required to take a General, Organic, and Biological (GOB) chemistry course to fulfill their chemistry requirement. Some factors that present challenges and consequently successful performance in a GOB chemistry course are summarized in Figure 1.

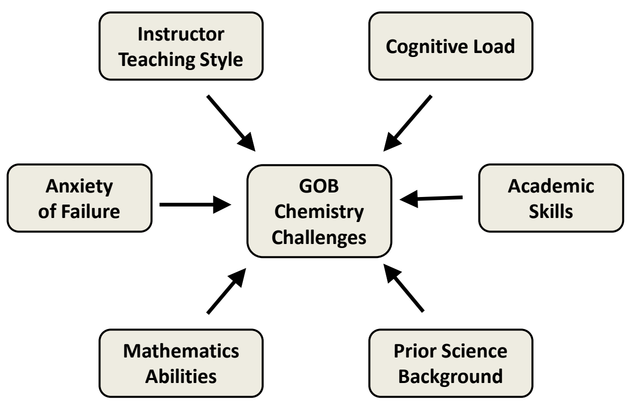

Figure 1: Factors affecting success in a general, organic, and biological chemistry course.

Among the factors mentioned regarding success in a GOB chemistry course (see Figure 1), the instructor's approach and the cognitive load of the course are two very important factors that can be modified by chemistry instructors. The GOB chemistry instructors are typically chemists and often present the material as they would to chemistry majors; therefore, they tend to teach with a rather discipline-based approach.

An appropriate example of how the approach taken by chemistry instructors differs from what nurse educators think is important for the profession can be illustrated using the concept of *pH*.

Chemistry Instructors' Perspective

From the perspective of the chemistry instructors in this study, *pH* is typically introduced in connection with the self-ionization of water. This is often followed by a derivation of the K_w expression. Students are told that the concentration of hydronium ion $[H_3O^+]$ in an aqueous solution can range from about 18 M to $1x10^{-15}$ M. Because it is inconvenient to work with such a large range of concentrations, the calculations are simplified by introducing the logarithmic mathematical function. Things can become even more challenging for nursing students when the relationships among *pH*, pK_a, and the concentrations of a weak acid and its conjugate base are introduced and described by the Henderson-Hasselbalch equation in relation to a buffer solution.

It is often difficult for non-chemistry majors to see the relationship between $[H_3O^+]$ and *pH*, making the concept of *pH* difficult to understand as well as to apply. Studies have shown that nurses do not always have the necessary skills to calculate correct drug dosages, and there is need for improvement of both mathematical skills and conceptual skills of nursing students (Chrisensen and Miller, 2008, Wilson, 2003, Hutton, 1998). Since the mathematical skills of pre-nursing students are often limited, this perspective of *pH* can not only increase their cognitive load but also reduce students' self-efficacy (Chrisensen and Miller, 2008, Vasile et al., 2011).

Nursing Educators' Perspective

From the perspective of the nurse educators in this study, the *pH* concept should be considered in the context of homeostasis. It should be explained that there is an inverse relationship between the value of *pH* and the concentration of hydronium ions. It should be mentioned that many compounds in the body contain functional groups that can act as acids or bases by donating or accepting hydrogen ions, respectively, and that the concentration of hydronium ions determines the acidity of the solution, which consequently affects many biological reactions. As a connection to clinical practice, the *pH* range of blood should be mentioned (as illustrated in Fig. 2); the normal blood *pH* range is 7.35-7.45. The range 7.35-6.80 is an indication of metabolic acidosis and the range 7.45-8.00 is an indication of metabolic alkalosis. This type of introduction to the *pH* scale offers a direct opportunity to connect *pH* to metabolism.

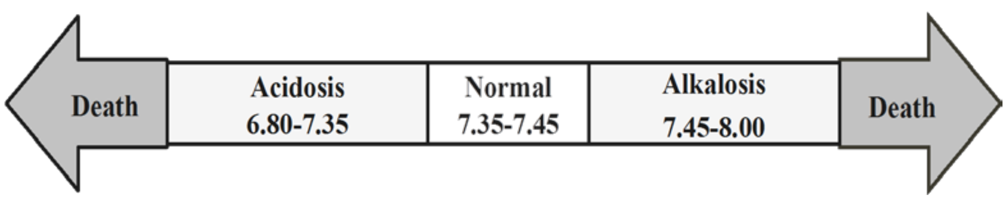

Figure 2: Normal and abnormal *pH* of blood.

Purpose of This Study

This research study focused on an undergraduate course that covers a broad range of topics in General, Organic, and Biological (GOB) chemistry at a mid-size, Western U.S., state university. The purpose of the study was to identify topics from the GOB chemistry course that are relevant to the clinical practice of nurses. The quandary of what should be taught and how it should be taught in allied-health programs is not trivial. This

problem is heightened given the anxiety of pre-nursing students who fear that requirements of the course may close doors and opportunities for them (McCabe, 2007, Jordan et al., 1999). Some pre-nursing courses, like GOB chemistry, are sometimes viewed as gatekeepers, thus determining who has access to the profession (Scalise et al., 2006).

Undergraduate nursing students often feel stressed by the cognitive load and content detail in their program (Nicoll and Butler, 1996). Despite the need for more knowledge in science, the nursing education literature shows that the level of science knowledge is far from being fulfilled (Scalise et al., 2006). While many studies document the importance of science content within undergraduate programs, the level and breadth of the content to be taught remains unclear (Friedel and Treagust, 2005). Research has identified that bioscience knowledge enhances nursing practice and that the incorporation of suitable scientific knowledge will help nurses in their clinical judgment and safe nursing practice (Torrance and Jordan, 1995). Walhout and Heinschel (1992) explored the perspective of nursing professionals regarding the ranking of topics included in a nursing chemistry course. However, in the two decades since their study, there have been no published studies pertaining to the main chemistry topics nurses should understand in order to be good practitioners. In the discussion section of this paper, parallels are explored between Walhout and Heinschel’s study and the current study.

Methodology

This study was based on qualitative methodology to acquire descriptive, detailed data collected directly from the participants. Qualitative research and analysis give the most relevant and problematic details of the phenomenon that can then be used to

formulate questionnaires or surveys for use in quantitative research (Creswell, 2001). In this study, the phenomenon being examined was the perceived relevance of topics presented in a GOB chemistry course to the clinical practice of nursing from the perspective of GOB chemistry instructors, nurse educators, and nursing graduate students. Phenomenography was chosen as the theoretical framework to guide this research, since the goal was to identify various ways experts perceive the relevancy of the GOB chemistry topics. According to Marton (1986), phenomenography "is a research method adapted to mapping the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of and phenomena in the world around them." This approach is suitable for description of differences and similarities in participants' opinions.

Participants

Participants were chosen based on either their expertise in the field of nursing, experience in clinical practice, or experience teaching a GOB chemistry course to pre-nursing students. In this study, criterion sampling was used, since experienced participants, hereafter referred to as experts, were required to identify the relevancy of chemistry topics useful in clinical practice. Experts consisted of four GOB chemistry instructors; six nurse educators, and four nursing graduate students with 2-5 years of clinical experience. The chemistry instructors (CI) have regularly taught a GOB chemistry course. One chemistry instructor is also a co-author of this paper. Nurse educators (NE) were faculty in a program granting B.S., M.S., and Ph.D. nursing degrees. One nurse educator is a co-author of this paper. All nurse educators interviewed have a baccalaureate degree in nursing and experience in clinical practice as one of these types

of nurses: RN, FNP, MSN, or CPNP. They have taught courses such as: Pathophysiology, Pharmacology, Medical Surgical Nursing, Clinical Nurse Specialist in Oncology and Hematology, Labor & Delivery/Postpartum Nursing, Pediatric Nursing, Health Assessment, Clinical Skills, Therapeutic Interventions, and Women's Health Care Gerontology. Nursing graduate students (NGS) were enrolled in either an M.S. or Ph.D. nursing degree program. All NGS were returning students with 2-5 years' experience in clinical practice. The period of 2-5 years of clinical practice for nursing graduate students was selected based on the rationale that going back more than five years may be too long for people to remember accurately the breadth/depth of their chemistry course(s). As for the lower end being specified as two years, it was assumed that first-year nurses may still be adjusting to their new setting and may not have gained enough experience to understand how some of the chemistry topics related to their clinical practice. All experts were recruited from a mid-size, western U.S., state university. Chemistry faculty were members of a Department of Chemistry and Biochemistry; nurse educators and nursing graduate students were members of a School of Nursing.

Data Collection

The main data collection method for this project consisted of semi-structured interviews with the experts. Person-to-person interviews were used in order to determine the personal experience and knowledge of the experts with the phenomenon (Merriam, 2001). A semi-structured interview was used because it "allows the researcher to respond to the situation at hand, to the emerging world view of the respondent, and the new ideas of the topic" (Merriam, 2001). Based on the Stoker textbook (Stoker, 2007), used by the instructors teaching GOB chemistry at this university, a list of topics usually taught in a

GOB chemistry course (see supplemental material) was developed. The list was compared to the Table of Contents of several other GOB chemistry textbooks: Denniston et al. (2007), McMurry et al. (2007), Raymond (2008), (Timberlake, 2010).

Using this list of topics along with the Stoker textbook , participants were interviewed about the relevancy of the GOB chemistry topics that a nurse should understand and were asked to classify the listed topics based on their importance to clinical practice; furthermore, they were asked about chemistry applications within nursing related to the GOB chemistry topics. The purpose of interviewing the participants was to understand their different perceptions and interpretations of the main chemistry topics deemed important for safe clinical practice. All interviews were digitally recorded and transcribed verbatim. From these transcribed interviews, a list of topics relevant to clinical nursing practice was generated. The first-listed author was the primary instrument for data collection and analysis.

Data Analysis

The initial outcome of a phenomenographic research study is identification of categories of description (Bowden, 2000). In this type of study, “there are no algorithms for the analysis of phenomenographic interviews, rather a series of iterations to distill the meaning by repeated reading of the transcripts” (Bowden, 2000). Each transcribed interview was analyzed by reading through the interview several times to look for patterns in the experts’ opinions. The interview transcripts were analyzed in order to address the research question: What are the experts’ perceptions of the topics in a GOB chemistry course that are relevant to clinical nursing practice? The interview transcripts were analyzed for similarities and differences. Based on observed trends in the experts’

responses, we developed an initial coding scheme as follows. Throughout the interviews, words such as “used,” “important,” or “needed” were stated by the experts in reference to some of the topics categorized as “important.” The topics that were referred to by the experts as “necessary in order to understand in general” or “foundational” were placed in the category “foundational.” The experts referred to some topics through the use of words such as “not used,” “never used,” “no application,” or “not important” and these topics were placed in the category “not important.” Once a set of codes was developed, two additional raters (besides the first author) were consulted. Neither of the additional raters were authors of this paper. The raters’ coding was consistent with the coding description developed. There was complete agreement among the raters regarding the categories of description and classification of topics. Over several meetings with a CI (a co-author) and two NE (one a co-author), information gathered from the fourteen interviews was clarified in terms of meaning of the words and terminology to produce a list of detailed topics relevant to nursing clinical practice. Summaries of the analysis of each transcript were sent to the respective experts; each agreed with the classification of the topics. Data (excerpts of transcripts) were organized into categories that addressed the phenomena, based on participants’ different views and responses. From the statements made by the experts, three categories emerged regarding the relative importance of topics presented in a GOB chemistry course and relevancy of topics to clinical nursing practice: topics that are *Important*--have a direct application in the nursing clinical practice; topics that are *Foundational*--facilitate the understanding of the important topics, but are not directly important for nursing clinical practice; and topics

that are *Not Important*--do not have a direct application or are not significant in nursing clinical practice.

Results and Discussions

Critical thinking is part of the everyday responsibilities that a nurse assumes as he/she attempts to define accurately patient care problems, makes the best decisions from an array of possibilities, safely implements the plan, and evaluates results of the delivered care (Miller, 1992). It is imperative that nurses question, analyze, and make decisions based in part on appropriate scientific knowledge. The experts in this study agreed on the significance of a good understanding of chemistry, critical thinking, and the need for scientific decisions; these ideas are expressed through these representative statements. The ratings of topics in GOB chemistry are outlined below along with opinions expressed by the interviewed chemistry instructors (CI), nurse educators (NE), and nursing graduate students (NGS).

> If you don't know what's going on [in terms of chemistry] you are standing on the sideline of the football game. The nurse educator emphasized the importance of being able to "pick up things that go south, and applying the critical thinking of what is going wrong in the body. (NE 006)

> It would be like a mechanic working on a car, but they would have no idea what the engine is, what the carburetor does, the relationship of fuel injector to gas line, sparkplugs to distributor. So, to me, it seems like if a mechanic couldn't understand the parts of an engine, he or she would have a difficult time working on one in a productive way. It's not a very good analogy, because the nurse isn't the only person working on a patient. There is also the physician, the pharmacist - a lot of people. But she or he should have at least a basic understanding of the science of that patient - the physiology, biochemistry, and pharmacology of the drugs that are being used. (CI 004)

> *S*ome opinions [nursing] will say it is more emotional, because they do like to care for people. But they also have to have some elements of being a scientist. It is not enough to be all warm and reassuring, you have to be intelligent. You have to combine caring with science, they call it 'high-tech, high-touch.' You have to

> be scientifically competent and also be very balanced. ‘High-tech’ meaning you must be technically competent to be safe. (NGS 005)

General Chemistry

Among the main general chemistry topics taught in a GOB chemistry course, as listed in Table 1, there was agreement among the experts regarding the importance of acid/base/salt chemistry, measurements, and solutions. In particular acid/base chemistry was considered one of the most relevant topics in nursing clinical practice due to the impact it has on homeostasis. All experts agreed that acid/base aspects, such as *pH* and buffers, are important. “Understanding what makes an acid and what makes a base and how they affect liquids and tissue are extremely important” (NGS 002).

The topic of measurements, especially using the metric system, was considered critical in nursing clinical practice for drug dosage and concentration calculations. One of the nursing graduate students stated that this topic is important in connection with “drug dosages, concentrations of solutions that we give. The whole medical world is measured in the metric system, so they have to understand that system” (NGS 003). Regarding solutions, osmotic pressure, osmolarity, and concentration of solutions were rated important to nursing practice. These all require special attention in a GOB chemistry course.

Most experts agreed that the topics of matter, atomic structure and the periodic table, ionic and covalent bonds, and chemical calculations are foundational to understanding GOB chemistry. Gases, liquids, solids were considered by most of the experts as foundational or not important but may represent good general knowledge.

Table 1. Distribution of Experts Regarding the Importance of the General Chemistry Topics

Topics	Expert	Important	Foundational	Not important
Matter	CI	1	3	0
	NE	0	5	1
	NGS	1	3	0
Measurements	CI	2	2	0
	NE	6	0	0
	NGS	4	0	0
Atomic structure and the periodic table	CI	0	4	0
	NE	2	4	0
	NGS	0	4	0
Ionic bonds	CI	0	4	0
	NE	1	4	1
	NGS	1	3	0
Covalent bonds	CI	0	4	0
	NE	1	3	2
	NGS	1	3	0
Chemical calculations	CI	1	3	0
	NE	0	4	2
	NGS	0	4	0
Gases, liquids, solids	CI	2	1	1
	NE	0	4	2
	NGS	0	2	2
Solutions	CI	4	0	0
	NE	6	0	0
	NGS	3	1	0
Chemical reactions	CI	2	2	0
	NE	3	0	3
	NGS	2	2	0
Acids, bases, and salts	CI	4	0	0
	NE	6	0	0
	NGS	4	0	0
Nuclear chemistry	CI	0	0	4
	NE	4	0	2
	NGS	3	0	1

n = 14, CI = chemistry instructor, NE = nurse educator, NGS = nursing graduate student

Although nurse educators and some nursing graduate students indicated that aspects related to the gaseous state were foundational, both groups indicated that some aspects such as the allosteric binding of oxygen to hemoglobin are very important for clinical practice, especially as it relates to the Bohr effect, metabolic acidosis, and oxygen perfusion in general.

The experts expressed mixed opinions about the importance of aspects of chemical reactions. However, all experts agreed that chemical reactions were considered essential in understanding metabolism. Chemical calculations in general were regarded as foundational. However, working with mole ratios and stoichiometry was considered as not important in nursing, although an understanding of moles and molecular weight is useful in calculating concentrations.

A difference in expert opinion is noted in Table 1 regarding the topic of nuclear chemistry. All chemistry instructors regarded this topic as not important, while most (70%) of nursing graduate students and nurse educators revealed this as an important topic. The reason for this difference can be seen in their reasoning. According to some nursing graduate students and nurse educators, knowledge of radioactivity is important in terms of safety and the ability to communicate with the patient.

> Nurses need to understand basic radiation safety. Why to stand away from the X-ray. Why, if you are pregnant, you shouldn't be exposed to radiation. I think they really need to know radiation principles, and how there are different radioactive particles in rays, and how they could be protected: lead, glass, aprons. (NGS 006)

Chemistry instructors did not think nuclear chemistry was important for allied-health majors. One instructor mentioned that just a summary presentation would be enough: "I would just gloss over nuclear rather quickly" (CI 001). Another chemistry instructor said:

> I don’t cover nuclear chemistry mainly because I don’t think that it really relates to what they [nurses] do. Isotopes like technetium used for imaging and iodine - a variety of isotopes but I don’t think nurses are involved in that at all. It’s relevant, but mainly for a physician or radiologist. (CI 004)

Even though nurses are not directly involved in taking an X-ray, they should be able to explain to patients the basics of the procedure and what the effects of radiation treatment are. According to the perspective of nurse educators and nursing graduate students, the basic topics of radiation and radioactivity should be taught to pre-nursing students, including radionuclides used in treatment and diagnosis, as well as safety involving the use of radionuclides and radiation.

In summary, for the general chemistry topics, experts agreed that measurements, solutions, and acids/bases/salts are important. All other topics of general chemistry were considered foundational, with the exception of nuclear chemistry, for which experts’ opinions were divided.

Organic Chemistry

The greatest disparity between the two cultures of nursing and chemistry was observed in experts’ opinions regarding organic chemistry topics (Table 2). For approximately one-third of the topics listed in Table 2, what chemists regarded as foundational, nursing graduate students and nurse educators considered not important. According to a nurse educator, “Not the structure but the function [of molecules] is important” (NE 001).

As revealed by chemistry instructors during their interviews, a common thread appeared relating the topics of structure and function. Chemistry instructors stated that the function of a molecule cannot be fully appreciated without understanding the structure.

Table 2. Distribution of Experts Regarding the Importance of the Organic Chemistry Topics

Topics	Expert	Important	Foundational	Not important
Saturated hydrocarbons	CI	1	3	0
	NE	0	3	3
	NGS	0	3	1
Unsaturated hydrocarbons	CI	1	2	1
	NE	0	2	4
	NGS	0	3	1
Alcohols, phenols, ethers	CI	1	1	2
	NE	1	2	3
	NGS	2	1	1
Aldehydes, ketones	CI	2	1	1
	NE	3	2	1
	NGS	2	2	0
Carboxylic acids, esters	CI	2	2	0
	NE	1	4	1
	NGS	0	4	0
Amines, amides	CI	2	2	0
	NE	3	3	0
	NGS	1	3	0

n = 14, CI = chemistry instructor, NE = nurse educator, NGS = nursing graduate student.

This disparity can have a significant impact on the way GOB chemistry is taught to pre-nursing students. The chemistry instructors considered understanding a compound's structure to be very important to understanding that particular compound's properties, function, and metabolism:

> Each one of these [organic topics] is important to get an overall basic understanding of organic chemistry and how different groups interact. But as far as it relates to nurses, this isn't really a clinical application, but they do have to take physiology and pharmacology, and they have to have an understanding of chemistry for physiology and pharmacology to make sense. And that's going to

> be true for the biological chemistry. Those courses would just be memorization and probably no understanding without the understanding of the chemistry. (CI 004)

The chemistry instructors mentioned that saturated and unsaturated hydrocarbons are foundational in understanding the structure and function of some biomolecules (lipids and proteins). More specifically, “The hydrocarbons are an important part of lipids as well as understanding hydrophobic interactions in macromolecules and membranes” (CI 004). Overall, hydrocarbon topics were seen by the experts as foundational with unsaturated hydrocarbons having less significance than saturated hydrocarbons. None of the nurse educators or nursing students could present a clinical application of saturated or unsaturated hydrocarbons.

Mixed opinions were expressed regarding alcohols, phenols, and ethers. In general, expert perspectives were mixed within both disciplines. Approximately half of each expert group considered alcohols, phenols, and ethers as not important. However, some chemistry instructors considered alcohols to be relevant in understanding carbohydrates and intermediates in metabolism. Nurse educators and nursing graduate students mentioned these topics as a basis for some medications: “Ethers were once used for anesthesia, but not anymore” (NGS 001).

The nursing culture (NE and NGS) considered aldehydes and ketones either foundational or important as metabolic by-products and in connection with different diseases. Although the significance of ketones in connection with diabetes was mentioned, it was from the perspective of function rather than structure. Some chemistry instructors considered aldehydes and ketones as important regarding carbohydrates and as functional groups of some of the intermediates involved in different metabolic pathways.

Most of the nursing culture considered carboxylic acids, esters, and amides as foundational. Amines were classified by nurse educators and nursing graduate students as either important or foundational; amines were mentioned in connection with nitrogen measured in certain types of analyses for diagnosis of some diseases. For the chemistry culture, these organic functional groups were considered important or foundational in understanding lipids (carboxylic acids and esters) as well as amino acids (carboxylic acids and amines) and in their role as components of proteins (amides).

In summary, with a few exceptions, organic chemistry topics overall were considered foundational in relevance to clinical practice. One nurse educator said, “In general, as a nurse, you don’t use a lot of this information clinically” (NE 001). Based on interviews with experts, the organic functional groups should be presented in connection with the structure and function of biomolecules, the nomenclature greatly simplified, and the connection of functional groups to properties, function, and metabolism of biomolecules and drugs well emphasized.

Biological Chemistry

There was considerably higher agreement among experts regarding biological chemistry topics of the course (Table 3). Most experts reported that all topics, with the exception of nucleic acids, are important for nursing. According to the experts, understanding enzymes and vitamins, carbohydrates, lipids, and proteins and their metabolism were considered important. One chemistry instructor noted: “If the patient doesn’t metabolize, the patient is dead” (CI 001).

The largest disagreement among experts regarding biological chemistry topics related to nucleic acids. Of the chemistry instructors, 75% said that the topic is not

relevant in a GOB chemistry course. Nurse educators and nursing graduate students (collectively, 70%) considered the topic important in understanding different diseases.

Table 3. Distribution of Experts Regarding the Importance of the Biological Chemistry Topics

Topics	Expert	Important	Foundational	Not important
Carbohydrates	CI	3	1	0
	NE	5	1	0
	NGS	4	0	0
Lipids	CI	3	1	0
	NE	5	1	0
	NGS	4	0	0
Proteins	CI	3	1	0
	NE	5	1	0
	NGS	4	0	0
Enzymes and vitamins	CI	4	0	0
	NE	6	0	0
	NGS	4	0	0
Nucleic acids	CI	1	0	3
	NE	4	2	0
	NGS	3	1	0
Biochemical energetics	CI	4	0	0
	NE	5	1	0
	NGS	3	1	0
Carbohydrate metabolism	CI	4	0	0
	NE	5	1	0
	NGS	4	0	0
Lipid metabolism	CI	4	0	0
	NE	5	1	0
	NGS	4	0	0
Protein metabolism	CI	4	0	0
	NE	5	1	0
	NGS	4	0	0

n = 14, CI = chemistry instructor, NE = nurse educator, NGS = nursing graduate student

The perspective of a nurse educator regarding nucleic acids was as follows: "[Nucleic acids are] Very, very, very important … And it's just because I think everything in medicine is going to change dramatically in the future. And so we need to understand that as well" (NE 005). Some nurse educators and nursing graduating students emphasized the importance of nucleic acids, especially in terms of function, such as replication and mutations. (This may provide another opportunity for chemistry instructors to argue that function cannot be well understood without structure). From interviews with chemistry instructors, it was revealed that, although they considered nucleic acids important for nursing, it is one of the topics that tends to be omitted due to time limitations; furthermore, it is assumed to be taught in biology courses.

> I have in the past, skipped nucleic acids – it depends on the time that is left in the semester. They [pre-nursing] do get nucleic acids in a biology class. It's from a very different perspective. I prefer to cover nucleic acids, but that I think it is the least important if we run out of time. It's the least important, not the least important of these molecules, but it's the least important because they will get it in some other class. (CI 004)

To many pre-nursing students enrolled in a GOB chemistry course, the collective pathways of catabolism and anabolism may look like the public transportation map for a large European city. The relationships of different pathways may be fascinating, but the details are overwhelming for pre-nursing students. Nurse educators and nursing graduate students mentioned that a good understanding of metabolism in general and integration of different pathways are important, although the details are not encountered in everyday clinical practice. These experts included in metabolic pathways: anaerobic metabolism of carbohydrates, since glucose is the primary source of energy, glycolysis (glucose metabolism) and "ketone body" production in understanding diabetes and metabolic

acidosis in general, and the urea cycle, since it is connected with liver and brain disorders.

The topic of biochemical energetics was regarded as important by most experts. However, knowing formation or breaking of bonds in ATP and the total ATPs produced as a result of a certain pathway may be important to a biochemist, but, according to the nurse educators and nursing graduate students, these are not used in clinical practice.

In summary, for biological chemistry topics there was good agreement among experts regarding the importance of biomolecules and their metabolic pathways, with the exception of nucleic acids, where the opinion was divided.

General, Organic, and Biological Chemistry Topics Considered Relevant to Clinical Practice

Thus far, we have addressed the relative importance of topics typically covered in a GOB chemistry course as viewed by experts' opinions. Chemistry instructors, who teach a one- or two-semester GOB chemistry course for allied-health majors, have been facing challenges of limited time and excessive content, possibly resulting in high cognitive load for students. Through analysis of interviews, we have established that not all topics presented in a GOB chemistry course are equally relevant to clinical practice. According to nurse educators, some topics are revisited in other courses, such as biology, nutrition, pathophysiology, and pharmacology. Based on experts' classifications and clinical applications cited of some of these topics, we developed a list of topics considered relevant for a nurse's clinical practice. The topics are presented in Table 4 and include aspects deemed significant by the experts. These topics, based on participants' opinions, may be helpful to GOB instructors selecting content of a GOB chemistry course

in terms of topics considered essential for pre-nursing students to understand for safe and effective practice.

To have a good understanding of acid-base equilibria, a basic knowledge of atoms and properties of compounds is important. It was specified by nurse educators that elements that are potential electrolytes should be specifically highlighted in the periodic table. A good understanding of atoms and ions (cations and anions) is important to understand the role and function of electrolytes. The importance of covalent bonds and polarity was especially emphasized by chemistry instructors. Nurse educators and nursing graduate students agreed that those topics are important to be presented and understood in connection with drugs and their excretion.

> When we look at any kind of chemical compound in medicine be it the medications we give patients, how they're metabolized, how they're formed and break apart into their active and inactive ingredients, that chemical bonding is extremely important for students to understand what's happening in the body when those work together. (NGS 006)

In addition to the covalent bond, hydrogen bonds should receive special attention since they contribute to the structure, physical and chemical properties, and function of some biomolecules, such as proteins, enzymes, nucleic acids, and carbohydrates.

To understand biomolecules, some basic knowledge of organic chemistry would be necessary, otherwise as stated by a chemistry instructor: "Everything is reduced to rote memorization leading to inability to make connections among topics involved in metabolism" (CI 004). An understanding of metabolism will enable nurses to better understand implications and side effects of prescribed medication, provide more effective interventions in trouble-shooting situations, and ease in professional communications at the patient's level of understanding.

Table 4. Relevant General, Organic, and Biological Chemistry Topics for Nursing Clinical Practice

Topics
▪ Periodic table/Atomic structure
▪ Ions/Electrolytes
▪ Bonds: ionic, covalent, hydrogen bonding, polarity
▪ Chemical reactions/Equilibria
▪ Dimensional analysis/Metric system
▪ Solutions: concentrations, osmotic pressure, osmolarity
▪ Acids and bases: *pH*, buffers, equilibria
▪ Gases: brief presentation of gas laws (especially Boyle's Law), solubility in liquids, hemoglobin (*pH* and O_2 perfusion)
▪ Nuclear medicine/Isotopes/Nuclear Safety
▪ Alkanes/Alkenes/Aromatics: brief nomenclature, physical and chemical properties, reactions (oxidation, addition)
▪ Alcohols/Aldehydes/Ketones: physical and chemical properties, hydrogen bonding, reactions (oxidation-reduction, dehydration)
▪ Carboxylic acids/Esters: physical and chemical properties, acid-base chemistry, reactions (reduction, esterification, hydrolysis)
▪ Amines/Amides: physical and chemical properties, acid-base chemistry, reactions (amide formation/hydrolysis)
▪ Proteins: structure, properties, function, enzymes and vitamins, metabolism
▪ Carbohydrates: structure, properties, function, metabolism
▪ Lipids: structure, properties, function, metabolism
▪ Nucleic Acids: structure, function
▪ Integration of Metabolism/Hormones/Homeostasis

Conclusions

This study enabled identification of the main GOB chemistry topics perceived to be relevant to the clinical practice of nurses. This information can assist GOB chemistry instructors to better understand which topics to emphasize in their teaching. Based on the interviews with the experts, an understanding of metabolism with clinical implications is a common goal of the two cultures. By associating these topics with clinical examples, pre-nursing students may be more motivated to learn (Pintrich et al., 1993). Ultimately,

their self-efficacy toward chemistry may improve which may directly affect their level of confidence with the nursing profession.

The topics presented in a GOB chemistry course are not equally relevant to nursing practice. The topics presented in this study are those considered by the experts as most relevant to the clinical practice; it is a common goal that, by the end of the course, the pre-nursing students have a good understanding of at least these identified topics. The agreement among experts regarding what GOB chemistry topics should be taught is significant, but perhaps from different perspectives. Chemistry instructors need to be aware of the perspectives of the nursing culture; these can be helpful when chemistry instructors prepare to select and teach topics and relate them to clinical practice. Likewise, nurse educators should appreciate how the chemistry instructors approach course content. Experts from both cultures agreed that chemistry topics would make more sense to the pre-nursing students if topics are taught with examples relevant to nursing practice.

For pre-nursing students enrolled in a GOB chemistry course, connections to clinical practice brings relevancy to chemistry topics. A proposed approach is given below as an example of teaching with clinical relevance using *pH*. In this case, it would be helpful if the concept of *pH* were connected to metabolism. For example, in the case of metabolic acidosis, students may wonder how an acidic environment originates in the body. It can be pointed out that a diabetic patient, compared to a non-diabetic person, will use much less glucose for ATP production. When glucose is not available, fatty acid β-oxidation leads to the production of 3-ketobutyric acid and 3-hydroxybutyric acid

(ketone bodies) leading to ketosis and metabolic acidosis. This is also a good opportunity to introduce the bicarbonate buffer system:

$$H_2O(l) + CO_2(aq) \leftrightarrow H_2CO_3(aq) \leftrightarrow H^+(aq) + HCO_3^-(aq)$$

The bicarbonate buffer system is one of the main buffer systems in blood; consequently, it attempts to buffer the excess acid produced in diabetics. From the perspective of chemistry instructors, the reaction is often considered fundamental and overlooked.

In general, our results are in agreement with those reported by Walhout and Heinschel (1992) regarding the importance of the major categories, i.e., the biological chemistry topics along with many general chemistry topics being ranked important with many organic chemistry topics receiving the lowest ratings in importance. Of the topics examined in both studies, most biological chemistry topics ranked high. Many of the general chemistry topics also ranked high (either important or foundational in our study). Many of the organic topics were ranked low (either foundational or not important in our study).

There were relevant differences between the two studies. The study of Walhout and Heinschel involved ranking topics in order of importance, whereas our study requested not only a ranking of importance but also whether a particular topic was considered foundational for understanding a concept considered important. In our opinion, this produced more depth and meaning to the ranking. Furthermore, our study involved participation of not only nurse educators and nursing graduate students, but also GOB instructors who considered many topics as foundational. They considered these fundamental as part of their instruction to better explain, in a comprehendible manner, topics consider as important. Since this exploratory study was conducted at a single

institution, the next step will be to gather data from a broader range of experts. The results of this qualitative study will be compiled into a survey for wide-spread administration. This survey will provide quantitative information regarding the importance of topics identified in this study. Ultimately, the research can establish a framework to build a bridge between the two cultures of chemistry and nursing.

Acknowledgments

The authors thank the experts (nurse educators, nursing graduate students, and chemistry instructors) for their interest and participation in this study. For the original manuscript, please see Appendix K.

CHAPTER V

ARTICLE 2: THE DESIGN AND PSYCHOMETRIC ANALYSIS OF A GENERAL, ORGANIC, AND BIOLOGICAL CHEMISTRY TOPIC INVENTORY

(This manuscript will be submitted for publication with Richard M. Hyslop and Jack Barbera as co-authors).

Abstract

The General, Organic, and Biological Chemistry Concept Inventory (GOB-CTI) is a multiple-choice instrument designed to assess students' understanding of the main chemistry topics identified as essential in clinical nursing practice. This manuscript describes the developmental process of the individual items along with an evaluation of a pilot version of the instrument. In developing items for this instrument, essential topics were identified through a series of expert interviews and a national survey. Individual items were tested with students from the target population for clarity and wording. The pilot version of the instrument contained 67 items covering the range of identified topics. The pilot version was tested with a sample of 458 students and a revised version with a sample of 200 students. Data from the two pilot studies were used to evaluate each item and narrow the total item count to 45. A detailed analysis is given to illustrate how items were selected and/or modified for the final version of the instrument. A psychometric analysis performed on data from the 45-item final version was used to evaluate validity, reliability and item statistics. The final version of the GOB-CTI has a Cronbach's alpha value of 0.763. An expert panel assessed face and content validity. Convergent validity

was established by comparing the results from the GOB-CTI instrument with the General-Organic-Biochemistry Exam (Form 2007) of the American Chemical Society (GOB-ACS). The GOB-CTI instrument was developed in collaboration with nurses, nurse educators, and chemistry instructors to focus attention on the subset of chemistry topics deemed important to practicing nurses. By using this concept inventory, chemistry instructors may better understand the incorrect ideas and difficulties their nursing students have in chemistry.

Introduction

In the last few decades, there has been significant progress in the advancement of patient care and medical technology. In the midst of the more demanding world of nursing, nurses are striving toward true professionalism in their work (Wilkes and Batts, 1996). Since nursing is a practice profession, it is important that clinical practice is based on scientific knowledge (Webb, 1997). Research has identified that appropriate bioscience content knowledge possessed by nurses enhances their practice, and the incorporation of suitable scientific knowledge will help nurses in their clinical judgment and safe nursing practice (Jordan and Reid, 1997). The importance of chemistry and the multitude of applications of chemistry in nursing practice have been emphasized in the literature. Nurses must not only be able to recognize symptomatic patterns but also have an understanding of the cause, which is important in assessing the physiological status of the patient as well as the appropriate medical therapy.

With the evolution of the profession, nurses are performing among many roles the role of a decision maker. To be efficient in this role, nurses need to possess meaningful knowledge that allows them to make thoughtful judgments and, if needed, even debate protocols they are asked to follow (Townsend, 1991). Research shows that nurses in clinical practice respond to situations often with actions dictated by rote learning of protocol. Additionally, nurse mentors can give misleading explanations rather than the scientific basis for the rationale behind a particular task or activity. Training in the undergraduate years is very important in helping the nursing students become well-rooted in scientific theory so they have a

strong foundation when they become active in the clinical arena (Wilkes and Batts, 1998).

According to the theory of constructivism, educators cannot directly transfer intact knowledge that they possess to students; learning occurs through the assimilation of new topics into existing conceptual frameworks held by the learner. A student's conceptual frameworks are composed of different ideas about how the world works and are developed as a result of personal experiences and formal education (Wilkes and Batts, 1998). Students must "build" knowledge on information they are given, thus making knowledge gain a highly personal process. Educational research has shown that some ideas developed by students are not always in agreement with the scientific theory of a certain discipline. Consequently, it is important to help pre-nursing students relate new information to previously assimilated knowledge and to ensure that the knowledge that already exists in their cognitive structure is in agreement with the scientific theories of chemistry.

This research investigated students' knowledge and understanding of General, Organic, and Biological (GOB) chemistry topics identified to be relevant to clinical practice. Herein, we describe the design, development, and pilot studies of an instrument in the form of a concept inventory that can be used to assess students' knowledge of GOB chemistry. The GOB chemistry course is the only chemistry course required in many Bachelor of Science in Nursing programs and potentially impacts the understanding of many course subjects important in nursing education (Timmer, 2006) as illustrated in Figure 1.

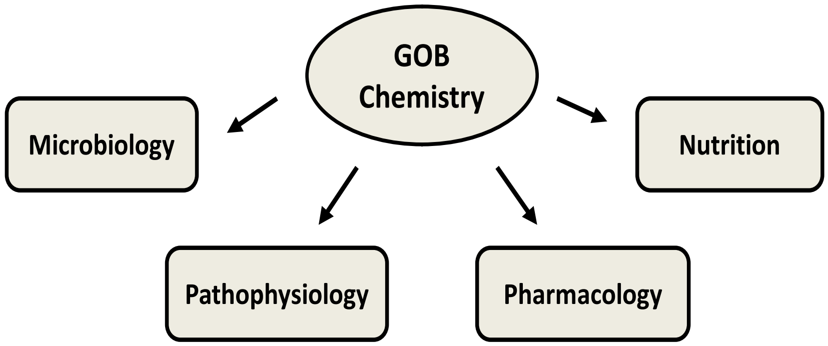

Figure 1: A sampling of courses impacted by general, organic, and biological chemistry understanding.

In the last two decades following the advent of the Force Concept Inventory (Hestenes et al., 1992), concept inventories have been developed and used in order to document conceptual learning and to identify students' alternative conceptions in different areas of science and engineering (Richardson, 2004) . Despite the abundance and progress of concept inventories in different areas of science, there is a void of conceptual assessment in the area of biochemistry (White, 2005). Only a limited number of conceptual questions have been developed by educational researchers to obtain qualitative data on students' misconceptions of topics such as metabolism (Grayson et al., 2001, Anderson and Grayson, 1994), protein synthesis (Kaplan and Saccuzzo, 1997), antibody structure (Schonborn et al., 2002), and enzyme-substrate interactions (Bretz and Linenberger, 2012). To date, no published concept inventories exist in the area of GOB chemistry.

It is anticipated that the GOB concept inventory described herein will provide a tool to measure students' learning of clinically relevant topics and determine whether students have the required knowledge to successfully manage other courses in the nursing

program that require a fundamental knowledge of GOB chemistry (Figure 1). With this GOB chemistry concept inventory, chemistry instructors will have the opportunity to evaluate the knowledge level and identify the difficulties that pre-nursing students have with chemistry.

Protection of Human Subjects

The participants solicited in this research were a minimum of 18 years of age. All ethical considerations common to research with human subjects were used in the development of this study. All participation in the study was voluntary.

Instrument Design and Development

The General, Organic, and Biological Chemistry Concept Inventory (GOB-CTI) purports to measure pre-nursing students' conceptual understanding of the main chemistry topics deemed by experts to be important in clinical practice. The inventory contains 45 items covering the three sections of GOB chemistry: general (approximately 30% of the items), organic (approximately 20% of the items), and biological chemistry (approximately 50% of the items). The percentage for each section is based on experts' opinions regarding the significance of the topics from each section presented in the GOB course (Brown et al., 2012). Additionally, the instrument was designed with a reasonable number of items, which allows coverage of the topics deemed relevant and also allows for completion in a typical 50-minute class period. The multiple-choice format of the instrument is consistent with the NCLEX-RN licensing examination (McGahee and Ball, 2009) as well as the exams written by the American Chemical Society Exams Institute.

General Model for Test Design

Research was conducted in several stages with a multi-methods approach to data collection. Herein, we present the research design, data collection procedures, and instrumentation employed in each stage of the study. In the design of the GOB-CTI, the general model illustrated in Figure 2 was followed. The design and development of the inventory consisted of several phases. Each phase in the development and evaluation process of the inventory (as outlined in Figure 2) with the corresponding results and discussion is presented in the following sections.

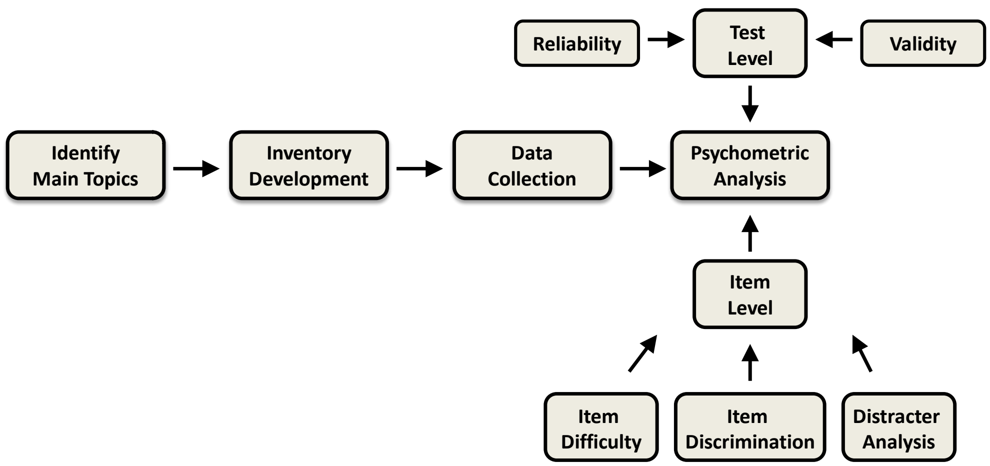

Figure 2: General model for design of the General, Organic, and Biological Chemistry Topic Inventory.

Identification of the Main General, Organic, and Biological Chemistry Topics Relevant to Nursing Clinical Practice

In a previous study (Brown et al., 2012), a list of topics considered relevant for a nurse's clinical practice was developed based on interviews with experts and on experts' classifications of the topics taught in a GOB chemistry course. The data collection

involved open-ended interviews of both nursing and chemistry teaching faculty as well as practicing nurses. From the resulting interviews, three themes emerged pertaining to chemistry topics: topics that are *Important*--have a direct application in nursing clinical practice; topics that are *Foundational* --are not directly important in nursing clinical practice but facilitate the understanding of the important topics; and topics that are *Not Important*--do not have a direct application or are not significant in nursing clinical practice.

In order to ascertain if there was consensus among the opinions of nursing educators and GOB chemistry instructors regarding the topics and to make the study more generalizable, a national survey was conducted. The survey was developed and administered on-line. The sample used in the national survey was a random sample. The experts (nursing and chemistry instructors) were identified and recruited from the websites of different nursing schools and chemistry departments of universities that have a nursing school. A total of 264 nurse educators (response rate of 26.2%) and 16 GOB chemistry instructors (response rate of 23.1%) participated in the survey. Participants were asked to classify the topics taught in a GOB chemistry course in one of the categories: important, foundational, or not important. The list of clinically-relevant chemistry topics identified in the prior study (Brown et al., 2012) was confirmed by the results from the national level survey. There was 95% agreement between the opinions of the experts from the two studies regarding the GOB chemistry topics relevant to clinical practice.

Inventory Development

The list of topics identified by the experts served as the blue print in writing 67 open-ended questions. All open-ended questions constructed were tested with students through interviews utilizing a think-aloud protocol. The purpose of these interviews was to assure that the questions were clearly worded and that students were not confused with terminology. A think-aloud protocol allows the researcher to gain an insight into the students' thinking and understanding of terms and topics. The way a student answers a question and the explanation of how he/she arrived at a certain answer is a revelation in his/her beliefs, alternative conceptions, and incorrect ideas (Bowen, 1994). This type of approach can also ensure that the assessment instrument measures what it is intended to measure. Interviews with students from the target population assures novice face validity, which is important since sometimes students understand and interpret a question in a way very different from an expert (Pellegrino et al., 2001).

Interview Participants

Student participants in this phase of the research were enrolled in a one-semester GOB chemistry course at a mid-size, western U.S. state university. The course involved four 50-minute lectures and one 3-hour laboratory session weekly during a 16-week semester. A brief overview of the project was presented to the GOB chemistry students in order to recruit participants. As an incentive for students to participate and provide thoughtful responses, the lead author offered a help session at the end of the semester. In this phase of the project, 20 students volunteered to participate. All the students that participated in the interview were pre-nursing majors. Each interview took 30-45 minutes and each student was presented with a total of 7 to 10 open-ended questions, one question

at a time. As an “ice breaker,” the researcher talked with the interviewees about some demographic information, which included when they graduated from high school and any other chemistry courses as well as biology and math courses they may have had. After the introductory time, students were asked to read each question aloud. A few minutes were offered for students to think and write an answer. Students were asked to verbalize their thoughts as they answered each question. Students were also consulted about whether the questions were clear regarding the wording and meaning of certain terms.

Pilot Inventory Development

The data obtained from think-aloud interviews guided revision of the open-ended items as well as the development of distracters for the multiple-choice question format of the instrument. The multiple-choice version of the items represented the pilot version of the GOB-CTI. Boxes 1, 2A, 2B and 3 present the development of a multiple-choice item from the open-ended format.

Box 1. Sample “think-aloud” question.

If a diver returns too quickly to the surface after a deep dive, a painful condition known as *the bends*, caused by $N_2(g)$ in blood, can cause paralysis or death. How can this condition of divers be explained?

Box 2A. Excerpt from a student "think-aloud" interview showing understanding of the question and content.

Student: When a diver experiences the bends, he is experiencing the effect of little air bubbles expanding in his blood. If one pops in the spine or something it can cause catastrophic damage to him.

Interviewer: Do you understand the terms? Have you heard of the term "bends"?

Student 1: Yes. We watched a documentary in my biology class in high school.

Student 1: How can this condition of divers be explained? [Does that] mean to explain what happens?

Interviewer: Yes, can you explain how it is caused?

Student 1: I believe it is caused by the nitrogen in the air we breathe.

Interviewer: What is in the tank of the divers?

Student 1: Oxygen, not pure oxygen … [it] is a mixture of air. I think the nitrogen in the air bubbles and our blood expands and stuff can pop. If [it] pops in the brain, [it] is really bad, and this is why the divers should come up slowly… the body has time to adjust.

Interviewer: Why do you think only nitrogen creates the problem but not oxygen?

Student 1: Because there is more nitrogen in the air than oxygen, probably there is more nitrogen dissolved in blood; oxygen can adjust quicker, nitrogen needs more time to adjust.

The interview excerpt (Box 2A) revealed that the student is familiar with the terminology used in the open-ended question, though there are some incorrect ideas about the cause of the "bends" and gas solubility. Analysis of the "think-aloud" interview transcripts provided information used to increase the clarity of the open-ended questions and to develop the distracters for each question. Some of the distracters were formulated based on students' incorrect ideas and, whenever possible, the language of the interviewees was

used exactly. Other incorrect ideas (about the question in Box 1) revealed during the interviews are presented in Box 2B; these ideas were subsequently utilized as distracters.

Box 2B. Excerpts from student “think-aloud” interviews showing incorrect ideas that were utilized for multiple-choice distracters.

Student 2: If you are adding nitrogen into the blood, you are changing its pH. I don’t know how it changes pH; if it raises it or lowers it.

Student 3: The nitrogen dissolved in the blood prevents the oxygen to bind to hemoglobin, not as much oxygen can bind. The lack of oxygen will create problems for the brain; the diver can paralyze.

The open-ended question was converted to a multiple-choice question as illustrated in Box 3.

Box 3. Pilot version of the multiple-choice item.

When divers return too quickly to the surface, a painful condition known as *the bends*, caused by $N_2(g)$ in the blood, can cause paralysis or death. What is the cause of this condition?

A. The dissolved $N_2(g)$ changes the pH of blood.
B. The dissolved $N_2(g)$ inhibits the binding of oxygen to hemoglobin.
* C. The dissolved $N_2(g)$ is less soluble in blood at lower pressures causing bubbles of gas to form.
D. The dissolved $N_2(g)$ is more soluble in blood at lower pressures and prevents oxygen from dissolving in blood.

(*) indicates the correct answer

In the design and development of the pilot version of the multiple-choice instrument, each item was mapped to the content domain to ensure representation of each concept from the blue print. The pilot version of the instrument contained three to five questions per concept for a total of 67 questions (some items mapped to multiple topics).

Each item was designed to have four options, a correct answer and three distracters; in case of deletion of one of the distracters as a result of data analysis, the item would still function well with two distracters. The distracters utilized alternative conceptions, incorrect ideas identified among the pre-nursing students that participated in the think-aloud protocol, and plausible but incorrect answers gathered from the experience of one of the chemistry instructors (a co-author) with the course. The bank of items was analyzed by the three authors for thorough coverage of the topics, wording, and for possible confusing or misleading aspects of the item.

Data Collection with Pilot Version of the General, Organic, and Biological Chemistry Topic Inventory

The pilot version was used in data collection with a convenience sample of 458 pre-nursing students enrolled in GOB chemistry courses at two different universities. None of the students in this pilot study data collection had participated in the interview protocol during the developmental stage of the inventory items. The pilot version was administered to students near the end of the semester. This occurred during the lecture class at one university and during the laboratory portion of the course at the other university. Participation was voluntary; however, the students were encouraged to participate and perform to their best ability by advertising this test as a practice test for their final exam. Informed consent forms were provided to each student prior to the pilot test. The test was administered as a paper-and-pencil test with a Scantron form. Students were given 50 minutes to complete the consent form and the test. All students finished within 45 minutes. Pilot testing generated data about individual items and the test as a whole. A t-test of the data collected was performed in order to identify any significant

differences between the groups of students at the two universities. Since no significant difference was found, the data were analyzed collectively.

Psychometric Analysis of Pilot Data

Data collected with the pilot version of the GOB-CTI were analyzed through the prism of Classical Test Theory (CTT). Classical Test Theory item analysis in conjunction with an analysis of distracters provides the researcher with invaluable information regarding the quality of the items regardless of the measurement model applied in later stages of test development. Psychometric analyses based on CTT include item analysis, validity, and reliability studies. Results from these analyses guide retention, omission, or revision of the items on the inventory. In CTT, an item is identified for omission or revision based on its difficulty or discrimination index being either too high or too low (Hambelton and Jones, 1993). Data were analyzed at the item level as well as test level.

Psychometrics at the Item Level

Item analysis was conducted to determine the best items to retain in accordance with the purpose of the inventory. As part of the ongoing developmental process, individual item analysis was conducted including item difficulty, item discrimination, and distracter analysis (response frequency) based on the data collected from students in the pilot study. In order to calculate the difficulty and discrimination indices, students' responses were coded 0 for an incorrect response and 1 for a correct response. The difficulty and discrimination indices were computed for all items in the pilot version of the GOB-CTI using Excel® according to Eq 1 and Eq 2.

Item difficulty index: $p = (Up + Lp) / (U + L)$ Eq 1

Item discrimination index: $D = (Up – Lp) / U$ Eq 2

Where: Up = number of high performers who answer the item correctly; Lp = number of low performers who answered the item correctly; U = number of high performers; L = number of low performers.

The performance groups used for the difficulty and discrimination indices were determined by evaluating the percentage of students who scored in the upper 27% and those who scored in the lower 27% on the entire instrument. Kelley (1939) proposed that the upper and lower 27% of the total scores could lead to the optimal point when the total test scores are normally distributed. Item difficulty and discrimination indices are presented in Figure 3.

The *item difficulty index* in CTT reflects the proportion of students who respond with a correct answer to an item; its value ranges between 0.0 and 1.0. A high value indicates low difficulty. For example, if 80% of the students answered an item correctly, the item difficulty index would be 0.80. The difficulty index values of test items from the pilot study ranged from 0.19 to 0.93 (Figure 3). Very easy questions are not very discriminating (Kaplan and Saccuzzo, 1997); consequently, items with a difficulty index value between 0.3-0.8 are preferable for the purpose of the GOB-CTI instrument (Bretz and Linenberger, 2012) .

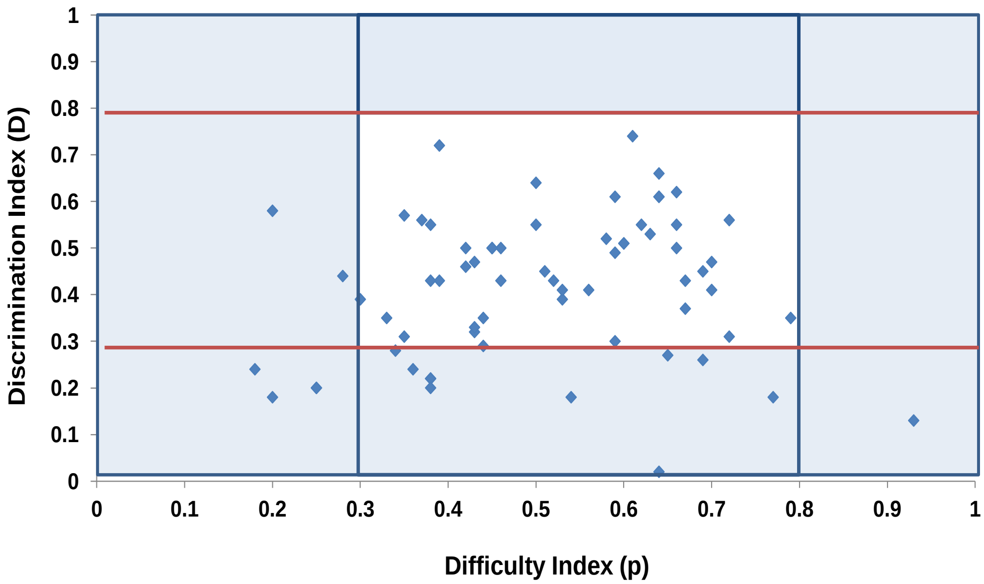

Figure 3: Scatter plot showing the relationship between difficulty and discrimination indices for the pilot item analysis of the General, Organic, and Biological Chemistry Topic Inventory. The unshaded area of the figure represents the range of acceptable values of the two indices.

The *item discrimination index* in CTT is a measure of how well an item differentiates between examinees who are knowledgeable in the content area and those who are not; its value ranges from -1.0 to 1.0. The closer the value is to 1.0, the more discriminating the item is. The maximum value of 1.0 indicates that all examinees of the upper performance group answered the item correctly, and all the examinees of the lower performance group answered the item incorrectly. For a discrimination index of -1.0, the item is said to be negatively discriminating and is an indication the item is measuring something other than what the rest of the test is measuring (Thorndike, 1997). A negative discrimination index can also be an indication of a mistake in the key for a certain item or a poorly worded or confusing item. The discrimination index values for

the pilot study ranged from 0.05 to 0.74 (Figure 3). According the guidelines of Ebel (1972) for CTT item analysis, items with discrimination indices above 0.4 are considered very good discriminators, between 0.3 and 0.4 are considered to be good discriminators, and below 0.3 are considered to be marginal or poor discriminators. However, because the GOB-CTI is a criterion-referenced test designed to identify topics that students do or do not understand and not to discriminate among students (Gronlund, 1993), items of moderate difficulty (0.30 to 0.80) and a discrimination index as low as 0.29 and as high as 0.8 were considered acceptable for the instrument, as indicated by the unshaded area in Figure 3.

The analysis of difficulty index along with discrimination index revealed 13 items with poor discrimination, and three items with very high or very low difficulty. Fifty-one items out of 67 showed a good or excellent discrimination index (≥ 0.29) and a difficulty index between 0.3 and 0.8.

Distracter Analysis

The items in the “acceptable area” of difficulty and discrimination indices (unshaded area of Figure 3) were further analyzed by distracter analysis. Distracter analysis provides a measure of how well each of the incorrect options contributes to the quality of a multiple-choice item. Data were analyzed in terms of the proportion (expressed in percent) of each option selected by the examinees. For an acceptable item, the responses should be distributed among all the distracters.

The following (Box 4 and Figure 4) is an example of the analysis of an item with a difficulty index of 0.53 and a discrimination index of 0.45. Both of these values are indicative of a good item. Distribution of the responses on the four options was:

A (7.6%), B (44.4%), C (46.5%, the correct answer) and D (1.4%) as presented in Figure 4. It is clear that two of the distracters (A and D) were not appealing to the students; therefore, the item basically functions on two choices. A closer analysis of this item indicates that some of the students do not differentiate between molecules and elements. This example shows that, besides the first two analyses described (i.e., item difficulty and discrimination), distracter analysis has an important role in the improvement or retention of an item. If a distracter is not chosen, or chosen in low proportion (7% was established as an arbitrary lower cut off point), it is an indication that the distracter is too easy (not plausible) or unattractive to the examinee. In this case, the distracter must be reworded or removed from the item.

Box 4. Example of item revealing low response rates.

From the following options, choose the one that contains **only** molecules.
A. H_2, O_2, Mg   B. Fe, Ca, K   *C. H_2, CO, $C_6H_{12}O_6$ D. O_2, CH_4, Na

(*) indicates the correct answer

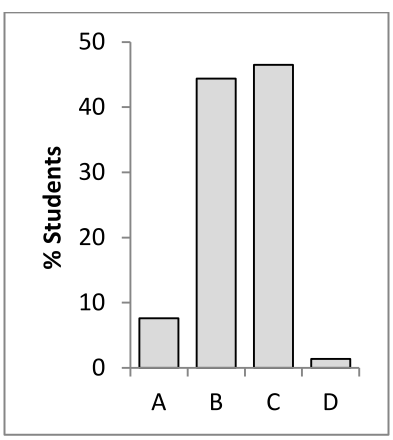

Figure 4: Percentage of responses for each option choice, item presented in Box 4.

Another example of an item with a questionable distracter had the original form as depicted in Box 5A. After analysis of this item from the pilot study, choice D was eliminated since it was chosen by the students in low proportion (4.8%). According to Haladyna et al. (2002), there is no reason, psychometrically, to have the same number of options for every item. The item was re-tested in the new format (Box 5B and Figure 5).

Box 5A. Example of modified item after item analysis.

Under aerobic conditions, in which of the following stages of glucose metabolism is the most ATP produced?

A. glycolysis	B. Krebs cycle
* C. oxidative phosphorylation	D. gluconeogenesis

(*) indicates the correct answer

After the item was re-tested a new issue arose. The distribution on the three choices was: A (24.7%), B (16.9%, the correct answer), and C (58.4%). Even though distracter C represents an alternative conception regarding the purpose of the Krebs cycle, the fact that the right answer was chosen in low percentage draws attention to the item. Interviews with five students revealed that this item was confusing and contains some unfamiliar terminology. Terms such as oxidative phosphorylation and the electron transport system ultimately describe the same functional process; however, because the latter was used more often in lecture, the students were not able to recognize the term "oxidative phosphorylation.” It is important for an instructor to mention both terminologies so the students are aware of the fact they describe the same process. Modifying the item would require using both terms in the item, with one term mentioned in parentheses; however, this format may draw attention to this option. Since there was

already an adequate number of items for this concept, it was decided to eliminate the item altogether.

Box 5B. Example of an item revealing unfamiliar terminology.

Under aerobic conditions, in which of the following stages of glucose metabolism is the most ATP produced?
A. glycolysis * B. oxidative phosphorylation C.Krebs cle

(*) indicates the correct answer

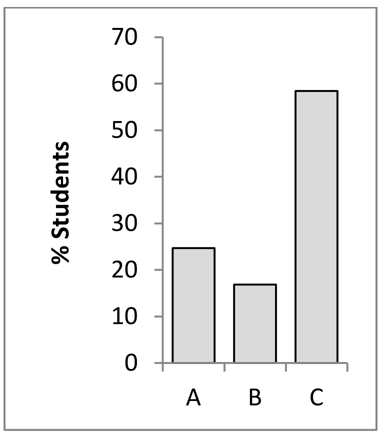

Figure 5: Percentage of responses for each option choice, item presented in Box 5B.

Based on the item analysis of the pilot study data, each item was reviewed and either retained, revised, or eliminated. This item analysis revealed twenty items that had low item difficulty or discrimination indices or a low percent of selection for some of the distracters. After the pilot study, 47 items were retained and the instrument was re-tested as a beta version.

Beta Version of the General, Organic, and Biological Chemistry Topic Inventory

The beta-version of the GOB-CTI (see supplementary materials for item set) was tested for two consecutive semesters at one mid-size, western U.S. state university with 118 students in the Fall semester and 82 students in the Spring semester. The results of an independent t-test for the two groups of students showed no significant difference between the performance of the students on the inventory; consequently the data sets from the two cohorts were combined for analysis. Scores on the 47-item beta version were M = 49.5% and SD = 10.7. With the exception of two items, the item difficulty indices ranged from 0.29 to 0.79. The average difficulty index of the inventory was 0.48, a value close to the 0.50 average difficulty suggested by Gronlund (1993) for typical classroom use. With the exception of two items, the item discrimination indices ranged from 0.29 to 0.63. According to the criteria formulated by Ebel (1972) for the interpretation of the discrimination index, 17 items showed very good discrimination and 28 items showed good discrimination. Two items showed low difficulty and discrimination indices and were flagged for further review.

One of the flagged items for review (Box 6 and Figure 6) had the lowest difficulty and discrimination indices ($p = 0.08$, $D = 0.05$) among all the items on the beta-version of the inventory. Among the distracters, D (47.9%) was the most popular. Distracters A and B were about equally chosen. A low percentage (6.3%) of the students chose option C (the correct answer). The choice of option D by the students reflects perhaps an alternative conception that glucose is the only source of energy and the ATP production will be affected without this source. Students' beliefs that carbohydrates are the main source of energy and that carbohydrates provide the most ATP is also tested by another

item (item 26) on the GOB-CTI. The results on the two items correlate very well and are similar to the findings of a Brazilian study (Oliveira et al., 2003) regarding students' alternative conceptions about biomolecules as metabolic fuels. Despite the fact this item did not present good difficulty and discrimination parameters, the authors decided to retain the item since it may be a warning for an instructor regarding a significant alternative conception about carbohydrates (glucose).

Box 6. The item with the lowest difficulty and discrimination indices among all the items on the inventory.

How will ATP production be affected by a high protein/high fat (triglyceride)/low carbohydrate diet?

A. Proteins will be converted to fatty acids for ATP production.
B. The ATP production will decrease.
* C. The ATP production will remain the same.
D. Fatty acids (from triglycerides) will be converted into glucose for ATP production.

(*) indicates the correct answer

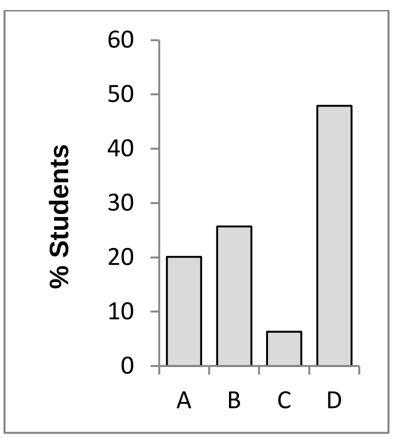

Figure 6: Percentage of responses for each option choice of the item presented in Box 6.

In addition to the psychometric analysis at the item level, the data from the beta-version study were explored in terms of reliability using the "Cronbach's alpha if an item is deleted" statistical analysis. The reliability of the test was not significantly affected if any individual item were to be deleted. Before omitting any questions, adequate coverage of the content domain was considered. Psychometric analysis at the item level in terms of item difficulty, item discrimination, and distracter analysis of both the pilot- and beta-version data proved valuable in deciding which questions were performing as desired and in the refinement of the inventory as a whole. The two items that were eliminated from the beta-version were discussed in the section *Distracter Analysis* (Boxes 4, 5A, and 5B). After the beta-version analysis, the set of 45 items retained represents the final version of the GOB-CTI. The 47-item beta-version of the GOB-CTI is presented in the supplementary materials. The items that were eliminated after the beta-version analysis of the instrument are noted in bold.

Psychometrics at the Test Level

This type of analysis involves the assessment of validity and reliability of the data collected with the instrument during the pilot- and beta-version studies. These are described below.

Assessment of Validity

Validity is the ability of an instrument to measure the construct it is intended to measure. The validity studies of the GOB-CTI focused on construct validity, which is the most widely reported form of instrument validity. For the construct validity of the GOB-CTI, evidence for *face validity*, *content validity* and *convergent validity* were established (Barbera and VandenPlas, 2011).

Face validity is a subjective measure of construct validity. For the GOB-CTI, face validity was explored in the form of expert and novice face validity. After the pilot inventory was assembled, four GOB chemistry instructors and nine nurse educators participated in the *expert face validity* of the GOB-CTI. The experts provided feedback regarding the construct of the instrument in terms of clarity, correctness, and relevance of the items based on the utility of the instrument. *Novice face validity* was established by assessing whether the students are able to understand and interpret the questions as intended by the authors. To ensure the novice validity, each question was examined in terms of consistency in meaning and wording during the think-aloud protocol interviews with students. As in the case of the item presented in Figure 5 and Box 5B, students did not correctly answer the question because they could not recognize the term since there are two different terms that describe the same process.

Content validity refers to the coverage of a certain content domain. The content domain was established from the interviews and consultation of a panel of experts. After the instrument was assembled, GOB chemistry instructors and nurse educators were invited to revise the content of the instrument for clarity, correctness, and the degree to which the items reflect the content domain. The experts were solicited to express their opinions, suggestions, and comments about each item on the instrument to ensure the items reflect each concept of the content domain. For this purpose, a blue print in the form of a table of the main GOB chemistry topics relevant to the clinical practice (Brown et al., 2012) was distributed to the experts along with the instrument for review. In this phase of the project, twelve independent GOB chemistry instructors were consulted to ensure that the domain was adequately covered. Some of the experts were recruited via

email and some during the 2012 Biennial Conference on Chemical Education. The experts received a package containing the 47 items of the GOB-CTI and a list of chemistry topics. They were asked to use the list of chemistry topics to determine which concept each of the 47 items on the GOB-CTI is testing. The test items were matched with the topics by placing the concept number from the table in the space provided below the item on the GOB-CTI. Additionally, space was provided for any potential comments regarding an item or a concept designation the experts may have. This process yielded a percentage agreement for each item and the concept represented. The rating consistency among the experts varied between 85-100%.

Convergent validity is an empirical measure of a construct and is used to evaluate the degree to which two or more measures that theoretically should be related to each other are actually observed to be related to each other (Barbera and VandenPlas, 2011). Convergent validity was established by comparing the results from the GOB-CTI instrument with the General-Organic-Biochemistry Exam (Form 2007) of the American Chemical Society (GOB-ACS). Students took the GOB-CTI the last week of the semester (N = 82) and took the GOB-ACS during finals week (N = 77). Comparison between the two tests was performed in two ways.

Scores on the 47-item beta-version of the GOB-CTI (M = 48.1%, SE = 10.4) were compared with the scores of the GOB-ACS (M = 47.1%, SE = 14.1). A t-test for paired samples revealed that there was not a statistically significant difference between the performance of the students on the two tests ($t_{(76)} = 0.892$, $p = 0.352$). The results of the paired samples t-test also show there is a strong positive correlation between the two tests

reflected by a correlation coefficient of 0.717, which indicates that students who performed well on the GOB-ACS also performed well on the GOB-CTI.

The GOB-CTI and GOB-ACS were also compared at the item level. General, Organic, and Biological chemistry items (13 items) from the GOB-ACS were compared with similar items on the GOB-CTI. The results of the independent t-test for the compared items show no significant difference between the performance of the students on the similar questions of the two tests.

Assessment of Reliability

Reliability of the GOB-CTI was analyzed in terms of internal consistency, which refers to the interrelatedness of a set of items and is expressed through a Cronbach's alpha value (Schmitt, 1996). An instrument that is functioning well will yield scores that are consistent, which is an indication that the items measuring the same concept produce scores that are correlated. For the 45-item, final version of the GOB-CTI, the Cronbach's alpha value is 0.763. This value is above the recommended limit of 0.7 (Nunnally and Bernstein, 1994).

Conclusions

The goal of this project was to develop an instrument that measures students' conceptual knowledge of GOB chemistry while meeting accepted standards for validity, reliability, and discriminatory power in the data. The GOB-CTI does not evaluate all the topics covered in a typical GOB chemistry course. It purports to measure pre-nursing students’ conceptual understanding of the main chemistry topics deemed most relevant to the nursing clinical practice. The instrument contains 45 items and is intended to be completed in a 50-minute class period. The 45 items are divided into three sections:

general (approximately 30% of the items), organic (approximately 20% of the items), and biological chemistry (approximately 50% of the items) based on the significance of the topics from each section of chemistry presented in the GOB course.

The design and development of the GOB-CTI was divided into several phases and involved iteration of the steps illustrated in Figure 2. The GOB-CTI was analyzed from a Classical Test Theory perspective. As part of the ongoing developmental process, individual item analysis was conducted which included item difficulty, item discrimination, and quality of distracters. In the developmental stage of the inventory, experts and students were consulted regarding clarity of the questions in terms of the wording and meaning of certain terms. Students' responses to open-ended questions were used as distracters in the multiple-choice test items. The beta-version of the multiple-choice instrument was tested and appropriate changes were made. Items with lower performance were eliminated. As the uses and the needs of the instrument evolve, the instrument should continue to be evaluated, which makes the process of validation an on-going process (Nunnally, 1978).

The GOB-CTI may be used in several ways. The instrument should be able to assist instructors in identifying the alternative conceptions and incorrect ideas that are most prevalent as well as topics considered difficult by students. Students enrolled in the course may have diverse background knowledge; some of the students in the course may have previously taken or be concurrently enrolled in biology, anatomy-physiology or another chemistry course. The inventory may be used as a pre-test and could inform the instructor about the student's incoming knowledge. The GOB-CTI may also be used only as a post-test, providing the instructor with feedback on those topics that may need more

attention in the future. The items themselves may suggest ideas for more conceptually based instruction and may be used as in-class formative assessment exercises.

The entire instrument is presented in the supplemental material. Instructors who wish to use the GOB-CTI for teaching and research have the permission to use the instrument if they cite this article and comply with the fair use of this copyrighted work.

Acknowledgments

The authors would like to acknowledge the students and instructors involved at different levels in the GOB-CTI testing. We would also like to thank the experts: GOB instructors, nurse educators, and nurses for their helpful and insightful feedback during the different phases of the project.

CHAPTER VI

CONCLUSIONS, IMPLICATIONS, AND FUTURE RESEARCH

Conclusions

The research presented in this dissertation describes a "ground breaking" work in the development, design, and psychometric analysis of a GOB chemistry concept inventory based on identified chemistry topics relevant to the nursing clinical practice. To this researcher's knowledge, no published GOB chemistry concept inventory exists. The purpose of the study was to investigate the main GOB chemistry topics deemed important in the clinical practice and the development of an assessment that tests the conceptual understanding of these topics by the pre-nursing students enrolled in a GOB chemistry course. This chapter presents the overall findings and summarizes the way each of the research questions of the study was addressed. The project consisted of three major parts each leading to the GOB-CTI as depicted in Figure 1.

The first part sought to identify the main GOB chemistry topics perceived by experts to be relevant to nursing clinical practice answering the question:

Q1 What are the topics in a GOB chemistry course that are perceived by experts to be relevant to nursing clinical practice?

This part of the project was developed based on interviews with experts from the areas of chemistry and nursing followed by a national survey of experts. The interviews and the national survey were guided by the Table of Contents of the text book (Stoker,

2007) used in the GOB chemistry course. The Table of Contents was compared with the Table of Contents of other GOB chemistry textbooks. Most textbooks examined emphasize the same topics.

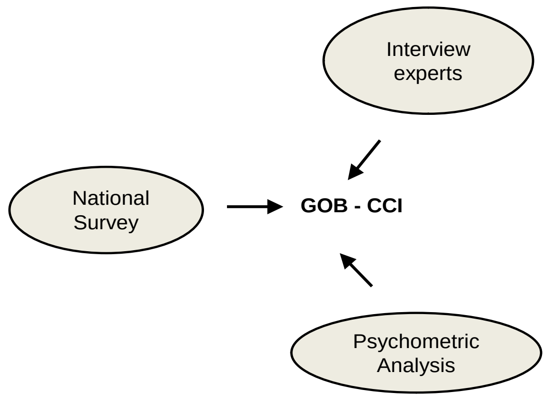

Figure 1: Major parts of the project.

The second part of the project assessed the consensus among experts addressing the question:

Q2 Is there a consensus among the nursing educators and GOB chemistry instructors and between the two cultures regarding the topics perceived to be relevant?

Data from interviews of the experts at the western U.S., state university, where the research was initiated, were tabulated and compared for consensus both within each group of experts in the same discipline and between groups of experts (chemistry and nursing) and also compared the consensuses with data from the national survey. The comparison showed a 95% agreement among the experts regarding the classification of the chemistry topics taught in a GOB chemistry course. As a result, a list of chemistry topics deemed important to clinical practice was formulated.

The third part addressed the design and the development of an inventory based on the GOB chemistry topics deemed both important and foundational to the nursing clinical practice addressing the question:

Q3 How does one appropriately measure pre-nursing students’ conceptual understanding of the topics perceived by the experts to be relevant to clinical practice?

In order to address this research question, an instrument in the form of a concept inventory (GOB-CTI) was developed. In this part of the study, an array of statistical methods including qualitative, quantitative, survey, and psychometric methodology was employed. In the developmental stage of the inventory, experts and students were consulted regarding clarity of the questions, wording, and meaning of certain terms. Students' responses to the open-ended questions along with plausible incorrect choices created by the researcher were used as distracters in the multiple-choice test items. The beta version of the multiple-choice instrument was tested and appropriate changes were made. Items with lower performance ($0.3 < p < 0.8$ and $D < 0.29$) were eliminated. The GOB-CTI measures students' conceptual knowledge of GOB chemistry while meeting accepted standards for test validity, reliability, and discriminatory power. Different levels of validity were assessed which is helpful in establishing greater evidence of validity. Reliability of the instrument was expressed through Cronbach's alpha and has a value of 0.763.

Implications

This section details the contribution made by this study in several areas: (1) the field of GOB chemistry education, (2) the development of an assessment instrument (GOB-CTI) that can measure the understanding by pre-nursing students of the main

chemistry topics relevant to clinical practice, and (3) the curriculum and teaching of chemistry for allied-health majors. The impact of the study in these areas are briefly described:

1. The field of general, organic, and biological chemistry education. The national trend involves a restructuring in many nursing programs leading to reduction from two semesters to one semester for this course (Frost, 2010); this adds more to the frustration for the instructors and to the cognitive load of the course for the students. The current research study has identified the important topics the pre-nursing students should know at the end of the course based on the experts opinion.

2. The development of an assessment instrument (GOB-CTI) that can measure the understanding of the pre-nursing students of the main chemistry topics relevant to clinical practice. The instrument contains 45 multiple-choice items and is intended to be completed in a typical 50-minute class period. The 45 items are divided into three sections: general, organic, and biological chemistry based on the significance of the topics from each section of chemistry presented in the GOB course.

3. The curriculum and teaching of chemistry for allied-health majors. The GOB-CTI may be used in several ways. The inventory may be used as a pre- and post-test in order to inform the instructor of the topics the student has mastered and to what extent some of the topics should be emphasized in teaching. The GOB-CTI may also be used only as a post-test providing the instructor with feedback on those topics that may need more attention in the future. The items themselves may suggest ideas for more conceptually based instruction and may be used as in-class formative assessment exercises. The instrument should be able to assist instructors in identifying the incorrect

ideas about specific topics and topics that are difficult for the students; this should provide the instructor with guidance for action.

The instrument can be used as an evaluation of different teaching approaches. Chemistry instructors can compare the effectiveness of different instructional approaches in their courses by comparing scores with other institutions. For example, the use of the Force Concept Inventory (FCI) suggested that replacement of traditional lectures with more interactive approaches can result in higher student learning gains (Hake, 1998).

Future Research

The researcher's intention is to continue with several additional studies that will complete the picture of the assessment and understanding of the pre-nursing students regarding topics deemed important in clinical practice. Further analysis of the GOB-CTI is planned in several key areas including: data collection at the national level, in-depth analysis of the national survey, Rasch or IRT analysis of the inventory, factor analysis, exploration of the predictive validity of the instrument, and development of short concept inventories in each area of GOB.

Data Collection at the National Level

In collaboration with faculty from other universities and through web-based administrations of the instrument, which ensures the retention of the full set of data necessary to conduct other analyses, data will be collected across universities and colleges. The administration of the inventory on-line will provide a convenient access to the full set of test results that will be used to refine and improve the test items. Also, the validity of the instrument will continue to be assessed and improved.

In Depth Analysis of the National Survey

The survey will be analyzed taking into consideration the impact of some demographic information on the classification of topics. Demographic information such as the clinical experience of the nurses, the years and types of chemistry in their education, and years of experience with the course of the GOB chemistry instructors will be used.

Rasch or Item Response Theory Analysis of the Inventory

This type of analysis has become prevalent in the assessment of ability and achievement tests. The analysis will offer deeper insight into item behavior and may help to distinguish between incorrect ideas and guessing.

Factor Analysis

Factor analysis can be an important tool for evaluating and interpreting any testing instrument. This type of analysis can provide further evidence for assessing whether dimensionality assumptions are met for both classical test theory and item response theory. An investigation of the factor structure of the instrument will also provide evidence for the validity of the instrument and can provide evidence for the validity of score interpretation.

Explore the Predictive Validity of the Instrument

Predictive validity refers to a test's ability to accurately predict future performance. An interesting study will be the analysis of a possible correlation of the students’ performance on the GOB-CTI and prediction of a student's performance on the NECLEX.

Develop Short Concept Inventories in Each Area of General, Organic, and Biological Chemistry

Based on the chemistry deemed important to clinical practice, concept inventories may be developed based on specific topics, i.e., acid-base chemistry, metabolism, or biomolecules. These concept inventories may have 10-15 items and used as formative assessments.

The biosciences in the nursing curriculum have an important role. This study brings clarity to the chemistry topics important for the pre-nursing students to learn in a chemistry course. The GOB-CTI should serve as a tool to make the desired outcome of the course measurable.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVALS AND INFORMED CONSENT FORMS

Informed Consent Form
University of Northern Colorado

Project Title: The General, Organic, and Biological (GOB) Chemistry Concept Inventory: experts' interview

Researchers: Corina E. Brown, doctoral student in the chemical education program
Phone number: (970) 351-1291

Research Advisor: Dr. Jerry Suits/Dr. Jack Barbera
Phone Number: (970) 351-1169/(970) 351-2545

Section I – Statement of Problem/Research Question

The central objective of the proposed research is to establish the main topics of GOB chemistry that are important for effective and safe practice in the field of nursing. Based on the identified topics, the project also seeks to develop and validate a GOB chemistry concept inventory. This instrument will facilitate the assessment of GOB curriculum and courses, serving as a measure of student learning.

The research question for the first phase of the research is: What are the main topics of GOB chemistry relevant to clinical nursing practice?

Section II – Procedure
Fall 2009 and Spring 2010 - the following materials will be completed

Semi-structured Interview - approximate 30 minutes to complete. The interviews will be recorded on an audio tape recorder and manually transcribed.

Risks and Benefits to Participants:
There are no anticipated risks to participants.

Compensation: The primary researcher will provide $10.00 gift cards to Starbucks, Subway or Barnes & Noble for the participants.

(Please initial here to indicate that you have read the IRB consent form)

Confidentiality: Confidentiality will be maintained during the course of data collection and analysis. Signed consent forms will be stored separately from the data so that names cannot be linked to the information collected. Each participant shall have a random eight digit code assigned to them for confidentiality and data analysis purposes. Sensitive data will be stored on a password-locked computer and only be accessible to the primary researchers. The consent forms and the audio tapes will be stored for a three-year period. The office number where the data will be locked and stored is Ross 3695 (the chemical education office).

Questions: If you have any questions about the design or results of this study, or about the nature of your participation, you may ask now or at any time during the course of the data collection and subsequent analysis. You may also contact me or my advisors at the phone numbers indicated at the top of this form.

Thank you for considering participation in our research.

Sincerely,
Corina Brown

Participation is voluntary. You may decide NOT to participate in this study and if you do begin participation you may still decide to stop and withdraw at any time. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Sponsored Programs and Academic Research Center, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-1907.

Print name____

____ ___________________
Participant's Signature Date

____ ___________________
Researcher's Signature Date

UNIVERSITY of NORTHERN COLORADO
Institutional Review Board (IRB)

September 1, 2009

TO: Teresa McDevitt
School of Psychological Sciences

FROM: Gary Heise, Co-Chair GDH
UNC Institutional Review Board

RE: Expedited Review of Proposal, *The General, Organic, and Biological (GOB) Chemistry Concept Inventory: Experts' Interview,* submitted by Corina E. Brown (Research Advisor: Jerry Suits/Jack Barbera)

First Consultant: The above proposal is being submitted to you for an expedited review. Please review the proposal in light of the Committee's charge and direct requests for changes directly to the researcher or researcher's advisor. If you have any unresolved concerns, please contact Gary Heise, School of Sport and Exercise Science, Campus Box 39, (x1738). When you are ready to recommend approval, sign this form and return to me.

I recommend approval as ~~is~~ revised. ______________ 9/23/09
Signature of First Consultant Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is approved as proposed for a period of one year: 2 Oct 2009 to 2 Oct 2010

______________ 2 Oct 09
Gary Heise, Co-Chair Date

Comments: Revision to consent form; clarifications on participants and procedures TMcD 9/23/09

Informed Consent Form
University of Northern Colorado

Project Title: The General, Organic, and Biological (GOB) Chemistry Concept Inventory: experts' validation

Researchers: Corina E. Brown, doctoral student in the chemistry education program
Phone number: (970) 351-1291
Research Advisor: Dr. Jack Barbera
Phone Number: (970) 351-2545

Section I – Statement of Problem/Research Question

The central objective of the proposed research is to establish the main topics of GOB chemistry that are important for effective and safe practice in the field of nursing. Based on the identified topics, the project also seeks to develop and validate a GOB chemistry concept inventory. This instrument will facilitate the assessment of GOB curriculum and courses, serving as a measure of student learning.

The research question for the phase 1B of the research is: Are the questions, based on the main topics of GOB chemistry, relevant to clinical nursing practice?

Section II – Procedure
Spring 2010 - the following materials will be completed:

A survey of open-ended questions based on the identified main topics will be sent to the experts via email. It will take approximate 30 minutes to read and provide feedback.

Risks and Benefits to Participants:
There are no anticipated risks to participants.
There are no direct benefits to you, however, by participating in this study you will be informing chemistry and nurse educators about the knowledge needed by pre-health students. This knowledge acquisition is important and may help you to better understand how to assist your students in learning or how to better utilize their knowledge in your course.
Compensation: No compensation is provided.

(Please initial here to indicate that you have read the IRB consent form)

Confidentiality: Confidentiality will be maintained during the course of data collection and analysis. Signed consent forms will be stored separately from the data so that names cannot be linked to the information collected. Each participant shall have a random eight digit code assigned to them for confidentiality and data analysis purposes. The consent forms will be stored for a three-year period. The office number where the data will be locked and stored is Ross 3695 (the chemical education office).

Questions: If you have any questions about the design or results of this study, or about the nature of your participation, you may contact my advisor or me at the phone number, indicated at the top of this from.

Data will be collected by the researcher as a result of feedback received via email. The list of questions will be sent to the experts that already participated in the first phase (1A) of the project via email, it will be printed by the participant and done using paper and pencil. It will be collected in two weeks. Appendix A presents a sample of the survey with potential open-ended questions formulated on the main GOB chemistry identified.

Please print the survey and complete via hard copy and pencil. Please print two consent forms, sign one copy and keep the other one for your own record. Two weeks after you received these documents, the researcher will contact you and arrange a time to stop by your office to collect the completed survey and the consent from.

Thank you for considering participation in our research.

Sincerely,
Corina Brown

Participation is voluntary. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time without any negative repercussions to you. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. An additional copy of this form should be printed for you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-2161.

Print name_______________________________________

____ ____________________
Participant’s Signature Date

____ ____________________
Researcher’s Signature Date

UNIVERSITY of
NORTHERN COLORADO
Institutional Review Board (IRB)

January 15, 2010

TO: Spencer Weiler
ELPS

FROM: Megan Babkes Stellino, Co-Chair MBS
UNC Institutional Review Board

RE: Expedited Review of Proposal, *The General, Organic, and Biological (GOB) Chemistry Concept Inventory: Experts' Validation,* submitted by Corina E. Brown (Research Advisor: Jack Barbera)

First Consultant: The above proposal is being submitted to you for an expedited review. Please review the proposal in light of the Committee's charge and direct requests for changes directly to the researcher or researcher's advisor. If you have any unresolved concerns, please contact Megan Babkes Stellino, School of Sport and Exercise Science, Campus Box 39, (x1809). When you are ready to recommend approval, sign this form and return to me.

I recommend approval as is. Spencer Weiler 1-26-10
Signature of First Consultant Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is approved as proposed for a period of one year: 2/19/2010 to 2/19/2011.

Megan B Stellino 2/18/2010
Megan Babkes Stellino, Co-Chair Date

Comments: Please see revised application along w/ email communications. SW
revised consent form & Appendix A attached.

UNIVERSITY of NORTHERN COLORADO

CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF NORTHERN COLORADO

Project Title: The General, Organic, and Biological (GOB) Chemistry Concept Inventory: students' interview

Researchers: Corina E. Brown, doctoral student in the chemistry education program
Phone number: (970) 351-1291 Email: brow2423@bears.unco.edu
Research Advisor: Dr. Jack Barbera, Assistant Professor, School of Chemistry and Biochemistry
Phone Number: (970) 351-2545 Email: jack.barbera@unco.edu
Research Advisor: Dr. Richard M. Hyslop, Professor, School of Chemistry and Biochemistry
Phone Number: (970) 351-1288 Email: richard.hyslop@unco.edu

Section I – Statement of Problem / Research Question
The central objective of the proposed research is to establish the main topics of GOB chemistry that are important for effective and safe practice in the field of nursing. Based on the identified topics, the project also seeks to develop and validate a GOB chemistry concept inventory. This instrument will facilitate the assessment of GOB curriculum and courses, serving as a measure of student learning.

The research question for the second phase of the research is: What are the students' conceptions regarding the GOB chemistry questions presented to them?

Section II – Procedure
Summer 2010, Fall 2010 and Spring 2010 - the following materials will be completed:

Each student interview will last approximately 1 hour, with the possibility for a recap and review session following the interview, if interest exists. During the interview, you might be asked to elaborate your reasoning by the researcher, to ensure that the topics you are using are being accurately identified.

We do not foresee any risk to you by participating in this study. You may feel anxious or frustrated by taking quizzes or tests, but we hope to minimize these feelings because the outcome of this interview will have no connection with your evaluation in your

(Please initial here to indicate that you have read the IRB consent form)

Fundamentals of Biochemistry (CHEM 281) course or your final grade. The benefits to you include being able to verbalize your thought process and gaining a better

understanding of the material by discussing your topics of GOB chemistry with the researcher after your interview. This experience can give you a better grasp of GOB chemistry and could make you better prepared for future exams or the final for your GOB chemistry course. If at any point during the interview you wish to no longer participate in this survey, you can withdraw without penalty or need for explanation.

Confidentiality will be maintained during the course of data collection and analysis. The instructors of the CHEM 281 course will not know which students participated in the study. Also, the instructors will not have access to the responses of the participating students, nor will they be allowed to know how students performed on any content-based questions. Signed consent forms will be stored separately from the data so that names cannot be linked to the information collected. Each participant shall have a random eight digit code assigned to them for confidentiality and data analysis purposes. Sensitive data will be stored on a password - locked computer and only be accessible to the primary researchers. The consent forms and the video tapes will be stored for a three-year period. The office number where the data will be locked and stored is Ross 3695 (the chemical education office).

Questions: If you have any questions about the design or results of this study, or about the nature of your participation, you may ask now or at any time during the course of the data collection and subsequent analysis. You may also contact me or my advisors at the phone numbers indicated at the top of this form.

Thank you for considering participation in our research.

Participation is voluntary. You may decide NOT to participate in this study and if you do begin participation you may still decide to stop and withdraw at any time. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Sponsored Programs and Academic Research Center, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-1907.

Print name____

____ ___________________
Participant's Signature Date

____ ___________________
Researcher's Signature Date

UNIVERSITY of
NORTHERN COLORADO
Institutional Review Board (IRB)

May 5, 2010

TO: Heather Helm
APCE

FROM: Gary Heise, Co-Chair
UNC Institutional Review Board

RE: Expedited Review of Proposal, *The General, Organic and Biological (GOB) Chemistry Concept Inventory: Students' Interview,* submitted by Corina E. Brown (Research advisors: Jack Barbera and Richard Hyslop)

First Consultant: The above proposal is being submitted to you for an expedited review. Please review the proposal in light of the Committee's charge and direct requests for changes directly to the researcher or researcher's advisor. If you have any unresolved concerns, please contact Gary Heise, School of Sport and Exercise Science, Campus Box 39, (x1738). When you are ready to recommend approval, sign this form and return to me.

I recommend approval as is. Heather Helm 6/19/10
Signature of First Consultant Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is approved as proposed for a period of one year: 6/24/2010 to 6/24/2011.

Gary D. Heise 6/24/2010
Gary Heise, Co-Chair Date
as revised - - - 6/22/2010

Comments: emailed 18 June 2010

CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF NORTHERN COLORADO

Project Title: The General, Organic, and Biological (GOB) Chemistry Concept Inventory: Data Collection (paper and pencil)

Primary Researcher: Corina E. Brown, chemistry education doctoral student, Department of Chemistry and Biochemistry
Phone number: (970) 351-1291 Email: brow2423@bears.unco.edu
Research Advisor: Dr. Jack Barbera, Assistant Professor, Department of Chemistry and Biochemistry
Phone Number: (970) 351-2545 Email: jack.barbera@unco.edu
Research Advisor: Dr. Richard M. Hyslop, Professor, Department of Chemistry and Biochemistry
Phone Number: (970) 351-1288 Email: richard.hyslop@unco.edu

Statement of Problem/Research Question

The objective of the proposed research is to develop and validate a concept inventory based on some identified topics of GOB chemistry that are important for effective and safe practice in the field of nursing. This instrument will facilitate the assessment of GOB courses, serving as a measure of student learning.

Procedure: Participants will be asked to take a concept inventory that contains 40 questions; there is time limit of 45 minutes to complete the test.

We do not foresee any risk to you by participating in this study. You may feel anxious or frustrated by taking quizzes or tests, but we hope to minimize these feelings because the outcome of this test will have no connection with your evaluation in the GOB chemistry course or your final grade. This experience can give you a better grasp of the main GOB chemistry topics relevant to clinical practice and may better prepare you for the final exam in your GOB chemistry course. If at any point during the test you wish to no longer participate in this study, you can withdraw without penalty. For the success of the study, we recommend you try to finish the test and answer each question to your best ability.

(Please initial here to indicate that you have read the IRB consent form)

Confidentiality will be maintained during the course of data collection and analysis. The instructors of the course will not know which students participated in the study. Also, the instructors will not have access to the individual responses of the participating students. Signed consent forms and demographic forms will be stored separately from the data so that names cannot be linked to the information collected. Each participant shall have a random eight-digit code assigned to them for confidentiality and data analysis purposes. Sensitive data will be stored on a password-locked computer and will be accessible only to the primary researcher. The consent forms and the demographic forms will be stored for a three-year period. The office number where the data will be locked and stored is Ross 3695 (the chemical education office).

Questions: If you have any questions about the design or results of this study, or about the nature of your participation, you may ask now or at any time during the course of the data collection and subsequent analysis. You may also contact me or my advisors at the email addresses indicated at the top of this form.

Thank you for considering participation in our research.

Participation is voluntary. You may decide NOT to participate in this study and if you do begin participation you may still decide to stop and withdraw at any time.

Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado, Greeley, CO 80639; 970-351-2161.

Print name____

____ ___________________
Participant's Signature Date

____ ___________________
Researcher's Signature Date

 ____
(Please initial here to indicate that you have read the IRB consent form)

UNIVERSITY of NORTHERN COLORADO
Institutional Review Board (IRB)

July 20, 2011

TO: Wendy Highby
University Libraries

FROM: Megan Babkes Stellino, Co-Chair MS
UNC Institutional Review Board

RE: Expedited Review of Proposal, *The General, Organic, and Biological (GOB) Chemistry Concept Inventory: Data Collection,* submitted by Corina E. Brown (Research Advisor: Jack Barbera and Richard Hyslop)

First Consultant: The above proposal is being submitted to you for an expedited review. Please review the proposal in light of the Committee's charge and direct requests for changes directly to the researcher or researcher's advisor. If you have any unresolved concerns, please contact Megan Babkes Stellino, School of Sport and Exercise Science, Campus Box 39, (x1809). When you are ready to recommend approval, sign this form and return to me.

I recommend approval as ~~is~~ revised: W. Highby 8-5-11
Signature of First Consultant Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is approved as ~~proposed~~ revised → 2nd revision for a period of one year: Aug. 10, 2011 to Aug. 10, 2012

Megan Babkes Stellino 8/10/11
Megan Babkes Stellino, Co-Chair Date

Comments:
note - application should have been exempt!

UNIVERSITY of NORTHERN COLORADO

College of Natural and Health Sciences
Department of Chemistry and Biochemistry

Project Title: Topics of General, Organic, and Biological (GOB) Chemistry Relevant to Clinical Practice: survey experts

(to be placed in email header)

(name),

You are invited to participate in a research study being conducted by a group of researchers from Department of Chemistry and Biochemistry at the University of Northern Colorado in consultation with faculty from the School of Nursing at the University of Northern Colorado. The purpose of this research is to explore the relevancy of chemistry topics taught in a GOB chemistry course. By participating in this study, you will be informing chemistry and nurse educators about the knowledge needed by allied health students. This knowledge acquisition is important and may help you to better understand how to assist your students in learning or how to better utilize their knowledge in your course.

Participation in this study will involve classification of topics taught in a GOB chemistry course and their relevancy to clinical practice. This survey will take you approximately 15-20 minutes to complete online. There are no foreseeable risks in participating in this survey and your participation is completely voluntary. We guarantee confidentiality of your responses There are no foreseeable risks in participating in this survey and your participation is completely voluntary. The survey is administered through software that will not track your individual responses, disallowing me from tracing any individual response to you. Finally, no one will have access to the information given on the surveys besides the primary researcher of the project.

Participation is voluntary. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-2161.

If you would like to participate, you may do so by clicking on the link below.

If you have any questions regarding the design or results of this study, or the nature of your participation, you may contact my advisors or me at the appropriate phone number.

Primary Researcher: Corina E. Brown, Chemistry Education doctoral student, Department of Chemistry and Biochemistry at the University of Northern Colorado

Phone number: (970) 351-1291 Email: brow2423@bears.unco.edu

Research Advisor: Dr. Jack Barbera, Assistant Professor, Department of Chemistry and Biochemistry
Phone Number: (970) 351-2545 Email: jack.barbera@unco.edu

Research Advisor: Dr. Richard M. Hyslop, Professor, Department of Chemistry and Biochemistry
Phone Number: (970) 351-1288 Email: richard.hyslop@unco.edu

THANK YOU for your willingness to assist us with this important area of research!

Participation in this study about relevancy to the nursing clinical practice of chemistry topics taught in a GOB chemistry course is completely voluntary. If you decide not to participate, your decision will be respected. In addition, if you begin participation but decide to stop, you can withdraw at any time. Having read the above and having had the opportunity to ask any questions you have about the study, if you are willing to participate in this research, please begin the survey by clicking the following link.

PARTICIPATORY SURVEY LINK HERE

UNIVERSITY of
NORTHERN COLORADO
Institutional Review Board (IRB)

December 2, 2011

TO: Megan Babkes Stellino
School of Sport and Exercise Science

FROM: The Office of Sponsored Programs

RE: Exempt Review of *Topics of General, Organic, and Biological (GOB) Chemistry Relevant to Clinical Practice: National Survey of Experts* submitted by Corina E. Brown (Research Advisor(s): Jack Barbera and Richard Hyslop)

The above proposal is being submitted to you for exemption review. When approved, return the proposal to Sherry May in the Office of Sponsored Programs.

I recommend approval ✓ as revised

Megan Stellino 12/7/11
Signature of Co-Chair Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is exempt from further review.

IT IS THE ADVISOR'S RESPONSIBILITY TO NOTIFY THE STUDENT OF THIS STATUS.

Comments:

~ email 12/5
• ⊕ participant mistreatment OSP # to consent ✓

25 Kepner Hall ~ Campus Box #143
Greeley, Colorado 80639
Ph: 970.351.1907 ~ Fax: 970.351.1934

APPENDIX B

ANNOUNCEMENTS

Announcements to Nursing Professors

Dear Nursing Professor,

I would like to thank you again for your willingness to participate in the interviews. The information you provided is very valuable for this research. By analyzing the interviews I have generated a list of general GOB chemistry topics important in nursing. Based upon those topics, questions were generated that in their final form will be multiple choice.
I would like to inform you about the GOB chemistry topics that were found important for clinical nursing practice according to the interviews. Also, I would like to solicit your help again in offering feedback on the questions written based on these main topics identified. The questions will be further used in the interviews with the students. The misconceptions students have will be used for constructing distracters for questioner.

I would like to ask you to look over the questions and give me some feedback on the wording of the questions and their importance for nursing. If you are interested Dr. Henry would provide you the questions. Thank you very much for your valuable input.

Sincerely,

Corina Brown

Doctoral Student
Department of Chemistry and Biochemistry

Announcement for Students Interviews

I am a graduate student in the Department of Chemistry and Biochemistry, and I am working on a dissertation in Chemical Education. I am conducting a study to identify student's conceptions on some important GOB chemistry topics taught in CHEM 281. I am here today to see if there are any interested students who would like to volunteer for this study. If you are interested, I would ask for approximately one hour of your time.

Your participation in the study will be confidential and your name will not be included in any reports of the findings. If you at any time wish to withdraw from participation in this study you can without penalty. The interview and questions may assist you in better understanding the material presented in class. As a bonus¸ after the interview, you can ask any questions you might have on the material to further help with your own understating of the material presented.

If you are interested in obtaining more information about volunteering for this study, please contact me via my UNC email address, which is written on the board.

Announcements for Experts
(face validity)

Dear Dr. ___________

I would like to express my gratitude for your willingness to help me evaluate the multiple-choice items I created. These are based on the GOB chemistry topics that were identified as being important for the clinical nursing practice. Your feedback is very important for this research.

As you review each item consider the following questions:

1. Do you think that the wording of the item and its responses is at an appropriate level for the pre-nursing students?
2. Do you think that the item covers an important topic/concept in the GOB course?
3. Do you agree that the marked option (***) is the only correct response?

If you disagree with any of the above questions for a particular item, please note your concerns on the document.
Thank you very much for your valuable input.

I will contact you and arrange a time to stop by your office on Monday (Feb 27, 2011) to collect the document with your comments.

Sincerely,

Corina E. Brown
Doctoral Student
Department of Chemistry and Biochemistry

Announcement Nursing Educators

Dear Nursing Professor,

I would like to express my gratitude for your willingness to help me with this questionnaire. The information you provided is very valuable for this research.
I would like to solicit your help in offering feedback on the questions written based on some main chemistry topics important in nursing. These topics were identified from interviews with experts. Based upon those topics, questions were generated that in their final form will be multiple choice. The questions will be further used in the interviews with the students. The misconceptions students have will be used for constructing distracters for the questionnaire.

I would appreciate you taking the time from your busy schedule to look over the questions and give me some feedback on the wording of the questions and their importance for nursing. I would also appreciate it very much if you could return your comments along with the signed consent form to me at your earliest convenience. Please use the self-addressed envelope. Thank you very much for your valuable input.

Sincerely,

Corina E. Brown
Doctoral Student
Department of Chemistry and Biochemistry

Announcement to students regarding the administration of the
GOB Chemistry Concept Inventory

The concept inventory that you will be taking today was design by researchers at the University of Northern Colorado based on the main GOB chemistry topics deemed relevant to clinical practice.

The test contains 47 multiple-choice questions and you have 45 minutes to complete it. It will be a good practice for the final exam in this course. Your participation in the study will be confidential, your name will not be included in any report of the findings, and your performance will not be used for your evaluation or final grade for this course. The students that are not at least 18 years old are asked not to participate in the study and they are welcomed to leave the room. While every student 18 years of age and older will have the opportunity to take the concept inventory, your answers will be considered only if you sign the consent forms on the first pages preceding the concept inventory. Likewise, should you choose not to participate, your lack of participation in the study will be confidential and will not affect your evaluation or final grade for the course. A copy of the consent form will be given to you to retain for future reference. If at any time you wish to withdraw from participation in this study, you can do so without penalty. In order for the data to be useful, it is important to answer each question to the best of your ability. Students interested in the correct answers to the questions on the concept inventory are invited to participate in a help session held by the researcher (date and time will be announced).

If you have any questions regarding this research, please do not hesitate to contact me.
My email address is: brow2423@bears.unco.edu

To reiterate, you have the following options:
To not participate;
To stop and withdraw at any time after beginning to participate;
To participate only in taking the concept inventory, but not the research, by completing the inventory without signing the consent form;
To fully participate in the research by completing the inventory and signing the consent form.

Dear GOB Chemistry Expert,

I am currently developing a GOB Chemistry Topic Inventory (GOB-CTI). In this phase of the project, I would like to establish the content validity of the instrument. To do this, I am asking faculty who regularly teach GOB chemistry courses to read and classify the items on the GOB-CTI.
If you wish to participate, you will be given a copy of the GOB-CTI and a copy of the topics from which the 47 items were derived. You will be asked to read the item and determine (based on the topic list) what topic the item is testing. Each topic has been given a numerical code. You will also be able to provide written comments if you wish. The process is expected to take about 20 minutes.

If you would like to participate in this phase of the project, please respond via email and include your mailing address. A packet along with a self-addressed and stamped envelope will be sent to you.

Sincerely,

Corina E. Brown
Chemical Education Doctoral Student
Department of Chemistry and Biochemistry
University of Northern Colorado

APPENDIX C

DEMOGRAPHIC FORMS

Demographic Form
(Students)

Name:

Gender: M / F

Are you less than 18 yrs old?   YES*/NO

*If you are less than 18 years old, please do NOT sign the consent form for this study.

Year of high school graduation:

Current Major:

Are you planning to change your major or will you be transferring in to another program? If so, please list your intended major (e.g., Biochemistry, Physical Therapy, Nutrition)

Previous classes (and year taken) in chemistry:

Previous classes (and year taken) in math:

Email:

Demographic Form
(Chemistry Instructors)

Name:

Gender: M / F

At what institution are you a faculty member?

How frequently do you teach the GOB Chemistry?

Is the GOB Chemistry you teach: a one- or two-semester course?

Are you using the ACS exam in GOB Chemistry at the end of the course?

What percent of your GOB course is devoted to general, to organic, to biological and specifically to metabolism?

What is your email address?

Demographic Form
(Nurse Educators)

Name:

Gender: M / F

What years did you receive your nursing degree(s) college?

What degree did you receive and in what year?

For how long have you been practicing?

What is your nursing specialty?

What courses in chemistry and how many semesters have you had and when?

- Introductory Chemistry
- General Chemistry
- Chemistry
- General, Organic and Biological Chemistry

What is your email address?

APPENDIX D

LIST OF TOPICS USED IN THE INTERVIEWS WITH THE EXPERTS

General, Organic, and Biological Chemistry (5th ed.), Stoker, S. H. (2007). General, Organic, and Biological Chemistry: Houghton Mifflin Company.

Part I: General Chemistry

1: Basic Topics About Matter
Physical and chemical properties of matter; Changes in matter; Pure substances and mixtures; Elements and compounds; Names and chemical symbols of the elements; Atoms and molecules; Chemical formulas.

2: Measurements in Chemistry
Measurement systems; Metric system; Conversion factors and dimensional analysis.

3: Atomic Structure and the Periodic Table
Internal structure of atom; Isotopes and Atomic masses; Electron arrangements within the atoms; Classification of elements.

4: Chemical Bonding: The Ionic Bond Model
Chemical bonds; Ionic compound formation; Chemical formulas and names for ionic compounds.

5: Chemical Bonding: The Covalent Bond Model
Covalent bond; Lewis structures of molecular compounds; Single, double and triple bonds; Bond and molecular polarity; Naming of molecular compounds.

6: Chemical Calculations: Formula Masses, Moles, and Chemical Equations
Formula masses; The mole and the mass of a mole; The mole and chemical calculations; Chemical calculations using chemical equations.

7: Gases, Liquids and Solids
Characteristics of gases; Gas laws; Changes of state; Characteristics of liquids.

8: Solutions
Characteristics of solutions; Solubility; Solution concentration units; Dilution.

9: Chemical Reactions
Types of chemical reactions; Chemical equilibrium; Equilibrium constants.

10: Acids, Bases, and Salts
pH concept; pK_a method for expressing acid strength; Buffers; Electrolytes; Acid-base neutralization chemical reactions.

11: Nuclear Chemistry
The nature of radiation; Radioactive decay and biochemical effects of radiation; Nuclear medicine.

Part II: Organic chemistry

12: Saturated Hydrocarbons
Alkanes; Nomenclature; Structural formulas; Physical and chemical properties.

13: Unsaturated Hydrocarbons
Characteristics; Nomenclature; Isomers; Chemical reactions; Polymerization; Alkynes; Aromatic hydrocarbons, fused-rings.

14: Alcohols, Phenols, and Ethers
Nomenclature; Bonding characteristic of oxygen atoms in organic compounds; Chemical Reactions; Classification and preparation.

15: Aldehydes and Ketones
The carbonyl group; Structure; Nomenclature; Isomerism; Physical properties; Oxidation and reduction; Reactions of aldehydes and ketones.

16: Carboxylic Acids, Ester, and Other Acid Derivatives
Structure; Nomenclature; "Metabolic" acids; Acidity; Preparation of carboxylic acids; Structure of esters; Preparation of esters; Chemical and physical properties of esters.

17: Amines and Amides
Bonding characteristics of nitrogen atoms in organic chemistry; Structure and classification; Properties; basicity of amines; Selected biochemically important amines; Alkaloids; Amides.

Part III Biological Chemistry

18: Carbohydrates
Biochemistry - an overview, occurrence and function of carbohydrates; Biochemically important monosaccharides; Reactions; Disaccharides; Polysaccharides.

19: Lipids
Structure; Classification; Fatty acids; Energy-storage lipids; Dietary considerations and triacylglycerols; Chemical reactions of triacylglycerols.

20: Proteins
Amino acids; Acid-base properties of amino acids; Primary, secondary, tertiary and quaternary structure of proteins; Fibrous and globular proteins; Protein denaturation; glycoproteins and lipoproteins.

21: Enzymes and Vitamins
General characteristics; Structure; Factors that affect enzyme's activity; Medical uses of enzymes; vitamins: Water-soluble and fat-soluble vitamins.

22: Nucleic Acids
Types of nucleic acids; Genetic code; Mutations.

23: Biochemical Energy Production
Metabolism, Important intermediate compounds in metabolic pathway, High-energy phosphate compounds.

24: Carbohydrate Metabolism

25: Lipid Metabolism

26: Protein Metabolism

APPENDIX E

LIST OF CHEMISTRY TOPICS RELEVANT TO THE NURSING CLINICAL PRACTICE

<table>
<tr><th>Concept</th><th>Topics</th></tr>
<tr><td>Basic topics
about matter</td><td>Periodic table
Atomic structure
Ions
Electrolytes
Isotopes
Nomenclature
Ionic bonds
Compounds
Covalent bonds
Molecules
Polarity
Chemical reactions</td></tr>
<tr><td>Solutions</td><td>Concentrations
Mixtures
Dimensional analysis; Metric system
Osmotic pressure; Osmolarity
Acids/Bases
pH
Buffers
Equilibria (Le Châtelier's principle)
Solubility</td></tr>
<tr><td>Gases</td><td>Brief presentation of the laws, especially Boyle’s Law
Solubility in liquids
Hemoglobin: pH and O_2 perfusion</td></tr>
<tr><td>Nuclear chemistry</td><td>Nuclear medicine/Applications
Safety</td></tr>
<tr><td>Non-polar
compounds/
Molecules</td><td>Alkanes/Alkenes/Aromatics: Skeletal molecules; Brief Nomenclature; Physical/chemical properties/Reactions (oxidation)</td></tr>
<tr><td>Polar compounds/
Molecules</td><td>Alcohols/Aldehydes/Ketones: Physical/chemical properties bonding; Reactions (oxidation/reduction)
Carboxylic acids/Esters: Physical/chemical properties; Reactions (reduction, esterification, hydrolysis); Acid-Base chemistry
Amines/Amides: Physical/chemical properties; Acid-Base chemistry; Reactions (oxidation, reduction)</td></tr>
<tr><td>Biochemistry</td><td>Amino Acids, Proteins: Structure; Properties; Function; Metabolism
Enzymes/Vitamins
Carbohydrates: Structure; Properties; Function; Metabolism
Lipids: Structure; Properties; Function; Metabolism
Nucleic Acids: Structure; Function
Integration of Metabolism
Hormones/Neurotransmitters</td></tr>
</table>

APPENDIX F

SAMPLE OF ONLINE SURVEY FORMAT

Default Question Block

Below you will find a list of topics typically taught in a GOB chemistry course. Please classify the topics in terms of their relevance to the nursing clinical practice using the following scale:

Important – topics that have a direct application in the nursing clinical practice.

Foundational– topics that facilitate the understanding of the important topics, but are not directly important for nursing clinical practice.

Not Important– topics that do not have a direct application or are not significant in nursing clinical practice.

Please make comments or add additional subtopics if you wish.

College of Natural and Health Sciences
Department of Chemistry and Biochemistry

Project Title: Topics of General, Organic, and Biological (GOB) Chemistry Relevant to Clinical Practice

You are invited to participate in a research study being conducted by a group of researchers from Department of Chemistry and Biochemistry at the University of Northern Colorado in consultation with faculty from the School of Nursing at the University of Northern Colorado. The purpose of this research is to explore the relevancy of chemistry topics taught in a GOB chemistry course. By participating in this study, you will be informing chemistry and nurse educators about the knowledge needed by allied health students. This knowledge acquisition is important and may help you to better understand how to assist your students in learning or how to better utilize their knowledge in your course.

Participation in this study will involve classification of topics taught in a GOB chemistry course and their relevancy to clinical practice. This survey will take you approximately 15-20 minutes to complete online. There are no foreseeable risks in participating in this survey and your participation is completely voluntary. We guarantee confidentiality of your responses There are no foreseeable risks in participating in this survey and your participation is completely voluntary. The survey is administered through software that will not track your individual responses, disallowing me from tracing any individual response to you. Finally, no one will have access to the information given on the surveys besides the primary researcher of the project.

Participation is voluntary. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respectedand will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-2161.

If you would like to participate, you may do so by clicking on the link below.

If you have any questions regarding the design or results of this study, or the nature of your participation, you may contact my advisors or me at the appropriate phone number.

Primary Researcher: Corina E. Brown, Chemistry Education doctoral student, Department of Chemistry and Biochemistry at the University of Northern Colorado

Phone number: (970) 351-1291 Email: brow2423@bears.unco.edu

Research Advisor: Dr. Jack Barbera, Assistant Professor, Department of Chemistry and Biochemistry
Phone Number:(970) 351-2545 Email: jack.barbera@unco.edu

Research Advisor: Dr. Richard M. Hyslop, Professor, Department of Chemistry and Biochemistry
Phone Number: (970) 351-1288 Email: richard.hyslop@unco.edu

Matter

	Important	Fundational	Not Important
physical and chemical properties of matter	◯	◯	◯
changes in state of matter	◯	◯	◯
pure substances and mixtures	◯	◯	◯

Please make comments or add additional subtopics if you wish:

Periodic Table/Atomic Structure

	Important	Foundational	Not Important
atoms, molecules, elements, and compounds;	◯	◯	◯
chemical symbols and chemical formulas	◯	◯	◯
nuclear structure	◯	◯	◯
electron arrangements within the atoms	◯	◯	◯
isotopes and atomic masses	◯	◯	◯
ions/electrolytes	◯	◯	◯
physical and chemical properties of matter	◯	◯	◯
changes in matter	◯	◯	◯
pure substances and mixtures	◯	◯	◯
isotopes and atomic masses	◯	◯	◯

Please make comments or add additional subtopics if you wish:

Nuclear Chemistry

	Important	Foundational	Not Important
the nature of radiation	◯	◯	◯
radioactive decay	◯	◯	◯
biochemical effects of radiations	◯	◯	◯
nuclear medicine	◯	◯	◯
nuclear safety	◯	◯	◯

Please make comments or add additional subtopics if you wish:

Bonds: Ionic, Covalent, Hydrogen bonding

	Important	Foundational	Not Important

APPENDIX G

GENERAL, ORGANIC, AND BIOLOGICAL CHEMISTRY CONCEPT INVENTORY, PILOT TEST I

GOB-CTI, Pilot Test I
67 items

(*) indicates the correct answer

1. From the following options, choose the one that contains *only* anions.
   A. NH_4^+, HCO_3^- B. Cl^-, HCO_3^- (*)
   C. Ca^{2+}, NH_4^+ D. Cl^-, Ca^{2+}

2. From the list of elements important for the human body, which ones are cations under physiological conditions? Na, Cl, Ca, K
   A. Na, Cl, K B. Na, K, Ca (*)
   C. Ca, K, Cl D. Cl, Na, Ca

3. Under physiological conditions Mg is a good electrolyte. Which of the following is The right electronic configuration of its ion?
   A. $1s^22s^22p^63s^2$ B. $1s^22s^22p^6$ (*)
   C. $1s^22s^22p^43s^2$ D. $1s^22s^22p^63s^23p^2$

4. From the following options, choose the one that contains *only* molecules
   A. H_2, CO, O_2 (*) B. Fe, Ca, K
   C. H_2, O_2, Ca, Fe D. $C_6H_{12}O_6$, CH_4, Ca

5. Iron-59 is used in studies of iron metabolism in the spleen. What is the nuclear composition of this isotope?
   A. 26 protons, 59 neutrons B. 26 protons, 85 neutrons
   C. 59 protons, 26 neutrons D. 26 protons, 33 neutrons (*)

6. From the following pairs, choose the one that correctly matches the name of the compound with the chemical formula
   A. sodium bicarbonate ($NaHCO_3$), sodium carbonate (Na_2CO_3) (*)
   B. sodium phosphate ($NaHCO_3$), disodium bicarbonate (Na_2HPO_4)
   C. phosphoric acid (H_3PO_4), magnesium chloride (MgCl)
   D. ammonium chloride (NH_4Cl), ammonia chloride (NH_3Cl)

7. From the following options, choose the one that contains *only* mixtures:
   A. urine, glucose, air B. glucose, blood, sodium chloride
   C. air, blood, urine (*) D. carbon dioxide, sodium chloride, glucose

8. From the following options, choose the one that contains *only* ionic compounds
   A. NaCl, CaO, $CaCO_3$ (*) B. CO_2, NaCl, CaO
   C. CO_2, CaO, $C_6H_{12}O_6$ D. CO, $C_6H_{12}O_6$, NH_3

9. Hepatic metabolism of drugs often makes them more polar and thus more water soluble. The resulting metabolites are then more readily excreted in the urine. Which of the following are polar compounds: CH_3OH, CO_2, CO, CH_4

A. CO_2, CO, CH_3OH B. CO_2, CH_4
C. CO_2, CH_3OH, CH_4 D. CH_3OH, CO (*)

10. When red blood cells are placed in a hypotonic solution, water will be transported _____ the cell because the solute concentration is ______ in the cell

A. into; higher (*) B. into; lower
C. out of; lower D. out of; higher

11. An I.V. solution is running at 135 mL per hour. If the I.V. bag contains 1000 mL, how long will it last?

A. 1.2 h B. 7.4 h (*) C. 8.1 h D. 12.5 h

12. A patient's HDL has a value of 15 mg/dL and he is told the value is low. The normal is 40-135 mg/dL. The nurse explains that HDL is the "good" cholesterol and it should be higher because HDL transports cholesterol:

A. for storage in muscles for energy
B. to the tissues to be used for the synthesis of membranes
C. from the tissues to the liver for elimination (*)
D. by binding to fiber to be excreted from the body

13. How would one prepare a 1L solution of 0.9% (m/v) NaCl from a solution of 20%(m/v) solution of NaCl?

A. Add 45 mL of the 20% solution and dilute to make 1L (*)
B. Add 45 mL of the 20% solution and dilute to 1L of H_2O
C. Add 4.5 mL of the 20% solution and dilute to 1000 mL of H_2O
D. Add 4.5 mL of the 20% solution and dilute to make 1000 mL

14. In which set are the following compounds arranged in order of *increasing* (low to high) water solubility: CH_3CH_2CHO (propanal), CH_3CH_2COOH (propanoic acid), $CH_3CH_2CH_3$ (propane), CH_3OH (propanol)

A. propanoic acid < propanal < propane < propanol
B. propane < propanal < propanol < propanoic acid (*)
C. propane < propanol = propanal < propanoic acid
D. propanoic acid < propanol < propanal < propane

15. Which of the following is *true* about an enzyme?

A. It lowers the activation energy of a biological reaction.
B. It raises the activation energy of a biological reaction.(*)
C. It will shift the reaction equilibrium to the right.
D. It will shift the reaction equilibrium to the left.

16. When divers return too quickly to the surface, a painful condition known as *the bends* caused by $N_{2(g)}$ in the blood, can cause paralysis or death. What is the cause of this condition?
    A. The dissolved $N_2(g)$ changes the pH of the blood.
    B. The dissolved $N_2(g)$ inhibits the binding of oxygen to hemoglobin
    C. The dissolved $N_2(g)$ is less soluble in the blood at lower pressures causing bubbles of gas to form.(*)
    D. The dissolved $N_2(g)$ is more soluble in the blood at lower pressures and prevents oxygen from dissolving in blood

17. As a result of uncontrolled diabetes, a serious decrease in blood pH can occur. The normal blood pH, which is 7.4, may decrease to as low as 6.8. Explain how the blood bicarbonate system (H_2CO_3/HCO_3^-) attempts to compensate for the change in pH.
    A. H_2CO_3 is a base that can react with the excess H^+.
    B. HCO_3^- is an acid that can react with the excess OH^-.
    C. H_2CO_3 is an acid that can react with the excess OH^-.
    D. HCO_3^- is a base that can react with the excess H^+.(*)

18. As a result of diarrhea, large quantities of bicarbonate ion (HCO_3^-) are eliminateD. Consider the following equation (the bicarbonate buffer system):
    $$H_2O(l) + CO_2(g) \leftrightarrow H_2CO_3(aq) \leftrightarrow H^+(aq) + HCO_3^-(aq)$$
    In which direction does the bicarbonate buffer system shift under this circumstance and for what reason?
    A. to the left so the amount of CO_2 will increase
    B. to the right so the amount of H^+ will increase
    C. to the right so the amount of HCO_3^- will increase (*)
    D. to the left so the amount of H_2O will increase

19. A thyroid cancer patient is treated with radioactive iodine-131 which has a half-life of 8.08 days. If the patient is given 2.00 grams of iodine-131, how many days will it take for the amount of iodine-131 to reach 0.25 grams?
    A. 12.1 days B. 16.2 days C. 32.3 days D. 24.2 days (*)

20. The metabolism occurring when there is an intake of glucose and inadequate ATP in the cell is:
    A. glycolysis (*) B. gluconeogenesis C. glycogenesis D. glycogenolysis

21. The pathway which ultimately leads to the storage of excess carbon as triglycerides is:
    A. glycogenesis B. fatty acid synthesis (*)
    C. β-oxidation D. the Krebs' cycle

22. Which of the following molecules are able to form hydrogen bonds with molecules identical to themselves?

CH_3-CH_2-COOH
I. propionic acid

$H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$
II. Acetone

CH_3-CH_2-Cl
III. ethyl chloride

$CH_3-CH_2-NH_2$
IV. ethylamine

A. I and IV only (*)
B. I, II, IV only
C. II and III only
D. II, III, IV only

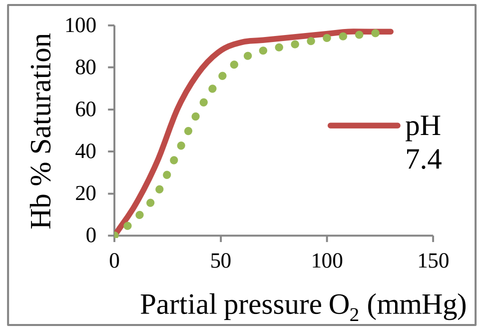
23. Explain why ethane has a very low solubility in water, whereas ethanol is very soluble in water.
A. Ethanol is nonpolar and can form hydrogen bonds; ethane is nonpolar.
B. Ethanol is nonpolar and can form hydrogen bonds; ethane is polar and is hydrophobic.
C. Ethanol is polar and is hydrophobic; ethane is nonpolar and can form hydrogen bonds.
D. Ethanol is polar and can form hydrogen bonds; ethane is nonpolar and is hydrophobic. (*)

24. A low carbohydrate intake, such as starvation or uncontrolled diabetes, results in the formation of which product:
A. a triglyceride B. a ketone body (*) C. glycogen D. glucose

25. What is the function of the urea cycle?
A. To remove ammonium ion from the body.(*)
B. Amino acid transamination.
C. Detoxification of lactic acid.
D. Elimination of carbamoyl phosphate.

26. In respiration during diaphragm contraction (moving downward) what is the relationship between air pressure in the lungs and the volume of the thoracic cavity (chest cavity)?
A. pressure decreases, volume decreases
B. pressure decreases, volume increases (*)
C. pressure increases, volume increases
D. pressure and volume are independent variables

27. If the blood pH increases from 7.4 to 7.8, then the
A. hydronium ion concentration increases
B. blood will become more basic (*)
C. hydroxide ion concentration decreases
D. blood becomes more acidic



28. In a metabolic acidosis, the pH of blood decreases. Based on the Bohr effect, how is the binding of O_2 to hemoglobin (Hb) affected?
    A. when the pH decreases, the binding of
    B. when the pH increased, the binding of oxygen decreases
    C. when the pH increases, the oxygen binding increases
    D. the pH does not have an effect on oxygen binding

29. The main difference between cholesterol and triglycerides is that
    A. cholesterol is a component of cell membranes; triglycerides are a storage form of fatty acids. (*)
    B. cholesterol is an ester of fatty acids and glycerol; triglycerides are waxy four ring compound.
    C. cholesterol is synthesized by the muscle; triglycerides are synthesized by the liver.
    D. cholesterol is insoluble in water; triglycerides are soluble in water.

30. The main purpose of the mitochondrial electron transport system is to:
    A. consume acetyl CoA and ATP
    B. produce ATP (*)
    C. consume CO_2 and produce ATP
    D. produce O_2 and ATP

31. Which statement is *true* about hemoglobin and myoglobin?
    A. Hemoglobin and myoglobin possess quaternary structure.
    B. A graph of % saturation vs [O_2] is sigmoidal for hemoglobin and hyperbolic for myglobin. (*)
    C. Hemoglobin stores oxygen; myoglobin transports oxygen.
    D. Hemoglobin and myoglobin demonstrate allosteric effects.

32. Which of the following twelve-carbon compounds has the potential for generating the most ATP?
    A. maltose (a disaccharide of glucose)
    B. lauric acid (a saturated fatty acid) (*)
    C. lysyl lysine (a dipeptide of the amino acid lysine)
    D. sucrose (a disaccharide of glucose and fructose)

33. Lauren (three years old) has *osteogenesis imperfect* which makes her bones very fragile. The doctor says it is a mutation in the gene for collagen. Which of the following is *not true* of a possible genetic mutation?
    A. It is a simple change in one base of the gene sequence.
    B. One or more bases are inserted or deleted in the gene.
    C. A simple change in one base will affect more than one gene. (*)
    D. It is a permanent change in the DNA sequence of a gene.

34. NAD^+ is
    A. an enzyme of the electron transport chain.
    B. an important coenzyme in the cell.(*)
    C. the oxidized form of coenzyme Q.
    D. a prosthetic group of complex I.

35. Which statement is *true* about DNA/RNA
    A. DNA contains the base uracil: RNA contains the base thymine.
    B. DNA and RNA contain a carbohydrate, a nitrogenous base, and a phosphate. (*)
    C. DNA is copied during transcription; RNA is produced during replication.
    D. DNA and RNA both have complementary double helical structures.

36. A gene contains the information for assembling which of the following structures:
    A. a polysaccharide B. a steroid C. a protein (*) D. a lipid

37. Which of the following types of radiation are used in therapy?
    A. X-ray, alpha and beta B. gamma (*)
    C. alpha D. X-ray, beta, and gamma

38. What are the functional groups in the following amino acid:
    A. aldehyde, alcohol, amine B. carboxylic acid, amine (*)
    C. alcohol, amine, ketone D. amide, ester

39. Which of the following *is not* a correct reason for limiting the exposure of a patient to radiation?
    A. radiation can cause free radical formation in living cells
    B. X-ray radiation can damage the DNA of the cell
    C. exposure to radiation can increase the risk of cancer
    D. radiation can affect the immune system, regardless of dose (*)

40. The radioisotopes used in nuclear medicine for diagnosis
    A. are alpha emitters B. have short half lives (*)
    C. usually cause nausea D. cannot be detected unless used in very high doses

41. The Krebs' cycle does which of the following:
    A. converts carbohydrates, fats, and proteins into carbon dioxide
    B. reduces acetyl-CoA to produce carbon dioxide
    C. oxidizes acetyl-CoA to produce NADH and $FADH_2$ (*)
    D. produces ATP needed for anabolism

42. Epinephrine and glucagon are two hormones involved in the release of glucose from glycogen. Which of the following statements is true regarding these hormones?
    A. the two have the same effect as insulin and use the same receptor.
    B. the two have the same effect and use the same receptor.
    C. the two have the same effect but use different receptors. (*)
    D. the two have the same effect as insulin but use different receptors.

43. A nutritional deficiency in B-vitamins affects metabolism due to the following reason?
    A. They form coenzymes important for many enzyme-catalyzed reactions. (*)
    B. They serve as enzymes in important reactions necessary for metabolism.
    C. They are involved in the absorption of minerals.
    D. They form hormones necessary for metabolism.

44. Glucose is metabolized to several different products, two of which are lactate and acetyl-CoA. Under what physiological conditions would each of these be products of glycolysis?
    A. Lactate is produced anaerobically; acetyl-CoA is produced aerobically. (*)
    B. Lactate is produced aerobically; acetyl-CoA is produced anaerobically.
    C. Both are produced aerobically.
    D. Both are produced anaerobically

45. In which of the following pathways is lactate recycled and converted into glucose in the liver and the glucose is returned to tissue to form lactate?
    A. Krebs'cycle B. Lactate cycle C. Urea cycle(*) D. Cori cycle

46. Which of the following compounds will form ions when dissolved in water: NaCl, glucose¸ a triglyceride
    A. only NaCl because it is an ionic compound (*)
    B. only glucose since it is a polar compound
    C. only a triglyceride since it is a nonpolar compound
    D. all will form ions

47. Which statement is true regarding hormones and neurotransmitters
    A. both require receptors to have activity (*)
    B. hormones act as enzymes, neurotransmitters do not
    C. neurotransmitters act as enzymes, hormones do not
    D. neurotransmitters require receptors to have activity, hormones do not

48. Vegetable oils and animal fats are triglycerides which result from the combination of glycerol and fatty acids. The functional groups of triglycerides are referred to as:
    A. alcohols B. carboxylic acids C. esters (*) D. aldehydes

49. The equilibrium reaction for the transport of oxygen by hemoglobin (Hb) can be represented as:

$$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq)$$

    When Hb is in the lungs, where oxygen has a high concentration, how will the reaction be affected?
    A. The reaction shifts to the right. (*)
    B. The reaction shifts to the left.
    C. The reaction will not be affected.
    D. More than four O_2 molecules will bind to hemoglobin.

50. Drinking methanol (CH_3OH) is harmful because the human body converts it to formaldehyde (also called methanal) by the following reaction:

$$CH_3OH + NAD^+ \rightarrow X + NADH + H$$

Which of the following would be the correct answer for product X:

A. CH_2O (*) B. HCOOH C. CH_4 D. CO_2

51. In the liver, the enzyme alcohol dehydrogenase catalyzes the conversion of ethanol to acetaldehyde. The enzyme acetaldehyde dehydrogenase then catalyzes the conversion of acetaldehyde to the harmless acetic acid:

Ethanol → Acetaldehyde → Acetic acid

Which of the following represent the structures of the compound in each step of the reaction ?

A. $CH_3CH_2OH \rightarrow CH_3CHO \rightarrow CH_3COOH$ (*)
B. $CH_3COOH \rightarrow CH_3CHO \rightarrow CH_3CH_2OH$
C. $CH_3COOH \rightarrow CH_3CH_2OH \rightarrow CH_3CHO$
D. $CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO \rightarrow CH_3CH_2COOH$

52. Why would isopropyl alcohol or ethanol be used on the skin before an injection is given?

A. Alcohols denature proteins of pathogens. (*)
B. Alcohols denature proteins of the skin.
C. Alcohols will remove dirt from the skin.
D. Alcohols will open the pores of the skin.

53A. Regarding protein structure, which of the following would explain why a high fever (108 ˚F) can be life threatening?

A. Many proteins denature at this temperature (*)
B. Metabolism will proceed too rapidly
C. Too much water will evaporate
D. The rate of breathing increases

53B. Regarding protein structure, which of the following would explain why a high fever (108 ˚F) can be life threatening?

A. Many proteins denature at this temperature (*)
B. Metabolism will proceed too rapidly
C. This temperature is above the boiling point of water
D. The pressure in the lungs increases

54. Digestion of triglycerides, catalyzed by lipases, produces monoglycerides and fatty acids through a process called:

A. dehydration B. hydrogenation
C. oxidation D. hydrolysis (*)

55. Cyanide binds to a cytochrome involved in the mitochondrial electron transport system. How does this explain the death of a person due to cyanide poisoning?
    A. The cyanide is reduced to a toxic product.
    B. The electrons cannot flow through the system. (*)
    C. The cyanide is oxidized to a toxic product.
    D. Oxygen cannot be transported by hemoglobin.

56. One of the antidotes used in the traditional treatment of ethylene glycol poisoning is ethanol. Which statement best explains the use of ethanol?
    A. Ethanol will prevent the reduction of ethylene glycol since they compete for the same enzyme.
    B. Ethanol will prevent the oxidation of ethylene glycol since they compete for the same enzyme. (*)
    C. Ethanol neutralizes the basicity of the ethylene glycol metabolites.
    D. Ethanol will compete with ethylene glycol for binding to calcium ions.

57. The phosphate buffer system operates in the internal fluid of all cells. Which of the following is the conjugate acid of the HPO_4^{2-} ion?
    A. H_3PO_4 B. $H_2PO_4^-$ (*) C. PO_4^{3-} D. $H_4PO_4^+$

58. A patient was instructed to take vitamin B_3 and vitamin C daily. The explanation for taking these vitamins on a daily basis would be that vitamin B_3 and vitamin C are
    A. unstable and easily destroyed by light B. soluble in fat
    B. soluble in water (*) D. stored in adipose tissue

59. All buffer solutions
    A. maintain a neutral pH (7.0) in the solution.
    B. maintain a physiological pH (7.4) in the solution.
    C. maintain a relatively constant pH in the solution. (*)
    D. cause dramatic pH changes in the solution.

60. When there is insufficient glucose, the metabolism of fatty acids will produce ketone bodies that provide:
    A. blood with a neutral pH B. support for the digestive system
    C. of source of energy for brain (*) D. pyruvate for the Krebs' cycle

61. The trace element that serves as a cofactor for the action of insulin is Cr^{3+}. This ion is formed from the element Cr by:
    A. losing 3 electrons (*) B. accepting 3 electrons
    C. accepting 3 protons D. losing 3 neutrons

62. How will ATP production be affected by a high protein/high fat (triglyceride)/low carbohydrate diet?
    A. Metabolism cannot exist without dietary carbohydrate (glucose).
    B. The ATP production will decrease.
    C. The ATP production will remain the same. (*)
    D. Fatty acids (from triglycerides) and proteins will be converted into glucose for ATP production.

63. In which of the following stages of glucose metabolism is the most ATP produced?
    A. glycolysis
    B. Krebs' cycle
    C. oxidative phosphorylation (*)
    D. gluconeogenesis

64. During recovery from intense muscular exertion, lactate in the liver is converted to glucose through the process of:
    A. gluconeogenesis (*)
    B. glycolysis
    C. glycogenolysis
    D. glycogenesis

65. The main role of oxygen in cellular respiration is to:
    A. combine with CO to form CO_2.
    B. combine with NADH and $FADH_2$ to form ATP.
    C. catalyze the reactions of the Krebs'cycle.
    D. accept electrons and form water. (*)

66. A person with a blood alcohol concentration of 0.03% is considered over the legal limit. If the blood plasma volume is 3 L, how many mL of alcohol does this concentration represent?
    A. 0.09 mL
    B. 0.9 mL (*)
    C. 9 mL
    D. 90 mL

67. A nurse in the pediatric unit has an order to give a patient 0.3 mg of atropine I.V. The vial contains 200 µg/mL of atropine. How many mL should be given to the patient? (1 mg = 1000 µg)
    A. 1.5 mL (*)
    B. 15 mL
    C. 60 mL
    D. 6 mL

APPENDIX H

GENERAL, ORGANIC, AND BIOLOGICAL CHEMISTRY CONCEPT INVENTORY: BETA TEST AND FINALVERSON

General, Organic, and Biological Concept Inventory (GOB-CTI)

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Note: Items **2** and **31** removed to form the 45-item final version

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1. Under physiological conditions, Mg^{2+} is a good electrolyte. Which of the following is the correct electronic configuration of this ion?
   A. $1s^22s^22p^63s^2$ B. $1s^22s^22p^6$ C. $1s^22s^22p^43s^2$ D. $1s^22s^22p^63s^23p^2$

2. **From the following options, choose the one that contains *only* molecules.**
   A. H_2, O_2, Mg B. Fe, Ca, K C. H_2, CO, $C_6H_{12}O_6$ D. O_2, CH_4, Na

3. Iron-59 is used in studies of iron metabolism in the spleen. What is the nuclear composition of this isotope?
   A. 26 protons, 59 neutrons B. 33 protons, 26 neutrons
   C. 59 protons, 26 neutrons D. 26 protons, 33 neutrons

4. From the following, choose the one that matches the correct name of the compound with the correct chemical formula
   A. sodium phosphate (Na_3PO_4) B. disodium bicarbonate (Na_2HCO_3)
   C. magnesium chloride (MgCl) D. ammonia chloride (NH_3Cl)

5. From the following options, choose the one that contains *only* mixtures:
   A. urine, carbon dioxide, air B. glucose, blood, sodium chloride
   C. air, blood, urine D. carbon dioxide, sodium chloride, glucose

6. From the following options, choose the one that contains *only* ionic compounds.
   A. NaCl, CaO, $CaCO_3$ B. CO_2, NaCl, CaO
   C. CO_2, CaO, NaCl D. CO, NaCl, NH_3

7. Hepatic metabolism of drugs often makes them more polar and thus more water soluble. The resulting metabolites are then more readily excreted in the urine. From the following options, choose the one that contains *only* polar compounds.
   A. CO_2, CO, HCl B. CO_2, O_2, N_2 C. CO_2, N_2, NH_3 D. CO, HCl, NH_3

8. When red blood cells are placed in a hypotonic solution, water will be transported _____ the cell because the solute concentration is ______ in the cell
   A. into; higher B. into; lower C. out of; lower D. out of; higher

9. An I.V. solution is at a drip rate of 135 mL per hour. If the I.V. bag contains 1000.0 mL, how long will it last?
A. 1.35 h B. 7.41 h C. 8.10 h D. 12.5 h

10. The metabolic pathway occurring when there is an intake of glucose and inadequate ATP in the cell is:
A. glycogenolysis B. gluconeogenesis C. glycogenesis D. glycolysis

11. The pathway which ultimately leads to the storage of excess carbon as triglycerides is:
A. glycogenesis B. lipogenesis C. β-oxidation

12. A patient's HDL has a value of 15 mg/dL and he is told the value is low. The normal value is 40-135 mg/dL. The nurse explains that HDL is the "good" cholesterol and it should be higher because HDL transports cholesterol
A. for storage in muscle for energy.
B. to the tissues to be used for the synthesis of membranes.
C. from the tissues to the liver for elimination.
D. for binding to fiber to be excreted from the body.

13. A thyroid cancer patient is treated with radioactive iodine-131 which has a half-life of 8.08 days. If the patient is given 2.00 grams of iodine-131, how many days will it take for the amount of iodine-131 to reach 0.250 grams?
A. 12.1 days B. 16.2 days C. 32.3 days D. 24.2 days

14. How would one prepare a 1L solution of 0.9% (m/v) NaCl from a solution of 20% (m/v) solution of NaCl?
A. Add 45 mL of the 20% solution and dilute to make 1L
B. Add 45 mL of the 20% solution to 1L of H_2O
C. Add 4.5 mL of the 20% solution to 1000 mL of H_2O
D. Add 4.5 mL of the 20% solution and dilute to make 1000 mL

15. In which set are the following compounds arranged in order of *increasing* (low to high) water solubility: CH_3CH_2CHO (propanal), CH_3CH_2COOH (propionic acid), $CH_3CH_2CH_3$ (propane), CH_3OH (propanol)
A. propionic acid < propanal < propane < propanol
B. propane < propanal < propanol < propionic acid
C. propane < propanol = propanal < propionic acid
D. propionic acid < propanol < propanal < propane

16. When divers return too quickly to the surface, a painful condition known as *the bends* caused by $N_2(g)$ dissolved into the blood and tissues, can cause paralysis or death. What is the explanation of this condition?
   A. The dissolved $N_2(g)$ inhibits the binding of oxygen to hemoglobin.
   B. The dissolved $N_2(g)$ is less soluble in the blood and tissues at lower pressures causing bubbles of gas to form.
   C. The dissolved $N_2(g)$ is more soluble into the blood and tissues at lower pressures and prevents oxygen from dissolving in blood.

17. As a result of uncontrolled diabetes, a serious decrease in blood pH can occur. The normal blood pH, which is 7.4, may decrease to as low as 6.8. Explain how the blood bicarbonate system (H_2CO_3/HCO_3^-) attempts to compensate for this change in pH.
   A. H_2CO_3 is a base that can react with the excess H^+.
   B. HCO_3^- is an acid that can react with the excess OH^-.
   C. H_2CO_3 is an acid that can react with the excess OH^-.
   D. HCO_3^- is a base that can react with the excess H^+.

18. As a result of diarrhea, large quantities of bicarbonate ion (HCO_3^-) are eliminated. Consider the following equation (the bicarbonate buffer system):
$$H_2O(l) + CO_2(aq) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$
   In which direction does the bicarbonate buffer system shift under this circumstance and for what reason?
   A. to the left so the amount of CO_2 will increase.
   B. to the right so the amount of H^+ will increase.
   C. to the right so the amount of HCO_3^- will increase.
   D. to the left so the amount of H_2O will increase.

19. Which of the following molecules are able to form intermolecular hydrogen bonds with molecules identical to themselves?

   CH_3-CH_2-COOH
   I. propionic acid

   $H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$
   II. Acetone

   CH_3-CH_2-Cl
   III. ethyl chloride

   $CH_3-CH_2-NH_2$
   IV. ethylamine

   A.I and IV only B.I, II, IV only C.II and III only D.II, III, IV only

20. A low carbohydrate intake, such as with starvation or uncontrolled diabetes, results in the formation of which product:
   A. glycogen B. a ketone body C. glucose D. urea

21. What is the function of the urea cycle?
   A. To detoxify urea.
   B. To transaminate amino acids.
   C. To detoxify lactic acid.
   D. To convert ammonium ion to urea.

22. During diaphragm contraction (moving downward), what is the relationship between air pressure in the lungs and the volume of the thoracic cavity (chest cavity)?
    A. pressure decreases, volume decreases B. pressure decreases, volume increases
    C. pressure increases, volume increases D. pressure increases, volume decreases

23. If blood pH increases from 7.4 to 7.8, then the
    A. hydronium ion concentration increases.
    B. hydronium ion concentration decreases.
    C. hydroxide ion concentration decreases.
    D. hydroxide ion concentration is not affected.

24. NAD^+ is
    A. an enzyme of the electron transport chain. B. an important coenzyme in the cell.
    C. the oxidized form of coenzyme Q. D. the reduced form of niacin.

25. A person with a blood alcohol concentration of 0.03 % (v/v) is considered over the legal limit. If the blood plasma volume is 3.0 L, how many mL of alcohol does this concentration represent?
    A. 0.09 mL B. 0.9 mL C. 9.0 mL D. 90 mL

26. Which of the following twelve-carbon compounds has the potential for generating the most ATP?
    A. maltose (a disaccharide of glucose)
    B. lauric acid (a saturated fatty acid)
    C. lysyl lysine (a dipeptide of the amino acid lysine)
    D. sucrose (a disaccharide of glucose and fructose)

27. Epinephrine and glucagon are two hormones involved in the release of glucose from glycogen. Which of the following statements is true regarding these hormones?
    A. The two have the same effect and use the same receptor.
    B. The two have the same effect but use different receptors.
    C. The two have the same effect as insulin but use different receptors.

28. Lauren (three years old) has *osteogenesis imperfecta* which makes her bones very fragile. It is due to a mutation in the gene for collagen. Which of the following is *not true* for a genetic mutation?
    A. It is a change in one base of a gene.
    B. One or more bases are inserted or deleted in a gene.
    C. A simple change in one base will affect more than one gene.
    D. It is a permanent change in the DNA sequence of a gene.

29. Which of the following compounds will form ions when dissolved in water: potassium chloride, glucose, a triglyceride?
    A. only glucose B. only potassium chloride
    C. only a triglyceride D. all will form ions

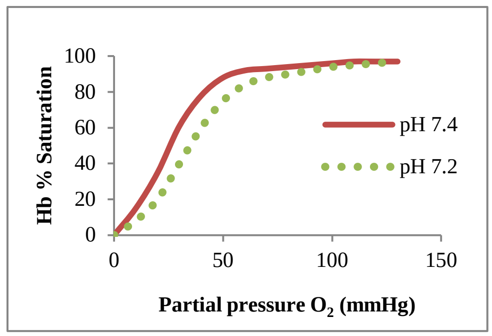
30. Digestion of triglycerides, catalyzed by lipases, produces monoglycerides and fatty acids through a process called:
A. dehydration B. hydrogenation C. oxidation D. hydrolysis

31. Under aerobic conditions, in which of the following stages of glucose metabolism is the most ATP produced?
A. glycolysis B. oxidative phosphorylation C. Krebs' cycle

32. What are the functional groups in the following molecule:

$$H_2N-CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-OH$$

A. aldehyde, alcohol, amine B. carboxylic acid, amine
C. alcohol, amide, ketone D. ketone, alcohol, amine



33. In metabolic acidosis, the pH of blood decreases. Based on the Bohr effect, how is the binding of O_2 to hemoglobin (Hb) affected?
A. when the pH increases, the O_2 binding decreases.
B. when the pH decreases, the O_2 binding increases.
C. when the pH decreases, the O_2 binding decreases.
D. the increase in H^+ reacts with O_2 to form water.

34. Which of the following *is not* a correct reason for limiting the exposure of a patient to radiation?
A. radiation can cause free radical formation, regardless of dose
B. X-ray radiation can damage the DNA of the cell
C. exposure to radiation can increase the risk of cancer
D. can affect the immune system, regardless of dose

35. B-vitamins affect metabolism due to which of the following reasons?
A. They form coenzymes important for many enzyme-catalyzed reactions.
B. They serve as enzymes in important reactions necessary for metabolism.
C. They are involved in the absorption of minerals.
D. They form hormones necessary for metabolism.

36. Glucose is metabolized to several different products, two of which are lactate and acetyl-CoA. Under what physiological conditions would each of these be products of glucose?
A. Lactate is produced aerobically; acetyl CoA is produced anaerobically.
B. Lactate is produced anaerobically; acetyl CoA is produced aerobically.
C. Both are produced aerobically.
D. Both are produced anaerobically.

37. In which of the following pathways is lactate recycled and converted into glucose in the liver and the glucose is returned to tissue to form lactate?
A. Krebs'cycle B. Alanine cycle
C. Urea cycle D. Cori cycle

38. During recovery from intense muscular exertion, lactate in the liver is converted to glucose through the process of:
A. gluconeogenesis B. glycolysis C. glycogenolysis

39. The main role of oxygen in cellular respiration is to:
A. combine with CO to form CO_2. B. combine with NADH to form ATP.
C. combine with glucose to form water. D. accept electrons to produce water.

40. During certain disorders, the metabolism of fatty acids will produce ketone bodies which can:
A. result in a neutral pH in the blood B. provide support for the digestive system
C. be a source of energy for the brain D. produce pyruvate for the Krebs' cycle

41. The equilibrium reaction for the binding of oxygen by hemoglobin (HbH^+) can be represented as:

$$Hb(nH^+)(aq) + 4\ O_2(aq) \rightleftharpoons Hb(O_2)_4(aq) + nH^+(aq)$$

When $Hb(nH^+)$ is in the lungs, where oxygen has a high concentration, how will the reaction be affected?
A. The reaction shifts to the right.
B. The reaction shifts to the left.
C. The reaction will not be affected.
D. The increase of H^+ reacts with O_2 to form water.

42. The trace element that serves as a cofactor for the action of insulin is Cr^{3+}. This ion is formed by the element Cr:
A. accepting 3 proton B. losing 3 electrons
C. accepting 3 electrons D. losing 3 protons

43. The liver enzyme alcohol dehydrogenase catalyzes the conversion of ethanol to acetaldehyde.
The enzyme acetaldehyde dehydrogenase then catalyzes the conversion of acetaldehyde to the relatively harmless acetic acid:

Ethanol $\rightarrow$ Acetaldehyde $\rightarrow$ Acetic acid

Which of the following represents structures of the compounds in each step of the reaction?
A. $CH_3COOH \rightarrow CH_3CHO \rightarrow CH_3CH_2OH$
B. $CH_3CH_2OH \rightarrow CH_3CHO \rightarrow CH_3COOH$
C. $CH_3COOH \rightarrow CH_3CH_2OH \rightarrow CH_3CHO$
D. $CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO \rightarrow CH_3CH_2COOH$

44. One of the antidotes used in the traditional treatment of ethylene glycol poisoning is ethanol. Which statement best explains the use of ethanol?
A. Ethanol will prevent the reduction of ethylene glycol since they compete for the same enzyme.
B. Ethanol will prevent the oxidation of ethylene glycol since they compete for the same enzyme.
C. Ethanol neutralizes the basicity of the ethylene glycol metabolites.
D. Ethanol will compete with ethylene glycol for binding to calcium ions.

45. How will ATP production be affected by a high protein/high fat (triglyceride)/low carbohydrate diet?
A. Proteins will be converted to fatty acids for ATP production
B. The ATP production will decrease.
C. The ATP production will remain the same.
D. Fatty acids (from triglycerides) will be converted into glucose for ATP production.

46. Cyanide inhibits a cytochrome involved in the reduction of oxygen in the mitochondrial electron transport system. How does this explain the death of a person due to cyanide poisoning?
A. The cyanide is reduced to a toxic product.
B. The electrons cannot flow through the system.
C. The cyanide is oxidized to a toxic product.
D. Oxygen cannot be transported by hemoglobin.

47. The following conversion is an example of what type of reaction:

$$H_3C-\underset{}{\overset{\overset{\displaystyle OH}{|}}{C}H}-CH_3 \longrightarrow H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$$

A. Hydrolysis B. Hydration C. Oxidation D. Reduction

Answers to the GOB-CTI:Items **2** and **31** removed to form the 45-item final version

1. B	11. B	21. D	**31. B**	41. A
2. C	12. C	22. B	32. B	42. B
3. D	13. D	23. B	33. C	43. B
4. A	14. A	24. B	34. D	44. B
5. C	15. B	25. B	35. A	45. C
6. A	16. B	26 .B	36. B	46. B
7. D	17. D	27. B	37. D	47. C
8. A	18. C	28. C	38. A	
9. B	19. A	29. B	39. D	
10.D	20. B	30. D	40. C	

APPENDIX I

ITEM ANALYSIS

Item Analysis, 47 items

Item #	Item Difficulty (p)	Item Discrimination (D)	Cronbach's Alpha if Item Deleted
Item 1	0.3	0.35	0.792
Item 2	0.53	0.40	0.792
Item 3	0.55	0.45	0.791
Item 4	0.44	0.34	0.795
Item 5	0.61	0.63	0.777
Item 6	0.45	0.35	0.794
Item 7	0.51	0.43	0.785
Item 8	0.35	0.29	0.789
Item 9	0.79	0.43	0.785
Item10	0.46	0.38	0.789
Item 11	0.74	0.33	0.786
Item 12	0.51	0.43	0.785
Item 13	0.54	0.33	0.787
Item 14	0.36	0.33	0.790
Item 15	0.50	0.15	0.795
Item 16	0.44	0.29	0.796
Item 17	0.59	0.53	0.787
Item 18	0.54	0.31	0.790
Item 19	0.38	0.25	0.798
Item 20	0.69	0.53	0.788
Item 21	0.58	0.45	0.790
Item 22	0.39	0.29	0.786
Item 23	0.56	0.63	0.786
Item 24	0.33	0.29	0.794
Item 25	0.29	0.28	0.795
Item 26	0.29	0.23	0.793
Item 27	0.58	0.31	0.792
Item 28	0.41	0.33	0.793
Item 29	0.66	0.63	0.781
Item 30	0.41	0.29	0.794
Item 31	0.21	0.28	0.795
Item 32	0.55	0.50	0.787

Item Analysis, 47 items (cont'd)

Item 33	0.59	0.38	0.788
Item 34	0.34	0.38	0.789
Item 35	0.55	0.45	0.788
Item 36	0.56	0.63	0.789
Item 37	0.55	0.55	0.782
Item 38	0.65	0.41	0.785
Item 39	0.36	0.58	0.780
Item 40	0.54	0.48	0.792
Item 41	0.36	0.58	0.781
Item 42	0.68	0.45	0.788
Item 43	0.61	0.40	0.784
Item 44	0.42	0.29	0.792
Item 45	0.08	0.05	0.792
Item 46	0.41	0.45	0.785
Item 47	0.44	0.29	0.794

APPENDIX J

CONTENT DOMAIN FOR THE GENERAL, ORGANIC, AND BIOLOGICAL CHEMISTRY TOPIC INVENTORY

Content Domain for the GOB-CTI, 47 items

Topic	Concept	Subconcept	Items GOB-CTI
Basic Topics of Matter	Atomic structure/ Periodic Table	Ions; Isotopes	1, 3, 42
	Bonds	Ionic bond, covalent bond, H-bonding, ionic compounds, molecules, basic nomenclature	4, 6, 7, 2, 19
Homogeneous and Heterogeneous Solutions	Concentration	Dimensional Analysis, Metric System	9, 14, 25
	Osmosis	Osmotic pressure, Osmolarity	8
	Acid/Base	pH, Buffers, Equilibrium	17,23, 18, 41
	Solubility/ Electrolytes	Characteristics of solute	15, 29
	Mixtures	Biological Fluids	5
Gases	Gas laws	Boyle's law, Solubility of gases in liquids	22, 16
Nuclear chemistry	Nuclear Medicine	Applications, Safety	13, 34
Organic Compounds	Non-Polar	Alkanes/Alkenes/ Aromatics: Skeletal molecules/Brief nomenclature/Physical/ chemical properties/ Reactions (oxidation)	15
	Polar	Alcohols/Aldehydes/ Ketones: Physical/ chemical properties/ Reactions (oxidation-reduction) Carboxylic acids/Esters Physical/chemical properties, Reactions: reduction/esterification, hydrolysis, Acid-Base chemistry Amines/Amides: Physical/chemical properties Acid-Base chemistry Reactions (oxidation), hydrolysis, amidation	47 32, 43 47

Content Domain for the GOB-CTI, 47 items (cont'd)

Biological	Amino Acids, Proteins	Structure, Properties/Function, Metabolism	21, 26, 45
	Enzyme/Vitamins, Coenzymes	Properties/Function	35, 44
	Carbohydrates	Structure, Properties/Function Metabolism overview	10, 31, 36, 37,38
	Lipids	Structure, Properties/Function Metabolism overview	11, 12, 20,30,
	Nucleic Acids	Structure/Function	28
	Integration of Metabolism and Bioenergetics	Metabolic overview	21, 24, 26, 37,39, 45, 46
	Hormones/ Neurotransimion	Function	27

APPENDIX K

ORIGINAL DRAFT FOR MANUSCRIPT ARTICLE 1

BRIDGING TWO CULTURES: UNCOVERING CHEMISTRY CONCEPTS RELEVANT TO NURSING CLINICAL PRACTICE

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Abstract

This project was a phenomenological study focused on the undergraduate "Fundamentals of Biochemistry" course addressing basic topics in general, organic, and biological (GOB) chemistry. The central objective of this research was to identify the main concepts of GOB chemistry relevant to clinical nursing practice. Data collection was based on open-ended interviews of both nursing and chemistry teaching faculty and professional nurses. From these interview transcripts, three themes emerged: (a) Important Topics–have direct application to nursing clinical practice; (b) Foundational Topics–are not directly important for nursing clinical practice, but facilitate student understanding of Important Topics; and (c) Unimportant Topics– do not have direct application or are insignificant to nursing clinical practice. Based on data collected, a list of validated, clinically relevant chemistry concepts was developed. This list can assist GOB chemistry instructors to identify key concepts to emphasize in their courses. Both cultures--the discipline of chemistry and nursing--agreed that a good understanding of chemistry, linked to clinical implications, is important background for practicing nurses.

Keywords: Chemical Education Research, Curriculum, Organic Chemistry, Nursing Chemistry, Nonmajor Course, Biochemistry, First-year Undergraduate/ General, Applied Chemistry.

Introduction

There have been significant changes in nursing and nursing education in recent years. The roles of nurses have also changed and are becoming more complex and more demanding. The expression in the nursing world of these days, “high tech, high touch” reflects the need for nurses to demonstrate the ability to combine humanistic skills with scientific knowledge and technological elements. Nurses should possess a high level of critical thinking skills and positive self-efficacy with the profession, especially in trouble shooting situations. General care nurses must know about the cytotoxicity of different drugs, dosage and concentration, and about the waste disposal of the byproducts of dangerous drugs (Scalise et al., 2006). Because of the increased expectations of nursing as a profession, the need for a strong scientific foundation is more demanding. It is very important that nurses question, analyze, and make decisions based on appropriate scientific concepts (Wilkes and Batts, 1996). Chemistry is viewed as an essential foundation for the health professions. Biochemistry is foundational for the understanding of disciplines like pathophysiology, nutrition, pharmacology and other biology and chemistry related disciplines (Ouyang et al., 2007). Studies concerning science courses in nursing programs have suggested that nursing students have inadequate preparation for science courses, a negative attitude toward the relevance of science in nursing, and lack the confidence necessary to study this subject (Caon and Treagust, 1993, Wharrad et al., 1994, Friedel and Treagust, 2005). Research in nursing education has revealed various potential factors which contribute to the perception of nursing students that biochemistry is a hard subject. Some of these factors include: the cognitive load of the course, the science background of students, the anxiety of failure, the age of the students, the math

abilities of the students, and the instructor's approach (Caon and Treagust, 1993, Wharrad et al., 1994). These factors that are affecting the success in a General, Organic, Biological (GOB) chemistry course are summarized in Figure 1.

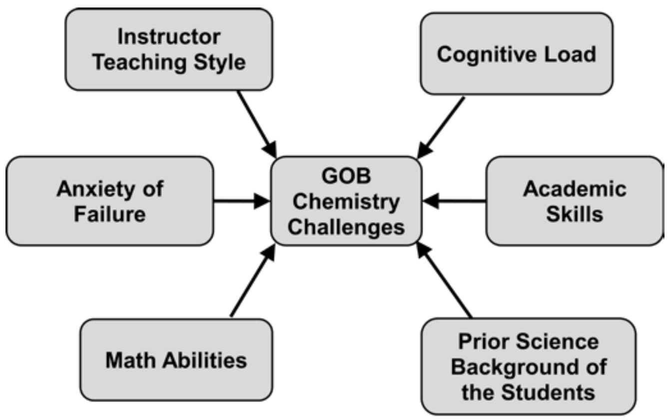

Figure1: Factors affecting success in a GOB chemistry course.

Among the factors mentioned regarding success in a GOB chemistry course (Fig.1), the instructor's approach and cognitive load are two factors very important factors. GOB instructors are typically chemists and often present the material as they would for chemistry majors; therefore, they tend to teach from a rather discipline-based approach. An appropriate example of how the approach taken by chemistry instructors differs from what nurse educators feel is important for the profession can be shown using the concept of pH. Cognitive load of the pH concept it will be presented from the perspective of the chemistry educators and nursing educators.

The Chemistry Educator Perspective

From the perspective of chemistry educators, the concept of pH is introduced in connection with the self-ionization of water equation. This is followed by a derivation of the expression of K_w and then K_a for a weak acid. The students are told that the

concentration of hydronium ion in an aqueous solution can range from about 18 M to $1x10^{-14}$ M and, because it is inconvenient to work with such a large range of concentration we simplify the calculations by introducing the concept of the pH scale and the logarithmic mathematical function. To make things even more challenging for the nursing students, the relationship among pH, pK, and the concentration of a weak acid and its conjugated base is introduced and described by the Henderson-Hasselbach equation in relation to buffer solution. The mathematical skills of the pre-nursing students are often limited. It is often difficult for them to see the relationship between hydronium ion and pH which makes the concept of pH difficult to understand as well as apply.

The Nursing Educators Perspective

According to nurse educators, the pH concept should be considered in the context of homeostasis. It should be explained that there is an inverse relationship between the value of pH and the concentration of the hydronium ion. It should be mentioned that many compounds in the body contain functional groups that can act as acids or bases, by releasing or accepting hydrogen ions, respectively. Since most biological reactions occur in aqueous solutions, the concentrationof the hydronium ion $[H_3O^+]$ determines the acidity of the solution. As a connection to the clinical practice, the pH range of blood should be mentioned (as illustrated in Figure 2 , the normal range is between: 7.35-7.45. The range from 7.35 to 6.8 is an indication of metabolic acidosis and the range from 7.45 up to 8 is a indication of metabolic alkalosis. This type of introduction to the pH scale offers a direct opportunity to connect pH to metabolism.

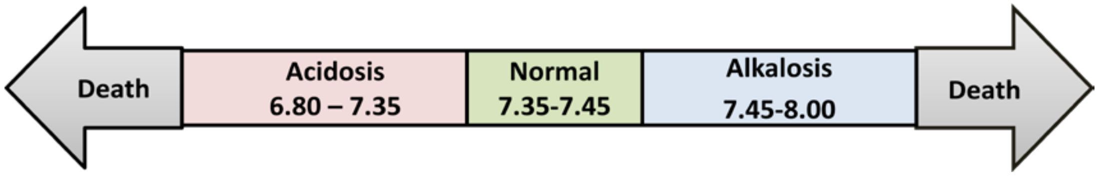

Figure 2: Normal and abnormal pH of blood.

Placing Concepts in the Context of Nursing

For the pre-nursing students enrolled in a GOB chemistry course, the connection to the clinical practice brings relevancy to the concepts of chemistry. In this case, it would be helpful if the concept of pH is connected to metabolism. For example, in the case of a metabolic acidosis, the students may be wondering how an acidic environment originates. It can be pointed out that a diabetic patient will use much less glucose for ATP production than a non-diabetic person. When glucose is not available, fatty acid β oxidation leads to the production of the acids 3-ketobutyric acid and 3-hydroxy butyric acid.

This is also a good opportunity to introduce the bicarbonate buffer system:

$$H_2O_{(l)} + CO_{2(aq)} \leftrightarrow H_2CO_{3(aq)} \leftrightarrow H^+_{(aq)} + HCO_3^-{}_{(aq)}$$

The bicarbonate buffer system is one of the main buffer systems in blood; consequently attempts to buffer the excess acid produced in diabetics. From the perspective of chemistry educators, the reaction is pretty basic and often the reaction is overlooked

Purpose of the Study

This project focused on the undergraduate “Fundamentals of Biochemistry” course that covers basic topics in general, organic, and biological (GOB) chemistry. The purpose of the project was to identify the most important chemistry concepts from the GOB course that are relevant to clinical practice of nurses. The dilemma of what should

be taught and how it should be taught for health care programs is not trivial. This dilemma is heightened given the anxiety of the nursing students who fear that the requirements of the class may close doors and opportunities for them. The pre-nursing courses are like GOB chemistry sometimes seen as a gatekeeper, determining who has access to the profession.

Undergraduate nursing students are stressed by the breadth and depth of content in their program. Despite the need for more knowledge in science, the literature in the area of nursing education shows that the level of expectations is far from being fulfilled (Scalise et al., 2006). Different studies present the importance of science content within undergraduate programs but the level of the content to be taught remains unclear (Logan-Sinclair and Coombe, 2007). It is recognized that a greater potential for understanding and efficacy in nursing practice is achieved when scientific knowledge is incorporated into nursing care(Wynne et al., 1997). Research has identified that bioscience knowledge can enhance nursing practice and is essential for safe nursing practice(Torrance and Jordan, 1995). However, there are no detailed studies on the main chemistry concepts nurses should understand in order to be good practitioners.

Methodology

This research study was based on qualitative methodology (Creswell, 2001) to acquire descriptive, detailed data collected directly from the participants. Qualitative research and analysis give the most relevant and problematic details of the phenomenon which can then be used to formulate the questionnaires of quantitative research. This study is classified as a phenomenological study which according to Merriam (2001), concentrates on the construction of an experience or a phenomenon. In this study, the

phenomenon being examined is the difficulty nursing students experience with the GOB chemistry course and how it can be addressed**.**

Creswell (2001) pointed out that in a phenomenological study the participants must have experienced the phenomenon to be qualified to express their own experiences and views about it. The participants were chosen because of their expertise in the field of nursing, experience in the clinical practice, and experience teaching the fundamentals of biochemistry course to the pre-nursing students.

Participants

In this project, purposeful sampling was used for collecting data. More specifically, criterion sampling was used since the experience of the “experts” was considered to identify the main chemistry concepts useful in clinical practice. A number of experts were interviewed. This group consisted of four biochemistry professors, six nurse educators, and four graduate nursing students (with 2-5 years of clinical experience).

1. The biochemists regularly teach the GOB chemistry course
2. The nurse educators are faculty in a program granting undergraduate, master’s and Ph.D. level nursing degrees.
3. The graduate nursing students were enrolled in either an M.S. or Ph.D. nursing degrees.

The period of 2-5 years of clinical practice for the nursing students was considered based on the rationale that going back more than five years may be too long for people to accurately remember the breath/depth of their chemistry course(s). As for the lower end being two years, we felt that first year nurses may still be adjusting to their new setting

and may not have had enough experience to see how some of the chemistry topics relate to their clinical practice.

All experts were recruited from the University of Northern Colorado. Chemistry faculty are members of the Department of Chemistry and Biochemistry, nurse educators and graduate nursing students are members of the School of Nursing.

Data Collection

The main data collection for this project consisted of semi-structured interviews with the “experts”. Person-to-person interviews were used in order to record the personal experience and knowledge of the experts with the phenomenon. A semi-structured interview was used because it “allows the researcher to respond to the situation at hand, to the emerging worldview of the respondent, and the new ideas of the topic” (Merriam, 1998). Participants were asked about the importance of GOB chemistry concepts that a nurse should understand, and to classify the concepts based on their relevancy to the clinical practice; furthermore, they were asked about the most important chemistry applications within the field of nursing related to the GOB chemistry course. The participants were interviewed based on the topics listed in the Table of Contents of the Stoker, “General, Organic, and Biological Chemistry” 4th edition, text (Stoker, 2007).The purpose of interviewing the participants was to understand their different interpretations of the main chemistry concepts deemed important for a safe clinical practice. From these interviews, a list of concepts was generated. All interviews were digitally recorded and transcribed verbatim.

Data Analysis

According to Merriam (1998), data in qualitative research are analyzed based on the content of the interviews and other documentation collected during the research study. Moreover, Creswell (2001) mentions that in a phenomenological analysis, the researcher must follow guidelines in order to analyze and then group the data from the specific derived phrases and meanings into themes. In this study, the interviews of the experts were analyzed in order to answer the research question: What are the main concepts of GOB chemistry that are considered relevant to clinical nursing practice? These data were organized into themes, which addressed the phenomena based on the participants' different views and answers. From the resulting interview transcripts, three themes emerged:

1. Topics that are Important--the chemistry concept has a direct application in the nursing clinical practice;
2. Topics that are Foundational--the chemistry concept is not directly important for the nursing clinical practice but it's understanding facilitates the understanding of the important concepts;
3. Topics that are Not Important--the chemistry concept does not have a direct application, or is not significant in the nursing clinical practice.

The interview transcripts were also analyzed for examples of clinical applications that were supporting the importance of the specific concepts.

Results and Discussions

All experts agreed on the importance of a good understanding of basic chemistry concepts expressed through the following statements.

Nurse Educator

> If you don't know what's going on [in terms of chemistry] you are standing on the sideline of the football game." The nurse educator emphasized the importance of being able to "pick up things that go south," and the critical thinking of "what is going wrong in the body. (A008)

Chemistry Educator

> It would be like a mechanic working on a car but they would have no idea what the engine is, what the carburetor does, the relationship of fuel injector to gas line, sparkplugs to distributor. So, to me it seems like if a mechanic couldn't understand the parts of an engine, he or she would have a difficult time working on one in a productive way. It's not a very good analogy, because the nurse isn't the only person working on a patient. There are also the physician, the pharmacist- a lot of people. But she or he should have at least a basic understanding of the science of that patient, the physiology, biochemistry and pharmacology of the drugs that are being used. (A004)

Nursing Graduate Student

> Some opinions will say [nursing] it's more emotional, because they do like to care for people. But they also have to have some elements of being a scientist. It is not enough to be all warm and reassuring, you have to be intelligent. You have to combine caring with science, they call it "high-tech, high-touch." You have to be scientifically competent and also be very balanced. "High-tech" meaning you must be technically competent to be safe. (A012)

While the experts agreed that a good understanding of chemistry is necessary for practicing nurses, they differed on what specific topics were important.

General Chemistry

Among the main general chemistry concepts taught in a GOB course, as listed in Table 1, there is high agreement among the experts regarding the acid/base chemistry, measurements in chemistry, and solutions.

Table 1: Distribution of experts, regarding the importance of the general chemistry topics (N = 14, CE = chemical educator, NE = nurse educator, N = nurse).

Concepts	Expert	Important	Foundational	Not important
Matter	CE	1	3	0
	NE	0	5	0
	N	1	3	1
Measurements in Chemistry	CE	2	2	0
	NE	6	0	0
	N	4	0	0
Atomic Structure and Periodic Table	CE	0	4	0
	NE	2	4	0
	N	0	4	0
Ionic Bond	CE	0	4	0
	NE	1	4	1
	N	1	3	0
Covalent Bond	CE	0	4	0
	NE	1	3	2
	N	1	3	0
Chemical Calculations	CE	1	3	0
	NE	0	4	2
	N	0	4	0
Gases, Liquids, Solids	CE	2	1	0
	NE	0	4	2
	N	0	2	2
Solutions	CE	4	0	0
	NE	6	0	0
	N	3	1	0
Chemical Reactions	CE	2	2	0
	NE	3	0	3
	N	2	2	0
Acid, Bases, and Salts	CE	4	0	0
	NE	6	0	0
	N	4	0	0
Nuclear Chemistry	CE	0	0	4
	NE	4	0	2
	N	3	0	1

An interesting split is noted in Table 1 regarding the topic of nuclear chemistry. All of the chemistry educators report this topic to be “not important,” while most (70%) of the

nurses and nurse educators find this to be an "important" topic. The reason for this dichotomy can be seen in their reasoning. According to two of the graduate nursing students:

> They [nurses] should know different types of radiation. Alpha, gamma, there are others. As it relates to safety-why shouldn't you go in the CAT scan with your patient? What kind of radiation are you being exposed to repeatedly? A CAT scan gives 100 times more radiation than a chest X-ray. They're really trying to be more cautious about using certain types of X-ray, using them carefully instead of abusing them. (A012)

> Nurses need to understand basic radiation safety. Why to stand away from the X-ray. Why if you are pregnant you shouldn't be exposed to radiation. I think they really need to know radiation principles, and how there are different radioactive particles in rays, and how they could be protected: lead, glass, aprons. (A008)

The chemistry instructors didn't think the nuclear chemistry is that important for the health-allied majors. One of the instructors mentioned that just a summary presentation would be enough: "I would just gloss over nuclear rather quickly" (A006). Another chemistry instructor's opinion:

> I don't cover nuclear chemistry. Mainly because I don't think that it really relates to what they do. Isotopes like technetium, used for imaging and iodine – a variety of isotopes but I don't think nurses are involved in that at all. It's good but mainly for a physician or radiologist. (A011)

Organic Chemistry

The greatest disparity between the two cultures, nursing and chemistry was observed in the experts opinions regarding the organic chemistry topics (Table 2). In general, what the chemists consider "foundational", the nurses and nurse educators considered "not important." According to the nursing perspective, "not the structure but the function [of molecules] is important." The chemistry educators believe that "the function cannot really be understood without understanding the structure." This disparity can have a significant impact on the way GOB chemistry is taught to the pre-nursing

students. The chemistry educators consider that the understanding of a compound's structure will be very important in understanding that particular compound's properties, function, and metabolism.

Table 2: Distribution of experts, regarding the importance of the organic chemistry topics (N = 14, CE = chemical educator, NE = nurse educator, N = nurse).

Topic	Expert	Important	Foundational	Not important
Saturated Hydrocarbons	CE	1	3	0
	NE	0	3	3
	N	0	3	1
Unsaturated Hydrocarbons	CE	1	2	1
	NE	0	2	4
	N	0	3	1
Alcohols, Phenols, Ethers	CE	2	1	2
	NE	3	2	3
	N	2	1	1
Aldehydes and Ketones	CE	2	1	1
	NE	3	2	1
	N	2	2	0
Carboxylic Acids, Esters	CE	2	2	0
	NE	1	4	1
	N	0	4	0
Amines and Amides	CE	2	2	0
	NE	3	3	0
	N	1	3	0

One of the nurses said in connection with the organic chemistry said, "In general, as a nurse, you don't use a lot of this information clinically" (A015). Though she admitted the importance of ketones in connection with diabetes.

In the opinion of chemistry educators the understanding of organic chemistry and structure is important in order to have a good understanding of the biological processes which otherwise can be just simple memorization.

> Each one of these is important to get an overall basic understanding of organic chemistry and how different groups interact. But as far as it relates to nurses, this isn't really a clinical application, but they do have to take the physiology, the pharmacology, and they have to have an understanding of work in the chemistry for the physiology and the pharmacology to make sense. And that's going to be true for the biological chemistry. Those courses would just be memorization and probably no understanding without the understanding of the chemistry. (A004)

> Structure dictates function. The way that molecules are going to be able to interact with one another. (A009)

Biological Chemistry

There was much more agreement among the experts regarding the biological chemistry part of the course. Most experts report that concepts like biomolecules and metabolism are important for nursing. One of the chemistry instructors made the remark, "If the patient doesn't metabolize, the patient is dead" (A006)

The largest discrepancy among experts on the biological chemistry topics is for nucleic acids. Of the chemistry instructors, 75% said that the concept is not important. Nurse educators and nursing graduated students consider the concept very important in understanding different diseases. From the interviews with the chemistry instructors, it was revealed that, although they considered it important for nursing, it is one of the concepts that tend to be omit due to time limitations since it is assumed to be also taught in Biology courses.

> I have in the past, skipped Nucleic Acids – it depends on the time that is left in the semester. They do get nucleic acids in a biology class. It's from a very different perspective. I prefer to cover nucleic acids, but that I think is the least important if we run out of time. It's the least important, not the least important of these molecules, but it's the least important because they will get it in some other class. (A004)

The perspective of a nurse educator regarding the nucleic acids is “[Nucleic Acids] Very, very, very important … And it’s just because I think everything in medicine is going to change dramatically in the future. And so we need to understand that as well” (A008).

Table 3: Distribution of experts, regarding the importance of the biological chemistry topics (N = 14, CE = chemical educator, NE = nurse educator, N = nurse).

Topic	Expert	Important	Foundational	Not important
Carbohydrates	CE	3	1	0
	NE	5	1	0
	N	4	0	0
Lipids	CE	3	1	0
	NE	5	1	0
	N	4	0	0
Proteins	CE	3	1	0
	NE	5	1	0
	N	4	0	0
Enzymes and Vitamins	CE	4	0	0
	NE	6	0	1
	N	4	0	0
Nucleic Acids	CE	1	0	3
	NE	4	2	0
	N	3	1	0
Biochemical Energy	CE	4	0	0
	NE	5	1	0
	N	3	1	0
Carbohydrate Metabolism	CE	4	0	0
	NE	5	1	0
	N	4	0	0
Lipid Metabolism	CE	4	0	0
	NE	5	1	0
	N	4	0	0
Protein Metabolism	CE	4	0	0
	NE	5	1	0
	N	4	0	0

Thus far, in the article we have presented the ranking of the concepts usually thought in a GOB course from the expert's perspective. Based on their ranking and the clinical applications of some of these concepts, we developed a list of the main concepts important in the nurse's clinical practice. These concepts are presented in Table 4.

Table 4: List of main concepts important in the nursing clinical practice.

General Chemistry	**Atom /Elements/Molecules/Compounds/ Mixtures** **Measurements** **Ionic bond /Covalent bonds** **Chemical reactions/Equilibria** **Gas laws/Solubility of gases in liquids/ Solutions /Osmotic pressure/ Osmolarity** **Acid-base chemistry/pH/Buffers** **Nuclear chemistry**
Organic Chemistry	**Alkanes/Alkenes** **Alcohols** **Aldehyde/Ketones** **Carboxylic acids** **Esters** **Amines / Amides**
Biochemistry	**Carbohydrates** **Lipids** **Protein structure** **Enzymes, Vitamins** **Metabolism**

Conclusions

This study enabled the identification of the main GOB chemistry concepts relevant for the nursing clinical practice. The information can assist the GOB chemistry instructors to better understand which concepts to emphasize in their teaching. By associating these concepts with clinical examples, the pre-nursing students should be more motivated to learn (Pintrich, *et al*., 1993). Ultimately their self-efficacy toward biochemistry may improve and which can directly have an impact on their confidence with the profession.

The concepts identified in this project will be further used in developing a concept inventory. With a GOB concept inventory, GOB chemistry instructors will have the opportunity to better understand the knowledge level and difficulties that their pre-nursing students have with chemistry. In this way, educators will better understand how to help the pre-nursing students become more successful on their path in the health sciences. Ultimately, the project establishes a framework to build a bridge between the two cultures of chemistry and nursing.

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