

A Bridge between Two Cultures: Uncovering the Chemistry Concepts Relevant to the Nursing Clinical Practice

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Supporting Information

ABSTRACT: This study focused on the undergraduate course that covers basic topics in general, organic, and biological (GOB) chemistry at a mid-sized state university in the western United States. 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: (i) topics that are important, having a direct application in nursing clinical practice; (ii) topics that are foundational, facilitating understanding of important topics, but are not directly important in nursing clinical practice; and (iii) topics that are not important, having no direct application and significance in nursing clinical practice. With the data collected, a list of clinically relevant chemistry topics was developed. Information from this study can assist GOB chemistry instructors to better understand which topics to emphasize in their teaching. Representatives of 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: First-Year Undergraduate/General, Chemical Education Research, Biochemistry, Interdisciplinary/Multidisciplinary, Organic Chemistry, Curriculum, Nonmajor Courses

FEATURE: Chemical Education Research

Significant changes in nursing and nursing education have occurred 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 troubleshooting situations.^{1–3} Due to the advances in technology and therapeutics the general care nurses must possess an “amalgam of knowledge” from different areas. They must be cognizant of the cytotoxicity of different drugs, dosage and concentration, and waste disposal of byproducts of toxic drugs.^{4,5} 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.⁶

In their case study of student nurses, Scalise et al. proposed that chemistry is an essential foundation for all healthcare professionals.⁵ Biochemistry is foundational for understanding disciplines such as pathophysiology, nutrition, pharmacology, and other biology- and chemistry-related subjects.⁷ 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.^{8–11}

Research in nursing education has revealed various potential factors that contribute to the perception by nursing students that bioscience courses are difficult.^{8–12} 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.^{8–10,13–15} Depending on the specific nursing school and its requirements, many prenursing 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 hinder successful performance in a GOB chemistry course are summarized in Figure 1.

Among the factors mentioned regarding success in a GOB chemistry course (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. 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 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 to 1×10^{-15} M. Because it is inconvenient to

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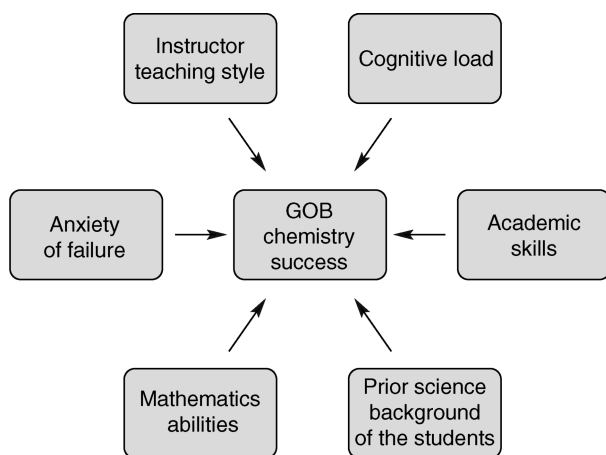


Figure 1. Challenging factors that affect students' success in a GOB chemistry course.

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 nonchemistry 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.^{17,18} As the mathematical skills of prenursing students are often limited, this perspective of pH can not only increase their cognitive load, but also reduce students' self-efficacy.^{16–19}

■ 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 Figure 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.

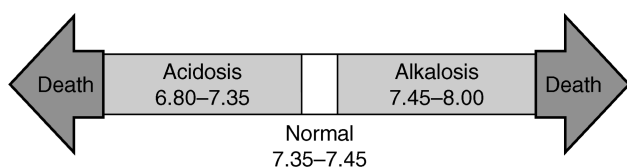


Figure 2. Normal and abnormal range of the pH of blood.

■ PURPOSE OF THIS STUDY

This research study focused on an undergraduate course that covers a broad range of topics in GOB chemistry at a mid-sized, state university in the western United States. 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 prenursing students who fear that requirements of the course may close doors and opportunities for them.^{20,21} Some prenursing courses, like GOB chemistry, are sometimes viewed as gatekeepers, thus, determining who has access to the profession.⁵

Undergraduate nursing students often feel stressed by the cognitive load and content detail in their program.¹² Despite the need for more knowledge in science, the nursing education literature shows that the level of science knowledge is far from being fulfilled.⁵ While many studies document the importance of science content within undergraduate programs, the level and breadth of the content to be taught remains unclear.¹¹ 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.^{22,23} Walhout and Heinschel²⁴ 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 study²⁴ and the current study.

■ METHODOLOGY

This study was based on qualitative methodology²⁵ 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. 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, as the goal was to identify various ways experts perceive the relevancy of the GOB chemistry topics. According to Marton,²⁶ 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 prenursing students. In this study, criterion sampling was used, because 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 graduating students with two–five years of clinical experience. The chemistry instructors

(CI) have regularly taught a GOB chemistry course. One chemistry instructor is also a coauthor 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 coauthor 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, CPNP. They have taught courses such as these: pathophysiology; pharmacology; medical surgical nursing; clinical nurse specialist in oncology and hematology; labor and delivery and 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 two–five years experience in clinical practice. The period of two–five 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 and 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-sized, state university in the western United States. Chemistry faculty were members of a chemistry department; 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 semistructured 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.²⁷ A semistructured 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.”²⁷ On the basis of the Stoker textbook,²⁹ used by the instructors teaching GOB chemistry at this university, a list of topics usually taught in a GOB chemistry course (see the Supporting Information) was developed. The list was compared to the table of contents of several other GOB chemistry textbooks.^{28,30–33} Using this list of topics along with the Stoker textbook,²⁹ 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 served as the primary collector and analyzer of the data.

Data Analysis

The initial outcome of a phenomenographic research study is identification of categories of description.³⁴ 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.”³⁴ 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. On the basis of 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”; 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 coauthor) and two NEs (one a coauthor), information gathered from the 14 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:

1. Topics that are important have a direct application in the nursing clinical practice
2. Topics that are foundational facilitate the understanding of the important topics, but are not directly important for nursing clinical practice
3. Topics that are not important do not have a direct application or are not significant in nursing clinical practice

RESULTS AND DISCUSSION

Critical thinking is part of the everyday responsibilities that a nurse assumes as he or she attempts to accurately define patient care problems, make the best decisions from an array of possibilities, safely implement the plan, and evaluate results of the delivered care.³⁵ 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.

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.” This nurse educator (NE 006) 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”.

Chemistry Instructor

This representative statement from a chemistry instructor highlights the importance of understanding the science behind a patient's current health status as well as the treatments. Without that basic understanding:

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)

Nursing Graduate Student

The nursing graduate student quoted below integrates science and nursing norms in this representative statement.

Some opinions [in 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)

Rating the Topics

Although the experts agreed that a good understanding of chemistry is necessary for practicing nurses, they differed on what topics were important. The ratings of topics in GOB chemistry are outlined below along with opinions expressed by the interviewed chemistry instructors, nurse educators, and nursing graduate students.

General Chemistry. Among the main general chemistry topics taught in a GOB chemistry course, as listed in Table 1, the experts agreed 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 because of the impact it has on homeostasis. All experts agreed that acid–base aspects, such as pH and buffers, are important: one nursing graduate student (NGS 002) summed it up, "Understanding what makes an acid and what makes a base and how they affect liquids and tissue are extremely important."

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 (NGS 003) stated that this topic is important in connection with "[D]rug dosages, concentrations of solutions that we give. The whole medical world is measured in the metric system, so they have to understand that system."

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

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

Topics	Expert ^a	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
Atomic Structure and the Periodic Table	NGS	4	0	0
	CI	0	4	0
Ionic Bonds	NE	2	4	0
	NGS	0	4	0
	CI	0	4	0
Covalent Bonds	NE	1	4	1
	NGS	1	3	0
	CI	0	4	0
Chemical Calculations	NE	1	3	2
	NGS	1	3	0
	CI	1	3	0
Gases, Liquids, Solids	NE	0	4	2
	NGS	0	4	0
	CI	2	1	1
Solutions	NE	0	4	2
	NGS	0	2	2
	CI	4	0	0
Chemical Reactions	NE	6	0	0
	NGS	3	1	0
	CI	2	2	0
Acids, Bases, and Salts	NE	3	0	3
	NGS	2	2	0
	CI	4	0	0
Nuclear Chemistry	NE	6	0	0
	NGS	4	0	0
	CI	0	0	4
	NE	4	0	2
	NGS	3	0	1

^a*n* = 14. CI is the abbreviation for chemistry instructor, NE for nurse educator, and NGS for nursing graduate student.

good general knowledge. 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 (CI 001) mentioned that just a summary presentation would be enough: "I would just gloss over nuclear rather quickly."

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 prenursing 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

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

Topics	Expert ^a	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

^a*n* = 14. CI is the abbreviation for chemistry instructor, NE for nurse educator, and NGS for nursing graduate student.

and nurse educators considered not important. According to a nurse educator (NE 001), "Not the structure but the function [of molecules] is important."

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. This disparity can have a significant impact on the way GOB chemistry is taught to prenursing 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, one chemistry instructor (CI 004) observed, "The hydrocarbons are an important part of lipids as well as understanding hydrophobic interactions in macromolecules and membranes."

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; one (NGS 001) noted, "ethers were once used for anesthesia, but not anymore."

The nursing culture (NE and NGS) considered aldehydes and ketones either foundational or important as metabolic byproducts 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 (NE 001) said, "In general, as a nurse, you don't use a lot of this information clinically."

On the basis of 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. The experts showed considerably higher agreement regarding biological chemistry topics of the course (Table 3). Most experts reported that all topics, with the

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

Topics	Expert ^a	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

^a*n* = 14. CI is the abbreviation for chemistry instructor, NE for nurse educator, and NGS for nursing graduate student.

exception of nucleic acids, are important for nursing. According to the experts, understanding enzymes and vitamins, carbohydrates, lipids, and proteins and their metabolism was considered important. One chemistry instructor (CI 001) noted: "If the patient doesn't metabolize, the patient is dead."

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. A nurse educator provided this perspective regarding nucleic acids:

[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 graduate 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 [prenursing students] 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 prenursing 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 prenursing 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 the following topics relating to metabolic pathways: anaerobic metabolism of carbohydrates, because 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, because 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.

■ GOB 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.

On the basis of 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

Table 4. Relevant GOB 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

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 prenursing 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 because 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 (CI 004), "everything is reduced to rote

memorization leading to an inability to make connections among topics involved in metabolism."

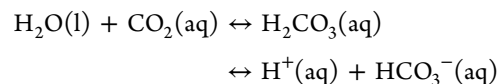
An understanding of metabolism will enable nurses to better understand implications and side effects of prescribed medication, provide more effective interventions in troubleshooting situations, and ease in professional communications at the patient's level of understanding.

CONCLUSIONS

This study enabled identification of 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. On the basis of 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, prenursing students may be more motivated to learn.³⁶ Ultimately, prenursing students' 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 prenursing 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 prenursing students if the topics were taught with examples relevant to nursing practice.

For prenursing students enrolled in a GOB chemistry course, connections to clinical practice brings relevancy to chemistry topics. A proposed approach using pH is given below as an example of teaching with clinical relevance. 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 patient with diabetes, compared to a person who does not have diabetes, 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:



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

In general, our results agree with those reported by Walhout and Heinschel²⁴ regarding the importance of the major categories; namely, the experts consulted ranked biological chemistry topics along with many general chemistry topics as

important, with many organic chemistry topics receiving the lowest ratings in importance. Of the topics examined in both studies, most biological chemistry topics ranked higher. Many of the general chemistry topics also ranked higher (either important or foundational in our study). Many of the organic topics were ranked lower (either foundational or not important in our study).

There were relevant differences between the two studies. The study of Walhout and Heinschel²⁴ involved ranking topics in order of importance, whereas our study requested a ranking of importance as well as an indication of 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 comprehensible manner, topics considered as important.

Because 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 widespread 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.

■ ASSOCIATED CONTENT

📄 Supporting Information

Topic list presented to experts during interviews. This material is available via the Internet at <http://pubs.acs.org>.

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