

EXAMINING NURSING STUDENTS' UNDERSTANDING OF THE CARDIOVASCULAR
SYSTEM IN A BSN PROGRAM

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DEDICATION

This dissertation is dedicated to four important people in my life. My mother, Kate, who has given me support and praise whenever I needed it the most. My father, Jim, whose love for academics and passion for “thinking deep thoughts” has inspired me throughout my life. Kelsey, my wife, who has been with me throughout the entire four year process and who has put up with my stress, bad moods and complaints while motivating me when I needed it the most. Finally, my grandmother Dorothy, who passed away during the writing process and was the most honest and loving person I have ever known. Thank you for being in my life and I love you all.

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ABSTRACT

This study investigated the alignment of important cardiovascular system (CVS) concepts identified by expert nurses with nursing student's knowledge. Specifically, it focused on the prevalence of nursing students' alternative conceptions for these important concepts as a potential reason for a theory-practice gap in nursing (Corlett, 2000; Jordan, 1994). This is the first study to target nursing student alternative conceptions exclusively whereas other studies focused on diverse groups of undergraduates' CVS knowledge (Michael et al., 2002). The study was divided into two phases and used a case study approach with each phase of the study representing a single case. The first phase of the study sought to understand what CVS concepts expert nurses deemed relevant to their daily practice and how these experts used these concepts. The second phase identified nursing student alternative conceptions through the use of open-ended scenarios based on the results of phase I.

For the first phase of the study involved four CVS expert nurses practicing in emergency rooms and cardiac intensive care units at two local hospitals. Interviews were used to elicit important CVS concepts. The expert nurses identified five broad concepts as important to their practice. These concepts were a) cardiovascular anatomical concepts; b) cardiovascular physiological concepts; c) homeostasis and diseases of the CVS; d) the interdependence and interaction of the CVS with other organ systems and e) the intersection of the CVS and technology in patient diagnosis and treatment. These finding reinforce concepts already being taught to nursing students but also suggest that instruction should focus more on how the CVS interacts with other organ systems and how technology and the CVS interact.

The presence of alternative conceptions in the nursing students was examined through the use of open-ended questions. A total of 17 students fully completed the scenario questions.

Results indicate that this group of nursing students hold some CVS alternative conceptions.

Overall, the alternative conceptions can be grouped into four categories: a) CVS anatomy, b) blood flow and pressure, c) anthropomorphic views and d) miscellaneous alternative conceptions. These findings suggest there is indeed a misalignment between expert nurses' and nursing students' knowledge of the CVS with this misalignment potentially contributing to the theory-practice gap.

CHAPTER ONE: INTRODUCTION

Understanding how the body moves material, exchanges oxygen with carbon dioxide and how systems interrelate is fundamental in understanding the human organism. Even though each of us uses our bodies every day, many individuals have an inadequate or limited understanding of how our body systems are interrelated (Gellert, 1962; Ozsevgec, 2007; Reiss & Tunnicliffe, 2001). With childhood obesity and diabetes rates increasing it is vital that students understand how their bodies work and how to keep their bodies healthy (Deckelbaum & Williams, 2001; Veugelers & Fitzgerald, 2005). Moreover, with our life expectancies increasing there is a need for highly trained physicians and medical personal to meet the needs of our aging population (Lubitz, Cai, Kramarow, & Lentzner, 2003). The American Association for the Advancement of Science (AAAS, 1989) has stated that a fundamental understanding of the human organism is necessary for achieving the goal of scientific literacy:

The human body is a complex system of cells, most of which are grouped into organ systems that have specialized functions. These systems can best be understood in terms of the essential functions they serve: deriving energy from food, protection against injury, internal coordination, and reproduction. The continual need for energy engages the senses and skeletal muscles in obtaining food, the digestive system in breaking food down into usable compounds and in disposing of undigested food materials, the lungs in providing oxygen for combustion of food and discharging the carbon dioxide produced, the urinary system for disposing of other dissolved waste products of cell activity, the skin and lungs for getting rid of excess heat (into which most of the energy in food eventually degrades), and the circulatory system for moving all these substances to or from cells where they are needed or produced. (p. 70).

Students should have a strong understanding of the human body by the time they graduate high school is further reiterated in the *Benchmarks for Science Literacy* (AAAS, 1993) and in the middle school and high school *Next Generation Science Standards* (Achieve, 2013). However, recent studies (Ahopelto, Mikkilä-Erdmann, Olkinuora, & Kääpä, 2011; López-Manjón & Angón, 2009; Michael et al., 2002; Mikkilä-Erdmann, Södervik, Vilppu, Kääpä, & Olkinuora,

2012) at the undergraduate level have shown that students who enter the medical fields harbor alternative conceptions about the body, specifically the cardiovascular system (CVS). Why is it that understanding the human body is highly stressed at the K-12 level and not at the undergraduate level? Many undergraduates in the fields of biology, biochemistry and chemistry will become tomorrow's health professionals and need to have a correct understanding of the human organisms to ensure the best possible care for their patients.

Recent research found that when students construct their own understanding they develop a more robust understanding of body systems (Brown, 2010; Carvalho, 2009; Goldberg & Dintzis, 2007; Hughes, 2011; Krontiris-Litowitz, 2009). A new effort from the AAAS entitled *Vision and Change in Undergraduate Biology Education: A Call to Action* calls for the creation of student centered learning environments in undergraduate biology classrooms (AAAS, 2009). This new approach presents a framework for college instructors consisting of five core biology concepts and six competencies which all undergraduate introductory biology courses should incorporate. The five core concepts are a) evolution, b) structure and function, c) information flow, exchange and storage, d) pathways and transformations of energy and matter and e) systems. College instructors are to use these concepts throughout their courses to give students a framework to situate future information. Along with this framework, *Vision and Change* makes pedagogical suggestions that undergraduate introductory biology courses should "reduce the amount of information in classes; teach students how to learn so they can gain depth on their own... More emphasis [placed] on application and problem solving... have projects where knowledge needs to be applied instead of exams where facts are regurgitated" (p. 19).

A biology-based course which could benefit from the *Vision and Change* framework is human anatomy and physiology (A&P). Four of the five core concepts align with current A&P instruction with only evolution being the outlier, though it can easily be incorporated (Feder,

2005). For example, instruction over the CVS would describe the composition of the heart and associated vessels as well as how these structures innervate other organ systems to facilitate gas exchange and waste excretion. The CVS contains chemoreceptors and baroreceptors which provide the body with signals through feedback loops to regulate blood pressure and hormone levels. The vessels of the CVS interconnect all of the organ systems of the body to allow communication, sequestration of nutrients and energy use. Since A&P is a foundational course for students who want to pursue allied health professions or a medical career (Schoon, 2001), the five core concepts from the *Vision and Change framework* align closely with current A&P content which leaves instructors needing to only modify how they present the material. One possible way is to incorporate patient case studies that help students apply their knowledge to real world situations (Rodriguez-Barbero & Lopez-Novoa, 2008).

Another source of student difficulties is when students develop ideas which differ from the scientifically accept view (Driver, 1983). These differing ideas have been identified as a multitude of terms such as naïve theories (Caramazza, McCloskey, & Green, 1981), misconceptions (Driver, Guesne, & Tiberghien, 1985), erroneous ideas (Fisher, 1983) or alternative conceptions (Abimbola, 1988; Gilbert & Swift, 1985; Millar, 1989). According to Wandersee, Mintzes, and Novak (1994) an alternative conception refers

to experience-based explanations constructed by a learner to make a range of natural phenomena and objects intelligible, but also confers intellectual respect on the learner who holds those ideas-because it implies that alternative conceptions are contextually valid and rational and can lead to even more fruitful conceptions (p. 178).

The term alternative conception will be used throughout this study.

Alternative conceptions to a given topic differ from individual to individual due to their prior experiences and knowledge about the topic. The size of college classes can range from as few as 20 students to as many as several hundred. Faculty cannot begin to understand all of the

differing ideas that students bring to the class but through different types of assessment they can begin to understand what ideas their students do have about a topic. One type of assessment that allows instructors to uncover their students alternative conceptions is formative assessment (Angelo & Cross, 1993).

Formative assessment allows instructors to judge student responses and is used to shape the student's competence (Sadler, 1989) and students can use their responses as a metacognitive approach (Pellegrino, Chudowsky, & Glaser, 2001). Students can monitor their own learning of a concept by how they respond to their instructor's formative assessment. In larger enrollment courses, students may be hesitant to offer answers to their instructor's questions and it is not possible to assess or address all students' prior conceptions due to time constraints. In this situation the use of an instrument is a viable type of formative assessment for students.

Instructors have a plethora of instruments to choose from. There are concept inventories (e.g. Halloun & Hestenes, 1985), two-tier diagnostic tests (e.g. Odom & Barrow, 1995) and even three-tier diagnostic tests (e.g. Schaffer, 2013) as well as case studies and personal response systems (clickers) which help students monitor their metacognitive processes (Tanner, 2012). Regardless of the type of formative assessment the goal is to access student's prior conceptions and alternative conceptions in order to modify instruction and student thinking to facilitate better alignment with scientifically valid explanations and alleviate alternative conceptions.

Vision and Change (AAAS, 2009) makes suggestions for college faculty to probe students' prior knowledge of course content in order to establish what they know about a topic and then move to new, unfamiliar ground to enable students to develop a deeper understanding of the material. The document also provides a list of instructional strategies

which are backed by research and are college classroom tested to elicit student's alternative concepts by "incorporate[ing] frequent informal assessment to address misconceptions and provides a balance between direct instruction and student interaction" (p.26).

Rationale of the study

One area of science which intersects both the *Vision and Change* and student's alternative conceptions is the topic of the CVS. The CVS can be taught to meet all of the five core concepts since the system is responsible for sending information around the body through receptors housed throughout its vessels (Silverthorn, 2013) as well as being a complex system whose structure and function has been shaped by evolutionary pressures (Farmer, 1999). The CVS is also an area which has been shown to be difficult for students of all grade levels to master (Arnaudin & Mintzes, 1986; Michael et al., 2002). Additionally, A&P is a foundational course for students who venture into the health professions such as medical school, nursing, physical therapy and allied health programs (Schoon, 2001). Students in these areas will be responsible for taking care of patients and is one area where CVS alternative conceptions must be alleviated since they are responsible for people's lives.

The area of allied health professionals consists of multiple programs such as nursing, medical assistants and nurse practitioners (Struber, 2004). These areas attract students due to the need of qualified personal to fill vacant jobs and is one of the fastest growing sectors with an estimated 587,000 jobs being created between 2006-2016 due to the aging population (Aiken, Cheung, & Olds, 2009). The difficulty is getting qualified graduates for these newly created positions since many younger nurses complete a two year degree instead of a four year degree (Buerhaus, Staiger, & Auerbach, 2004). It is of the utmost importance that allied health professionals have their foundational knowledge aligned with scientifically valid ideas to ensure the best possible care.

A growing concern with nursing education today is the appearance of a theory-practice gap (Corlett, 2000; Jordan, 1994). This gap exists between the bioscience knowledge learned in the classroom and the knowledge used in practice. Nursing bioscience courses are defined as anatomy, physiology, microbiology, pharmacology and immunology (Akinsanya, 1987; Wharrad, Allcock, & Chapple, 1994). Compounding this problem is that during the late 1980's and early 1990's nursing education switched from a bioscience focus to a more holistic approach which emphasized psychosocial aspects of illness (Wynne, Brand, & Smith, 1997). The result was that nursing students' bioscience curriculum does not adequately prepare them for practice (Clancy, McVicar, & Bird, 2000; Davis, 2010). This is problematic because practicing nurses play a significant role in patient education and are a source of information for patients (Newens, McColl, Lewin, & Bond, 1997).

The use of expert nurses will attempt to bridge the theory-practice gap by identifying important CVS concepts which are used in practice. Physical care of patients depends on the nurse's bioscience knowledge base which they draw on to make judgments regularly (Boore, 1981; Jordan & Reid, 1997) due to the profession becoming more autonomous (Jordan, Davies, & Green, 1999). Newens et al. (1997) found that nurses who have taken a six week cardiac rehabilitation course hold fewer misconceptions about patient recovery than nurses who did not receive the additional training. By interviewing these experts, insights will be gained into their application of their bioscience knowledge and how it links to practice. The use of this group will also meet the concern that pre-nursing courses does not adequately prepare nurses for practice since the participating nurses will have extensive training and coursework post-graduation.

Based on the expert nurses' responses, authentic scenarios will be generated around the identified, important cardiovascular concepts which will meet nursing students' need for relevant, clinical based bioscience knowledge (Jordan et al., 1999). It will also meet Phillips, Schostak, Bedford, and Leamon (1996) and Jordan et al. (1999) call for a link between bioscience theory and practice. McVicar, Clancy, and Mayes (2010) indicate that practicing nurses perceive experience to be the most important factor in learning bioscience knowledge so uncovering what practicing nurses deem as important concepts will reinforce the bridging of theory and practice.

Nursing students consider bioscience courses difficult (Barclay & Neill, 1987; Caon & Treagust, 1993; Wharrad et al., 1994), lacking a link to practice (Davies, Murphy, & Jordan, 2000; Davis, 2010) and as a source of anxiety in their program of study (Gresty & Cotton, 2003; Nicoll & Butler, 1996). This is problematic because a strong bioscience foundation is essential for high quality care (Prowse & Lyne, 2000a; Prowse, 2000; Prowse & Lyne, 2000b) and a lack of bioscience knowledge has been shown to be detrimental to patients (Davis, 2010; Jordan & Reid, 1997). Researchers (Akinsanya, 1987; Eraut, Alderton, Boylan, & Wraight, 1995; Trnobrański, 1993) have been advocating for a restructuring and improvement of nursing bioscience curriculum for almost three decades to alleviate these problems. In addition, Clancy et al. (2000) adds that both nurse educators and nursing students advocate for more educational support in the biosciences.

Nursing students view anatomy and physiology as the most valued and beneficial bioscience course (Wynne et al., 1997) yet, nursing students lack confidence in their physiology knowledge to understand the phenomena they face in practice (Courtenay, 1991). Findings from Courtenay (1991) attribute this to: a) students perceived their training to be in favor of the

behavioral sciences; b) the level of biological science knowledge being taught was perceived by students as inappropriate for their training; c) nursing teachers felt inadequately prepared to teach biological science which carried over into students feeling inadequately prepared; and d) teaching methods used by the instructors were ineffective.

The development of the open-ended scenarios through expert practitioners' interview responses will meet the concerns expressed by both nursing students and faculty. Student concerns about bioscience knowledge appropriateness or link to practice will be addressed due to the scenarios being generated from expert practitioners. Concepts which are used explicitly in practice will be emphasized and will allow students to apply their knowledge to real world situations before they enter the workforce. The generated scenarios will also give nurse educators a means to assess their student's knowledge during bioscience coursework. Results of the scenarios can be used to modify instruction and meet the needs of the struggling students.

Purpose of the study

The purpose of the study is three-fold. The first purpose is to identify CVS concepts that expert nurses deem important for practice. This is incredibly important since many nursing students will deal with cardiac patients in their practice and will put their knowledge into practice. Second, this study will attempt to uncover nursing students' alternative conceptions to these important CVS concepts. No study to date has focused explicitly on nursing students' CVS alternative conceptions. Finally, the study will attempt to identify if there is a misalignment between the important CVS concepts to practice and nursing student CVS knowledge. This will be done through the development of CVS scenarios based on the expert nurses' important concepts. The presence of alternative conceptions to these important CVS concepts could

potentially indicate where there is a gap between CVS theory and practice and have implications for areas where nursing educators need to focus.

Definition of Key Terms

Academic Physiologist: A person who has earned a PhD in an area of physiology but does not practice medicine.

Alternative Conception: The conceptual understanding students' hold that differs from the scientifically valid explanation. This misunderstanding may hinder a student's ability to understand new scientific content (Driver, 1981; Driver, 1983). Other researchers use terms such as misconception (Driver et al., 1985), naïve theories (Caramazza et al., 1981) or prior conceptions (Posner, 1982) can be used in the research literature as synonyms for alternative conception.

Arteries: Blood vessels which carry blood away from the heart. Arteries differentiate into smaller arteries called arterioles before the capillaries.

Arterioles: A small diameter blood vessel that extends and branches from an artery and leads to the capillaries.

Atrial Fibrillation (A fib): A disease which causes an irregular and often rapid heart rate which causes poor blood flow to the body.

Atrium: The two upper chambers of the mammalian heart.

Authentic Scenario: A passage of text consisting of a patient symptoms and disease prognosis followed by open-ended questions pertaining to the patient's description. The scenarios are grounded in important concepts elicited from nursing experts.

Bioscience Courses: Science courses taken through the nursing students' program of study.

These courses include anatomy, physiology, pharmacology, pathophysiology, and microbiology.

Blood Vessels: Structures of the CVS which transport blood and associated molecules around the body. There are three types of blood vessels in the CVS: arteries, capillaries and veins.

Capillaries: The smallest blood vessels of the body where gas, water, nutrient and gas exchange takes place.

Cardiac Output (CO): The volume of blood pumped by the left and right ventricles in one minute.

Cardiovascular Anatomy: The structural features of the CVS which includes the heart and associated blood vessels i.e. arteries, capillaries and veins.

Cardiovascular Physiology: Functions of the CVS which includes the regulation of blood pressure, electrical activity of heart, functions of circulation, the process and effects of vasodilation and vasoconstriction, and the process of gas and nutrient exchange between red blood cells and tissues.

Cardiovascular System (CVS): The heart and associated vessels (arteries, arterioles, capillaries, venules and veins) in the human body which pump blood in a dual circuit (the pulmonary and systemic), facilitating gas and nutrient exchange in organs and tissues.

Circumflex Artery: The circumflex artery, fully titled as the circumflex branch of the left coronary artery, is an artery which leads off the left coronary artery to supply parts of the heart with oxygenated blood. The area of the heart it always provides part of the left ventricle and the papillary muscle with blood but other areas of the heart vary between individuals.

Concept: “A perceived regularity in events or objects designated by a label” (Novak, 1995, p. 229) or “objects events, situations or properties that possess common critical attributes and are designated in any given culture by some accepted sign or symbol” (Ausubel, Novak, & Hanesian, 1978, p. 127).

Congestive Heart Failure (CHF): A disease which causes the inability or failure of the heart to meet the oxygen needs of the body.

Coronary Vessels: Arteries and veins which supply the heart with blood. The coronary arteries branch off of the aorta. The coronary veins return blood to the right atrium

Darting: Nursing slang for inserting a needle into the space between the pericardial sac and the heart itself.

Diuretic: A medication or substance which promotes the production of urine

Electrocardiogram (EKG): A diagnostic tool which portrays the electrical output of the heart as a segmental wave. Each wave indicates a physiological phenomenon in the heart and is represented by the letters PQRST. The P indicates atrial contraction; QRST represents ventricular contraction while T indicates ventricular relaxation.

Expert Nurse: A registered nurse who has been working with cardiac patient on a daily basis for at least eight months and has had special training in advanced cardiac life support.

Heart: A hollow muscle in mammals that pumps blood throughout the CVS through rhythmic contractions. The heart consists of a left and right side as well as four chambers. The two superior chambers are the left and right atria. The two inferior chambers are the left and right ventricles. The right superior and inferior chambers are separated by the tricuspid valve while

the left superior and inferior chambers by the mitral (bicuspid) valve. The heart is located in the thoracic cavity slightly to the left of the sternum between the left and right lung.

Homeostasis: The “stabilization of bodily states”(Cooper, 2008, p. 420) or the normal function of the body.

Hypoxia: A condition where an area of the body is deprived of oxygen.

Ischemia: A lack of blood supply to tissues.

Lack of Knowledge: A response to the authentic scenarios’ prompt where the student leave the question blank, did not use a qualifier to imply that they guessed and it cannot be inferred that they reasoned correctly or used a tautology to answer the prompt.

Myocardial Infarction (MI): When blood stops flowing to a part of the heart, commonly known as a heart attack.

Nitroglycerin: A medication which causes vasodilation of vessels and is used to treat heart attacks. It is converted by the body into nitric oxide which is a natural vasodilator.

Nurse Driven Practices: Clinical practice guidelines for caring for patients with certain symptoms. These consist of multiple protocols which nurses follow without consultation from physicians. For example, when a patient has a heart attack a nurse will administer aspirin without the need to consult a physician.

Nursing Student: A student who is seeking a four year bachelor of science in nursing.

Peripheral Artery Disease: A disease which refers to obstructions in the large arteries not within the coronary, aortic arch or brain. These obstructions can cause acute or chronic ischemia.

Preload: The end diastolic pressure that stretches the right or left ventricle of the heart to its greatest geometric dimensions under variable physiologic demand (Luecke et al., 2004).

Pro re nata (PRN): Latin for as needed. Nurses use this abbreviation when they are monitoring a patient and need to administer drugs when the patient's condition changes.

Registered Nurse (RN): A nurse who has completed either two or four year degree and passed the nursing licensure exam.

Sinoatrial (SA) Node: The impulse generating tissue located in the right atrium of the heart. Sometimes it is commonly called the “pacemaker” of the heart.

Starling Effect (Law)/ Frank-Starling Law: A law which states that stroke volume of the heart increases in response to an increase in the volume of blood filling the heart.

STEMI: Nurse's abbreviation for an ST elevated myocardial infarction. The ST refers to the ST portion of the EKG wave.

Stroke Volume: The amount of blood pumped from a ventricle with each contraction of the heart.

Swan Ganz Catheterization: The passing of a thin tube (catheter) into the right side of the heart and the arteries leading to the lungs to monitor the heart's function and blood flow.

Theory-Practice Gap: The difficulty experienced by nurses in transferring what they learn in their coursework to clinical practice (Cook, 1991).

Third Spacing: A term used to describe when fluid is trapped in the interstitial spaces especially out of the blood into a body cavity or tissue. This can occur in the lungs, abdomen, brain or other extremities.

Veins: Blood vessels which carry blood back to the heart from the venules and capillaries.

Venules: A small blood vessel that allows blood to return from the capillaries to veins.

Ventricles: The two lower chambers of the mammalian heart.

Widow Maker: The nickname used to describe a highly occluded left main coronary artery or proximal left anterior descending coronary artery. This is used by nurses because if the artery gets abruptly and completely occluded it will cause a heart attack which will likely lead to sudden death.

Assumptions of the Study

The following assumptions of the study are:

1. Nursing students who do not respond to a scenario question will be considered to lack knowledge for the question and do not hold alternative conceptions.
2. If a nursing student response lacks a qualifier or reasoning statement then it will be considered an alternative conception. All attempts will be made to clarify the student responses using the entirety of their response.

Limitations of the Study

The following limitations of the study are:

1. The study will only involve nurses who work in Midwestern hospitals in the ER and/or Cardiac ICU. Nurses in other departments such as NICU, nursing homes and surgical wards may deem other CVS content as important or identified content as unimportant.

2. The study will involve only nursing students who are enrolled at a Midwestern research university.
3. Not all of the nursing students will go on to work with cardiac patients so variation may be exhibited between students who seek to specialize with cardiac patients and those who do not.
4. No attempt will be made to control the number of college level courses which cover cardiovascular content. Prior coursework may influence the results of the study since variation will exist between past course choice.
5. No attempt will be made to control the cardiovascular content that was taught in previous bioscience courses. Variation in course instructors may also effect which CVS content was taught in those courses.
6. Alternative conceptions elicited by the scenarios may have been influenced by the student's non-scientific usage of scientific terms and/or misunderstandings of scientific terms.
7. No attempt will be made to contact students to clarify responses. Alternative conceptions may be incorrectly identified due to the language the students pose in their responses.
8. No attempt will be made to control the completion of the scenarios. The results of the study may be impacted because some participants will take their time to complete the scenarios thoroughly while other participants may try to finish quickly.

Organization of the Dissertation

This study will investigate undergraduate nursing students' knowledge of the CVS. The investigation involves the interviewing of expert nurses to identify important CVS concepts

as well as the development of scenarios to elicit nursing students' CVS alternative conceptions. The study will include five chapters: Chapter One provided a general introduction to the study; Chapter Two will include a review of related literature; Chapter Three will describe the participants, context and methods for creating the scenarios eliciting nursing students alternative conceptions; Chapter Four will present an analysis of the data; Chapter Five will summarize and discuss the findings of the study as well as provide recommendations for future studies.

CHAPTER TWO: REVIEW OF THE LITERATURE

The focus of this chapter is four-fold. First, a description of the theoretical framework guiding the study will be given. The theoretical framework centers on the constructivist perspective in relation to student understanding of bioscience content. Second, a discussion of students' alternative conceptions in A&P content, specifically focusing on the CVS, will be presented. Third, a brief discussion of assessments in science will be presented focusing on the CVS. Finally, a brief review will be given of the factors which contribute to success in health science courses as well as the role of nurses' bioscience knowledge in preparing them for their daily practice.

Theoretical Framework of the Study

This study will be guided by a constructivist learning perspective. Constructivism encompasses many related perspectives but at its core a "constructivist stance maintain that learning is a process of constructing meaning; it is how people make sense of their experiences" (Merriam, Caffarella, & Baumgartner, 2007, p. 291). Students are not blank slates when they come to class but bring a plethora of experiences which are modified through new experiences. Ausubel et al. (1978) explicitly state the "most important single factor influencing learning is what the learner already knows" (p.6).

Driver and her colleagues (Driver, Asoko, Leach, Scott, & Mortimer, 1994) break constructivism in science classrooms into two domains, the personal and the social. The personal domain follows the work of Piaget (1970) in which individuals create cognitive schema based on their personal experiences. This view of constructivism is contrasted with sociocultural or social constructivism based on the work of Vygotsky (1978). Vygotsky focuses on the use of dialog and how it influences learning. At the core of a social constructivist view of learning is that knowledge is constructed while engaged in social interactions centered on a

shared problem or task (Crowley & Jacobs, 2002; Feuerstein, 1990; Gergen, 1995; John-Steiner & Mahn, 1996).

The current study will center on the personal or cognitive perspective under the constructivist paradigm. Knowledge acquisition, according to this perspective, consists of the learner constructing their own meaning of an object, event or relations by taking the new knowledge and building on prior knowledge (Bransford, Brown, & Cocking, 2000). From this, individual learning is a “progressive adaptation of [an] individual ‘s cognitive schemes to the physical environment” (Driver et al., 1994, p. 6). In other words, learning is a mental process where new ideas modify previously held ideas with little prominence given to wider social aspects.

The cognitive perspective’s foundation can be traced to the highly influential work of Swiss cognitive psychologist Jean Piaget (1952). Beilin (1992) states “assessing the impact of Piaget on developmental psychology is like assessing the impact of Shakespeare on English Literature or Aristotle on philosophy—impossible” (p. 191). Most notably Piaget proposed a four stage theory of cognitive development. These stages represent “qualitatively different ways of making sense, understanding and constructing knowledge of the world” (Tennant, 1988, p. 68). Piaget’s theory brought forth the idea that an individual’s cognitive structure (schema) changes by interaction with and exposure to events in their environment. Through these interactions ideas go through a process of assimilation and accommodation. Assimilation is the process of interpreting sensory information whereas in accommodation the schema adapts to make sense of that information. In essence the learning process consists of iterations of assimilating information and then accommodating it.

Ausubel (1968) expanded the cognitive perspective when he proposed his theory of meaningful reception learning , sometimes called assimilation theory, using Piaget’s assertions

as a starting point. Meaningful reception learning is the acquisition of new information that is highly dependent on the relevant ideas already in cognitive structures. It is an active process and requires three conditions to be successful. First, cognitive analysis of the material is necessary for ascertaining which aspects of existing cognitive structure are most relevant to the new material. By this, learners must grapple with how the material fits into their current structure of the topic. Next, some degree of reconciliation is created with the existing structure. Learners must apprehend the similarities and differences between the old and newly acquired material. They must resolve any contradictions to their already established concepts and prepositions to create a more highly differentiated cognitive structure. Once these contradictions are resolved, the new cognitive structure is assimilated or combined into broader cognitive structures in terms of the idiosyncratic intellectual background and vocabulary of the particular learner. This causes material to potentially be understood in ways which differ from other learners.

Even if all of these conditions are met there is the possibility of a gradual loss or a reduction of ideas in the cognitive structures. A learner's culture, attitudinal bias or specific situational demands can influence the retention of new material. Another factor which can influence the retention of material is how it is anchored to existing relevant ideas. By this Ausubel meant that "new ideas tend to be assimilated or reduced, over the course of time, to more stable meanings of the established anchoring ideas" (Ausubel et al., 1978, p. 129). For example, if a new concept adheres closely and supports an already established cognitive structure then is more securely anchored than a concept which does not adhere closely. These ideas which do not adhere then enter the obliterative stage of assimilation and are forgotten.

In Ausubel's theory (1968) the interconnection of these cognitive structures is essential for knowledge development and concept learning. Concepts are "defined as objects events, situations or properties that possess common critical attributes and are designated in any given

culture by some accepted sign or symbol" (Ausubel et al., 1978, p. 127). These interconnection of cognitive structures represents how we understand concepts, which in turn influences how we proceed in explanation of a phenomenon (Finley, 1982).

Due to cognitive structures being an individual construct there is the possibility of learners resolving contradictions to their existing structures which deviated from scientifically valid explanations of the concept. A concept is said to be scientifically valid when experts agree with it (Klausmeier, Ghatala, & Frayer, 1974). When this deviation occurs an alternative conception can be formed (Driver, 1983; Driver et al., 1985; Hewson & Hewson, 1983; Sequeira & Leite, 1991; Wandersee et al., 1994).

In a seminal paper, Posner, Strike, Hewson and Gertog (1982) presented a theory which described how to modify students alternative conceptions through conceptual change. This theory was grounded in the works of Piaget (1952), Ausubel (1968), Kuhn (1970) and Lakatos (1970). The idea behind conceptual change is that "sometimes students use existing concepts to deal with new phenomena. Often, however, the students' current concepts are inadequate to allow [them] to grasp some new phenomenon successfully. Then the student must replace or reorganize [their] central concept" (Posner et al., 1982, p. 212). The failure to grasp the concept successfully could be understood to mean the formation of an alternative conception.

Posner and colleagues describe four conditions required for conceptual change. These conditions were a) dissatisfaction with an existing concept and the new concept must be b) intelligible, c) plausible and d) fruitful. When compared with Ausubel's theory the new concept would not reconciled successfully with existing cognitive structures (dissatisfaction) but the new concept would better explain the scientifically valid concept in that it makes more sense to the learner (intelligible and plausible) as well as being more interconnected to their other cognitive structures (fruitful). The model of conceptual change presented by Posner et al. (1982) has been

scrutinized for not explaining what changes during conceptual change (Disessa & Sherin, 1998) and for not considering other factors such as motivation and classroom context in their model (Pintrich, Marx, & Boyle, 1993).

Disessa and Sherin (1998) critique of conceptual change centered on unpacking the term concept into a more carefully defined theoretical construct. They differentiated the cognitive acquisition of concepts into coordinate classes and phenomenological primitives. Coordinate classes are “systematically connected ways of getting information from the world” (p. 1171). This would include the cognitive strategies for selecting and integrating information obtained from the world. For example, when learners encounter an animal they determine which category this animal fits into such as dog or bird. Phenomenological primitives are relatively simple abstractions from experience early in life. For example, while learning mechanics in physics, learners have the idea that greater force is accompanied by great results. If you push an object with a stronger force, it will move a greater distance. With these two constructs defined, researchers could measure what changes in conceptual change.

Pintrich et al. (1993) argue for a conceptual change model which includes personal interest, self-efficacy and buy in from the students. They identify two problematic areas in the model put forth by Posner et al. (1982) which are: a) inadequate theoretical development which takes into account the learners' beliefs about self and b)the role of context which could hinder or sustain conceptual change. Without these factors Pintrich and colleagues coined the phrase “cold conceptual change” when referring to models which are rational in that they follows logic and scientific findings. By this, a teacher can facilitate conceptual change in their students by only presenting logical, scientific findings. This cold view of conceptual change is opposed by a view where the learner's interest and motivation are considered.

Regardless of the conceptual change model, Scott, Asoko, and Leach (2007) identified three fundamental commonalities between the cognitive perspectives of conceptual learning. These commonalities are a) individuals' beliefs about the natural world are constructed, rather than received, b) there are strong commonalities in how individuals appear to think about the natural world, and c) a person's existing ideas about a given subject greatly influence their subsequent learning about that subject. These three features will underpin the current study.

Relevant Studies in Anatomy & Physiology

One area of science which has been shown to be difficult for students to master is A&P (Abdullahi & Gannon, 2012; Harris, Hannum, & Gupta, 2004; Hopp, 2009). The main focus of A&P is to describe the structure and function of the body with information exchange through multiple pathways. These pathways interconnect the organ systems of the body to allow communication, sequestration of nutrients and the use of energy. Since A&P is a foundational course for students who want to pursue allied health professions or a medical career (Schoon, 2001) identifying student's alternative conception is vital (Michael, 2002).

The majority of A&P courses follow a systems based approach (Silverthorn, 2002a). By this, students are typically taught through lecture with topics presented by organ system i.e. skeletal system followed by the musculature, followed by the nervous system. In these courses, students assume a passive role with rote memorization, not understanding, at its core (Carvalho, 2009; Richardson, 2000). This style of learning does not allow the learner to attach concepts to existing cognitive structures or as Ausubel states "They [rote learning tasks] are relatable to cognitive structures but *only* in an arbitrary, verbatim fashion that does not result in the acquisition of any meanings" (Ausubel et al., 1978, p. 45).

Multiple papers have been written which give suggestions on ways to alter A&P instruction from a rote manner to a more meaningful way. Some suggestions are using

technology in the classroom (Collier, Dunham, Braun, & O'Loughlin, 2012; Heidger Jr et al., 2002; Stein, Challman, & Brueckner, 2006), use of case studies (Bruce, 2001; Stephens, 2004) or student centered instructional techniques (Hughes, 2011; Modell, 2000; Richardson, 2008) but empirical evidence for successful implementation of these strategies is sparse. Of the empirical based research studies investigating student centered instruction, the literature base centers on either the K-12 classroom (Akpan & Andre, 1999; Siegle & Foster, 2001) or graduate institutions such as medical school (Chinnah, De Bere, & Collett, 2011; Griksaitis, Sawdon, & Finn, 2012; Nicholson, Chalk, Funnell, & Daniel, 2006) leaving the undergraduate level underrepresented. This possibly indicates that rote instruction is more prevalent at the college level than others.

Reviewing the literature base for empirical studies in A&P at the undergraduate level reveals that student conceptual learning of A&P can be separated into two general categories. The first consists of faculty perceptions of difficulties in student learning of anatomy and physiology (Michael, 2007; Rovick et al., 1999). Michael (2007) surveyed 63 physiology teachers to understand what faculty perceive to be the reasons for student difficulties in understanding physiology content. Survey responses were divided into three factors which lead to difficulties. These factors were a) the discipline of physiology (content is challenging), b) students ideas about learning (students memorizing vs. understanding) and c) how physiology is taught. Of the top ten survey responses, only one represented the last factor. This suggests that faculty perceive the majority of difficulties lie with the content or the students themselves and not how material is presented.

Rovick et al. (1999) assess the accuracy of faculty member's knowledge of their student's background knowledge of the respiratory system. Eleven faculty members selected ten questions to administer to their students prior to instruction on the respiratory system. Rovick and his colleagues then asked the faculty members to predict the performance of their

students on these self-selected items. Results indicate that faculty members tended to underestimate the students' conceptual knowledge but overestimate their ability to apply that knowledge. This further supports the mismatch between faculty perceptions and student difficulties surrounding A&P concepts.

The second, larger category investigates student misconceptions of individual organ systems (Cliff, 2006; Michael et al., 1999; Michael et al., 2002; Ranaweera & Montplaisir, 2010; Richardson & Spark, 2004; Windschitl & Andre, 1998). Interestingly, there appears to be a parallel between how A&P is traditionally taught and alternative conception research. Students are taught individual organ systems and research focuses on what alternative conceptions students have for these individual systems. The organ systems or processes which have received the most attention are the CVS (Ahopelto et al., 2011; Arnaudin & Mintzes, 1985, 1986; López-Manjón & Angón, 2009; Michael, 1998; Michael et al., 2002; Palizvan, Nejad, Jand, & Rafeie, 2013; Sungur, Tekkaya, & Geban, 2001; Windschitl & Andre, 1998; Yip, 1998), respiration and metabolism (Luz, de Oliveira, de Sousa, & Da Poian, 2008; Michael et al., 1999; Oliveira, Sousa, Poian, & Luiz, 2003; Songer & Mintzes, 1994), the nervous system (Montagna, de Azevedo, Romano, & Ranvaud, 2010; Ranaweera & Montplaisir, 2010; Silverthorn, 2002b), and osmosis and diffusion (Fisher, Williams, & Lineback, 2011; Odom, 1995; Tomažič & Vidic, 2012).

The focus of this study is the CVS which has research studies spanning the entire spectrum of K-20 education. This review will center on studies which identifies student's alternative conceptions of the cardiovascular system, though more extant literature exists which uses cardiovascular system content. One example of this type of literature are studies whose main focus is the evaluation of the effectiveness of different instructional strategies on student conceptual understanding (Abu-Hijleh, Kassab, Al-Shboul, & Ganguly, 2004; Carvalho, 2009; Laffey, Tupper, Musser, & Wedman, 1998).

Within the alternative conception literature, Arnaudin and Mintzes (1986) investigated fifth and eighth graders' alternative conceptions of the CVS. They asked the students a set of six questions dealing with the flow and composition of blood, heart anatomy and function of blood when it reaches the tissues. Results indicate that students held alternative conceptions dealing with the pathway the blood takes in the body and the number of chambers in the heart. Forty percent of the students thought the heart had three chambers with twenty percent of the eighth graders thought the heart was solid. Alternative conceptions about the pathway of blood were that the blood made a circular trip to the organ and back to the heart (never entering the lungs) or it was a one way trip to the target organ (excluding the lungs).

Building on these findings, Windschitl and Andre (1998) extended the range of students to include high school and college students. Using a 24 question survey to pre-assess the participants they found similar alternative conceptions as Arnaudin and Mintzes (1986). Results show that only 46% of the student chose the correct answer of how the blood flows through body. One question had the students circle a pictorial representation that indicated the number of chambers in the heart with only 52% of the students correctly identifying a four chambered heart. The most frequent incorrect answer was a five chamber heart. This study shows that as age increases certain misconceptions persist.

Sungur et al. (2001) investigated the effect concept mapping and conceptual change texts had on student understanding of CVS content. Forty-nine grade 10 biology students were split into two equal groups with concept mapping introduced in the treatment group while the control group was taught normally. Each group took a 16 item multiple-choice test prior to and after instruction to determine the effect of concept mapping on students' understanding of cardiovascular content. The pre-test indicated a total of 48 alternative conceptions between the two groups. These alternative conceptions center around six general areas: a) the composition

of plasma and blood, b) systemic blood velocity, c) shape of red blood cells, d) ventricular filling, e) blood pressure and f) material exchange between blood and tissues. Students in the treatment group did score higher (59%) on the post-test than the control group (51%) but statistical comparison was not viable due to small sample size of the treatment group (n=49).

Results of the study indicate that alternative conceptions dealing with interdisciplinary content such as velocity of blood and material exchange are difficult to alleviate even with the introduction of concept mapping. However, pre and posttest comparison of the treatment group indicate that conceptual change and concept mapping did alleviate some alternative conceptions about blood pressure. Sungur and her colleagues attribute this finding to the conceptual change texts which focus specifically on blood pressure alternative conceptions.

Seven studies (Ahopelto et al., 2011; López-Manjón & Angón, 2009; Michael et al., 2002; Özgür, 2013; Palizvan et al., 2013; Pelaez, Boyd, Rojas, & Hoover, 2005; Yip, 1998) investigated alternative conceptions of the CVS at the collegiate level or professional school. The participants of these seven studies span the entire spectrum of college students i.e. non-science majors, science majors and professional studies. Four of these studies (López-Manjón & Angón, 2009; Özgür, 2013; Pelaez et al., 2005; Yip, 1998) focus specifically on non-science majors, one (Michael et al., 2002) samples both non-science and science majors while Palizvan et al. (2013) targets only science majors. The remaining study (Ahopelto et al., 2011) samples medical students. Synthesis of these studies' findings show that regardless of collegiate level, many students hold persistent alternative conceptions about a) the flow of blood, specifically the role of the lungs in circulation, b) the relationship between blood pressure and flow, c) the structure and function of the heart and d) the effect of exercise on the cardiovascular system. These studies also reinforce that there is an underrepresentation of undergraduate studies comparing science and non-science majors' conceptual understanding of CVS anatomy and physiology.

Assessment of A&P Knowledge

Reviewing the literature base reveals the majority of CVS assessments are in the form of short questionnaires (Arnaudin & Mintzes, 1986; Michael, 1998; Michael et al., 2002; Özgür, 2013; Palizvan et al., 2013; Yip, 1998). Michael (1998) presented undergraduates with six short cases followed by six questions. The questions were based on known alternative conception yet validity or reliability of the instrument was not reported. Özgür (2013) developed two open-ended questionnaires for use in K-12 classrooms but did not report the reliability or validity of either questionnaire. Palizvan et al. (2013) used a four question instrument to understand undergraduates' knowledge of the CVS. These questions were a two-tiered multiple multiple-choice format. By this, students answered the first tier and depending on that answer they would respond to a second multiple choice question explaining their responding to the first tier.

Michael et al. (2002) was the only study which reported the content validity of their questionnaire. A focus group with physiology teachers was conducted to discuss student difficulties in A&P. The CVS was the major focus of the discussion. From this, undergraduates were interviewed about the CVS and a 13-item instrument was created based off of the undergraduates' alternative conceptions. Unfortunately, reliability measures were not reported. In summary, all of these studies failed to both validate and/or measure the reliability of their questionnaires. This indicates that the results of the surveys can only be used to guide instruction in the specific course they were administered and not in other contexts.

Factors Influencing Success in A&P and Health Sciences

As previously discussed the subject of A&P is difficult for students with multiple alternative conceptions in various topics. Despite this, many students successfully complete A&P and progress in their professional careers. Relatively few studies have been conducted trying to understand potential student attributes which lead to successfully completing an A&P course

(Hargroder, 2007; Harris et al., 2004; McCleary, Aasen, & Slotnick, 1999). Interestingly, areas related to A&P such as performance in nursing (Campbell & Dickson, 1996; Gallagher, Bomba, & Crane, 2001; Gilmore, 2008; Jeffreys, 2007; McClelland, Yang, & Glick, 1992; Wharrad, Chapple, & Price, 2003) or professional schools (Chisholm, Cobb, & Kotzan, 1995; Reede, 1999) have received more attention. Programs in these fields often required A&P as a prerequisite so it could be speculated that traits which garner success in medical or nursing school would also allow students to succeed in A&P. As such, a brief discussion of predictors of success in these areas will be included.

McCleary et al. (1999) surveyed 843 undergraduates enrolled in human physiology from 1996-1998 to understand what variables best predicted successfully passing the course. Survey questions included demographic information such as age, previous college science and mathematics courses, science GPA and total GPA at time of enrollment in physiology. Regression analysis indicates that predictor variables most strongly associated with successfully passing the course were pre-physiology GPA and number of college science courses completed. Another factor which contributed to success was the number of high school science and mathematics courses. Age of the student was negatively correlated with successful completion by itself but once other variables were entered into the model this correlation weakened.

In a similar study, Harris et al. (2004) surveyed 91 undergraduates enrolled in a first semester A&P course. Students' age, sex, degree sought (AA, BA, MA) number of work hours per week, number of high school science and mathematics courses completed, and science coursework completed in college were investigated to see if they affected successfully completing the A&P course. The step-wise regression model corroborated findings from McCleary et al. (1999) in that the number of high school mathematics and science courses as well as the number of science undergraduate courses correlated highly with course success. A

third variable, number of credit hours taken during the semester with the A&P course, was also highly correlated with student success.

Hargroder (2007) took a different approach and investigated student's self-efficacy in regards to successful completion of a human anatomy course. Four hundred and fifty undergraduates who were enrolled in a semester long human anatomy were surveyed using a self-efficacy instrument. Student self-efficacy scores were correlated with final course grades. Results of the study indicate that there is a significant, positive correlation between student self-efficacy and course outcome.

From these studies it can be suggested that the number of science and mathematics courses in high school and/or college and student GPA are significant predictors of student success in A&P. In addition if student's self-efficacy is high then they are also more likely to do well in anatomy.

Factors for Success in Nursing.

One area many students enter which requires A&P as a prerequisite is nursing. Nursing education literature shows similar predictors of success in their courses as studies centering on A&P courses. Many of these nursing studies define success as successfully passing the licensure examination or graduating from the program. Gilmore (2008) investigated multiple variables to gauge the pass rate of the National Council Examination for Registered Nurses. The variables of interest were the ACT composite score, ACT mathematics subscore, ACT reading subscore, ACT English subscore, ACT Science subscore, A&P grade and cumulative GPA prior to entrance into the nursing program. Results from the study indicate that the only variable which was significantly significant was the ACT English subscore. This score may be an indicator of the reading level required to comprehend the licensure examination.

Gallagher et al. (2001) explored the relationship between two factors: GPA and nursing entrance examination score, and successfully graduating with an undergraduate in nursing. Using data from 121 undergraduate nursing students they found that the entrance exam score was a better overall predictor of successfully graduating than GPA. The nursing entrance examination is divided into different subscores and the researchers tested each subscore's relationship with graduating from the nursing program. They found that the only subscore which effectively predicted success was the reading subscore. This finding give more support that reading level measured by a standardized test is highly related to successfully passing the nursing licensure examination

Wharrad et al. (2003) explored European nursing students' grades in advanced level or A-level Biological Sciences in addition to two other A-Level subjects' grades and successfully completing a bachelor of nursing degree. A-Level courses are similar to advanced placement (AP) courses in the US since they cover more difficult materials but unlike AP courses students do not get college credit from passing a summative examination. Results of the study indicate that students who do well in A-level science courses successfully complete an undergraduate nursing degree more often than students who do poorly in the same classes. Adding to this, students who take more A-level science courses are more successful than students who take fewer A-level science courses.

Adding support for the use of standardized tests and the science course work as predictors of success in health related fields are studies dealing with professional schools. Reede (1999) showed support for composite scores on the Medical College Admission Test as significant predictors of success in medical school. Chisholm et al. (1995) was contextualized in pharmacy school and results indicated that pre-pharmacy mathematics and science course GPA,

Pharmacy College Admission Test (PCAT) composite scores and PCAT verbal score were significant predictors of successfully completing pharmacy school.

All of these studies point to the use of previous mathematics and science courses, either total number or GPA, and scores on standardized tests as significant predictors of success in health related fields. Although, comparing the studies which investigate student success in A&P and in nursing school it can be concluded that students' science content knowledge is important for success in their courses and careers.

Bioscience Courses in Nursing Curriculum

One area of contention in nursing is whether to give greater emphasis to bioscience courses or to behavioral courses such as psychology or sociology (Akinsanya, 1987; Courtenay, 1991; Wynne et al., 1997). Over the past three decades this emphasis oscillated between the two areas with some authors (Clancy et al., 2000; Jordan, 1994; Trnobrański, 1993) arguing that the deemphasizing of bioscience courses has led to a theory-practice gap in nursing. A theory-practice gap is "the divide between abstract, possibly esoteric, concepts and the real problems of everyday clinical practice" (Jordan, 1994, p. 419).

The *Commission on Nursing ("Lancet commission on nursing," 1932)* from the *Lancet* was the first to begin to identify the gap between theory and practice or "Gap between school and hospital" (p.415). This commission consisted of 12 members who met officially 24 times and 25 times unofficially from 1930 to 1932. The goal of the report was two-fold, a) to inquire as to the reason for a shortage of candidates in the field of nursing, and b) "to make suggestions for making the service more attractive to women suitable for the necessary work" (p. 415). The appearance of the theory-practice gap falls into the second goal.

In an earlier iteration of the report on the *Commission on Nursing* (Hill, 1931) presented statistical analysis to a questionnaire given to 686 hospitals with 44,000 nursing staff completing

the questionnaire. Responses to question 12, which dealt with the shortage of nurses in hospitals, specifically focused on the notion of a gap between training in school and working in the hospital as a reason for the shortage. Hill eloquently stated that, “not many of those questioned believe in any lowering of the present educational standards demanded, but a number refer to the difficulties and disadvantages of combining ward work and theoretical work, which, in their opinion, makes life of the probationer too arduous” (p.456). So for over 80 years the gap between theory and practice has been discussed in the literature.

In order to begin to bridge the gap an emphasis has been placed on incorporating more bioscience courses into nursing curriculum (Akinsanya, 1987; Jordan, 1994). The major bioscience courses that nurses take are some type of anatomy and physiology, either sequential or separate course, pharmacology, immunology, chemistry and biology (Prowse & Lyne, 2000a; Wharrad et al., 1994). The two courses which nursing student perceive as the most difficult are A&P and pharmacology (Jordan & Reid, 1997; King, 2004) and are a source of anxiety (Akinsanya, 1987; Closs, 1994; Jordan et al., 1999; Nicoll & Butler, 1996).

Several studies (Caon & Treagust, 1993; Clancy et al., 2000; Courtenay, 1991; Jordan et al., 1999; Ostlind, 2006; Thornton, 1997) have been conducted asking nursing students and nursing educators to gauge the value of bioscience knowledge. Courtenay (1991) sought to understand why some students fail to support their practice with theory. Key findings from the study were a) that students perceived the balance between bioscience courses and behavioral courses were skewed in favor of the behavioral, b) the level of science taught in their bioscience courses was inappropriate to their RN training, c) nursing faculty felt inadequately prepared to teach the bioscience courses, and d) self-directed teaching methods were perceived to be ineffective by the students in relation to work preparation.

Results from Caon and Treagust (1993) also corroborated these claims. A survey investigating students' perceptions and reasons for difficulties in bioscience was administered to nursing students. The students responded that relevance and application to their future careers was a clear motivating factor for learning course content. However, it was unclear whether relevance produced motivation or that those students more able to learn science are also more capable of seeing the relevance of the material thus, increasing motivation.

Thornton (1997) took a qualitative approach to understanding the relevance of bioscience courses to practice. Nursing students and nursing educators were interviewed to understand the impact relevance to practice had on revisions of bioscience curriculum. The study indicated that how nursing educators viewed the role of a nurse as the major factor which influences course curriculum. By this, nursing educators view nursing as a skilled-focus career and it is beginning to become a profession where autonomy is the norm. Nurses are charged with making decisions which influence patient care without the need to consult the attending physician. This does not mean that the physicians are excluded but that nurses who view themselves as "an independent practitioner addressing the complexities of the human body, mind and spirit" (p. 182) will be the best prepared for practice. This view was reflected in the student responses because students who viewed nursing as a skill-focused career and not a profession which involves critical thinking and innovation had difficulties seeing the relevance of course work to their practice.

Nursing students do have difficulty in bioscience courses even though they are viewed as relevant to their profession. Jordan et al. (1999) created a seven item questionnaire asking nursing students ($n=339$) and nursing faculty ($n=78$) to rank the comparative difficulty of bioscience courses and other nursing programmatic courses. Results of the questionnaire found that students and faculty perceived bioscience courses to be either more or much more difficult

than: ethics and law (69%), nursing concepts (59%), nursing intervention (74%), psychology (67%), research and critical thinking (47%), sociology (66%) and social policy (56%). Interestingly, nursing students ranked bioscience courses as one of the most valued courses in their program of study despite the courses being difficult. The only course which outranked bioscience was the nursing practice course which students felt related more to their job since it taught them how to give injections and take blood pressure reinforcing the notion that career relevance is an important factor to nursing students.

Clancy et al. (2000) sought to understand how nursing students perceptions of bioscience courses compared to practicing nurses. The study used a nine item questionnaire in which participants ranked the strength of their view on a scale from 1 to 10. Questionnaire results from both the students and the practicing nurses indicate both groups strongly view bioscience knowledge as important to their practice (92.5% of students and 92.5% of practicing nurses) with practicing nurses being more confidence in their ability to explain the biological basis of their practice. Interestingly, both groups felt that application of biological science was important to patient care even though students could not explain the biological basis of the care they would provide to future patients. This lends further support that bioscience content play a major role and is valued in practice yet courses are perceived to be difficult and may not meet practicing nurses' needs (Ostlind, 2006).

CVS Alternative Conceptions in Nurses

Relatively few studies (Angus et al., 2012; Lin, Furze, Spilsbury, & Lewin, 2008; Newens, McColl, Bond, & Priest, 1996; Newens et al., 1997) have been done explicitly exploring nurses' and nursing students' CVS alternative conceptions, even though it has previously been discussed that courses which teach CVS content are difficult and are important to practice. All of these studies aim to identify the prevalence of cardiac misconceptions through survey responses but

do not identify specific cardiac misconceptions that the nurses harbor. Lin et al. (2008) found that Taiwanese nurses have a higher prevalence than nursing students on the York Cardiac Belief Questionnaire (Furze, Bull, Lewin, & Thompson, 2003). Conversely, Angus et al. (2012) found the opposite in a Scottish sample using the same instrument. The difference between the two studies was attributed to the cultural settings in each study.

Chapter Summary

The purpose of this chapter was to lay the foundation for the study. This study will be guided by a constructivist learning perspective, specifically that of meaningful learning (Ausubel, 1968), conceptual learning (Scott et al., 2007) and conceptual change (Posner et al., 1982). All of these theories at their core hold that students come to class with prior ideas about science topics with some misaligned with scientifically valid ideas about the topic. Through instruction the hope is that students will confront their alternative conceptions and alter their thinking to align with scientifically accepted ideas.

The topic of interest for this study is the CVS. Studies reviewed in this chapter show that students of all ages have alternative conceptions about this topic and these alternative conceptions even persist into medical school (Ahopelto et al., 2011). Some alternative conceptions for the CVS are the path of circulation in the body, specifically the role and position of the lungs, the anatomy of the heart and the relationship between red blood cells and the exchange of materials with tissues. Studies (Özgür, 2013; Palizvan et al., 2013) also show that there are relatively few instruments at the undergraduate level to uncover these alternative conceptions.

One area where having alternative conceptions can have dire consequences is nursing. Nurses care for patients and need to make decisions in some instances where the consequences mean life or death. Studies (Jordan et al., 1999) have shown that nursing students feel

bioscience courses, specifically A&P, are difficult and that these courses present content in ways that are not relevant to their future practices (Clancy et al., 2000; Ostlind, 2006). Yet, having a strong bioscience foundation has been shown to improve patient care (Prowse & Lyne, 2000a). Compounding this dilemma is the appearance of alternative conceptions to A&P and CVS content. This means is that new nurses do not see the relevance of the challenging material until they are in charge of taking care of a patient. In some circumstances these nurses may not understand what is physiologically occurring in these patients which can lead to negative patient outcomes.

CHAPTER THREE: METHODOLOGY

The purpose of this chapter is four-fold. First, the research questions guiding this study are presented. Second, a description of the context and participants will be given detailing the involvement of the expert nurses and the nursing students. Third, the design of the study, conveying a qualitative approach, and data sources will be presented. Fourth, the trustworthiness, or rigor, of the study will be described as well as the qualifications of the researcher.

Research Questions

This study answered the following research questions:

- 1) What are the major cardiovascular concepts identified by cardiovascular anatomy and physiology nursing experts?
- 2) How do cardiovascular anatomy and physiology experts use these major concepts in their daily nursing practice?
- 3) What cardiovascular anatomy and physiology alternative conceptions do nursing students hold?

The study involves two phases of data collection to answer these research questions (Figure 1). The first phase consists of interviewing experts in the field of cardiovascular nursing. The results of phase one will inform research questions 1 and 2. At the conclusion of phase one four scenarios were developed along with accompanying open-ended questions. The second phase of the study involves a new sample of nursing student participants who answer the open-ended questions. Results from the open-ended scenarios will inform research question 3.

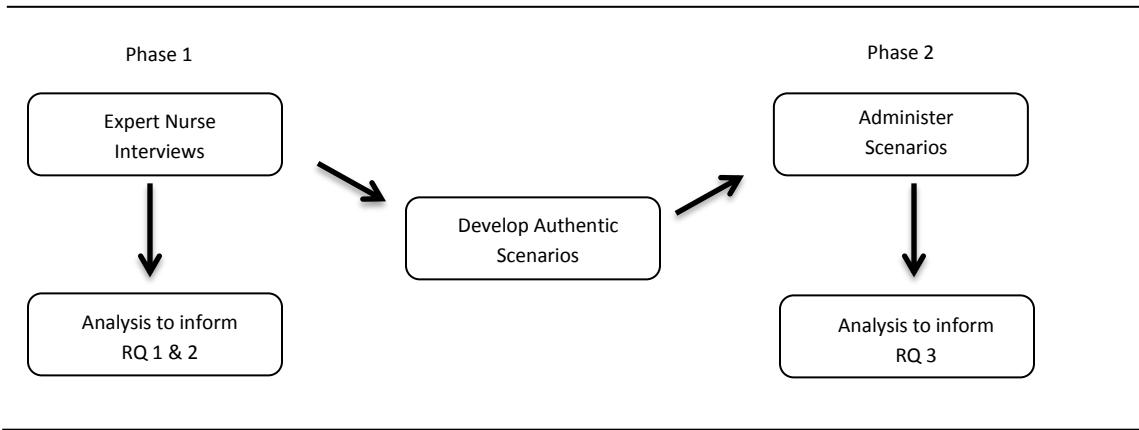


Figure 1. Phases of the research study

Context and Participants of the Study

The study involves both nursing experts and nursing student each having a different role in the study. The first group consists of expert nurses who were interviewed to gain insight into what CVS content they use in their daily practice. To be considered an expert, participating nurses must be a registered nurse caring, or have cared, for cardiovascular patients in either an intensive care unit (ICU) or emergency room (ER) in a hospital context. Nurses who work in cardiac ICU collaborate with a certified critical care nurse (CCN) at the onset of their career in the ICU.

There are multiple ways to become certified as a CCN and it is state dependent (B. Kolesar, personal communication, October 7, 2013). One way in the state of Missouri is to be accepted to a critical care fellowship after passing the licensure exam. Once accepted, nurses begin a residency under the tutelage of a preceptor. The preceptor is a certified critical care nurse who mentors the fellow through course work, practicum experiences and certification examination. Upon successful completion of the fellowship, the nurse is certified as a critical care nurse though not all nurses who work in an ICU become a CCN.

Nurses who work in the ER are required to take continuing educational courses to remain working in the ER. Many of these courses overlap with the courses taken by the CCN certification (S. Colvin, personal communication, February 2, 2014). For example, both types of nurses take advanced cardiac life support (ACLS) courses. A total of 4 expert nurses were participated in the study (See Table 1).

Table 1

Expert nurses demographic information (n=4)

Participant*	Gender	Degrees	Hospital*	Years practicing	Science courses taken	Related CVS experience
Sarah	Female	BSN, MSN	Davis	30	Advanced Chemistry, Anatomy, Microbiology Pharmacology Physiology Pathophysiology	6 years as ICU nurse assistant
Tom	Male	AA	Jefferson	22	Chemistry Anatomy Bacteriology Pharmacology Physiology	14 years as Combat Medic
Claire	Female	AA	Davis	8 months	Intro to Chemistry Chemistry I Chemistry II Anatomy & Physiology I Anatomy & Physiology II Pharmacology	10 years as an ER Pharmacy Tech,
Gary	Male	AA	Jefferson	8 months	Anatomy Biology Chemistry Pathophysiology Physiology	5 years as an EMT

*pseudonyms

The expert nurses were recruited from two local hospitals, Jefferson and Davis (pseudonyms), through the collaboration with hospital administrators, recruitment flyers and snowball sampling. Recruitment permission letters for each hospital were received from nursing

administrators prior to the onset of the study. The recruitment flyers were reviewed by each of the hospitals' Nurse Research and Evidence Based Practice Council due to regulations regarding advertisement materials in the hospitals.

Jefferson hospital is a county-owned not for profit hospital. It provides services to 25 surrounding counties and employs over 2000 people. Davis hospital is a level I trauma center which houses the only burn intensive care unit in the region. Davis is a teaching hospital and is affiliated with the local university.

The second group of participants are undergraduate nursing students (n=28) enrolled in a BSN program at a large Midwestern university. The participating students were enrolled in their final semester of the BSN program. The course of interest was a seven hour clinical practicum with lecture component housed in the university's nursing school. The students attend class once a week for four hours with the remaining time spent in hospitals gaining clinical hours. Prior to administering the survey, an unaffiliated third party described the study and recruited the nursing students. The students asked questions about the study prior to collection of demographic information (See Table 2). Attached to the demographic survey was a consent form to obtain written consent (see Appendix A).

Table 2

Nursing students self-reported demographic information (n=28)

Question	Response	Number of Students	Percent (%)
Age	18-22	28	100
Gender	Female	25	89
	Male	3	11
Ethnicity	African American/Black	2	7
	Caucasian/White	26	93
Do you have any previous college degrees or licenses?	Yes*	1	3
	No	27	97

Continued

Are any of your relatives in a health care profession?	Yes**	11	39
	No	16	61

* One student reported a Certified Nursing Assistant but was unsure if that was a standalone license

** Reported professions were nurses (n=7), medical doctor(n=2), respiratory therapist (n=1), doctor assistant (n=1),nursing PhD (n=1), physical therapist (n=1), worked in a small health clinic (n=1)

All the nursing students followed a similar program of study to be admitted to their nursing program. The program of study required them to take bioscience courses (see Table 3). During their nursing program students were exposed to CVS knowledge in their bioscience course work (see Table 4) with a variety of CVS content covered (see Table 5) (For verbatim responses see Appendix B).

Table 3

Self-reported bioscience courses taken by nursing students (n=28)

Bioscience course	Number of Students	Percent of students
Chemistry	26	92.8
Organic Chemistry	0	0
Biology	27	96.4
Physics	0	0
Pharmacology	28	100
Pathophysiology	28	100
Human Anatomy	25	89.2
Human Physiology	23	82.1
Anatomy and Physiology I	5	14.8
Anatomy and Physiology II	1	3.5
Other*	1	3.5

*Did not specify the course

Table 4

Bioscience courses that contained cardiovascular content during BSN program (n=28)

Course	Number of Students	Percent of students
Biological Science	7	25
Pharmacology	10	64
Pathophysiology	19	67
Human Anatomy	22	78
Human Physiology	17	60
Anatomy & Physiology I	3	10
Anatomy & Physiology II	1	3
Medical Surgery I	14	50
Medical Surgery II	11	39
Microbiology	1	3

Table 5

Cardiovascular system content covered during BSN Program (n=28)

Content	Number of Students	Percent (%)
Cardiovascular Anatomy	16	57
Cardiovascular physiology	9	32
Specific diseases*	3	11
Medications/Pharmacology	11	39
Treatments/Nurse Driven Practices	9	32

*Congestive heart failure, Aneurysms, dysrhythmias, cancer

The scenario survey was administered electronically in the following two weeks. The survey consisted of four scenarios that were generated from the results of phase I of the study (See Appendix C).

Design of the Study and Qualitative Approach

The study was designed following the constructivist perspective. This paradigm "assumes a relativist ontology (there are multiple realities), a subjectivists epistemology (knower and respondent co-create understanding) and a naturalistic methodology ([set] in the natural world" (Denzin & Lincoln, 2000, p. 21). The multiple realities in this study were both the participants' perspectives on their use and understanding of CVS content and the researcher's perspective interpreting their use and understanding. The subjectivist epistemological views of the study were aligned with its constructivist design which allowed the continual analysis and interpretation of the interview and open-ended scenario questions. This contributed to the generation of the major concepts the expert participants' used and the student participants' understanding of these concepts.

Institutional Review Board and Data Storage

The research study gained IRB approval. Permission letters from both hospitals and the nursing course instructor was obtained (See Appendix D). The letters' purpose was to describe the study and provide evidence that each hospital approved of the use of the participants. Written consent from all of the expert nurses and nursing students was obtained prior to the interviews or administration of the open-ended scenarios. All consent forms, digital audio files, survey responses and researcher journals were kept on a secure, password protected server or locked filing cabinet following the final data collection of the study.

Data collection

When using a qualitative approach, Yin (2009) suggests three key principles when collecting data: a) use of multiple sources of evidence; b) create a data base and c) maintain a chain of evidence. The multiple sources of data used in this study were interviews, a researcher journal which includes memo writing and scenario responses. The data base was created using Nvivo software (QSR International, 2008) and kept an audit trail to maintain a credible chain of evidence. The audit trail will be discussed more in the Trustworthiness section.

Phase one of the study (see Figure 1) consisted of interviewing the expert nurses to understand what CVS concepts they used in their practice. Interviews lasted between 45 and 60 minutes. Interviews served as the primary data source for research questions 1 and 2. Phase two began with the creation of the authentic scenarios from the responses during phase one. The scenarios were given to a panel of experts consisting of science educators, nursing educators and physiologists. The scenarios were refined and modified until approval was given by the panel. Administration of the scenarios was done electronically in the survey program Qualtrics. Responses were the primary data source for research question 3.

Interviews. This study involved multiple nursing experts who each have a different background and different experiences which in turn lead to multiple views of reality. The use of interviews is one way to access these multiple realities (Stake, 1995). In understanding the different CVS concepts which the nurses used, the interviews were the primary data source. The interview consisted of questions that elicited demographic information and stories about common patient cases and one case which stretched the nurse's knowledge of the cardiovascular system (See Appendix E). Specifics of the patient cases were not sought with only the descriptions of the diseases and treatment regime being of interest.

Memo Writing and Researcher Journal. An electronic researcher journal was kept based on the subjectivist perspective. The journal was a means for the researcher to reflect on the research process, any personal bias and potential insights into interpretations. The journal also served as a place to memo write during the analysis phase (Glaser & Strauss, 1967). The researcher journal was a means to get ideas down and to "tap initial freshness and to relive conflict" (Lincoln & Guba, 1985, p. 342).

Data Analysis

The constant comparative method of data analysis (Boeije, 2002; Denzin & Lincoln, 2000; Glaser & Strauss, 1967) was used for both phases of the study. The constant comparative method establishes analytical distinctions in the data and makes comparisons at different levels within the project (Charmaz, 2006). For example, codes and categories are created and compared within one interview as well as compared between different interviews. Thus, codes created in one expert nurse's interview were compared internally and to other expert nurse's interview. Taylor and Bogdan (1984) summarize the constant comparative method as "the researcher simultaneously codes and analyses data in order to develop concepts; by continually comparing specific incidents in the data, the researcher refines these concepts, identifies their

properties, explores their relationships to one another, and integrates them into a coherent explanatory model" (p. 126).

Data analysis of Phase I began immediately after interviewing the first expert nurse. The interview was transcribed verbatim and the interview transcript was open coded to create broad, general concepts that appeared in the data. Initially, 31 general concepts were identified in the researcher's journal from the four expert nurses' interviews. Examples of these open codes were disease and disorders, cross-discipline knowledge, advice, drugs, drug actions. The researcher journal was used during this time to note similarities, differences and questions pertaining to the initial concepts identified. An illustrative example is,

When coding for the CVS, should I include the diseases and anatomy in the content, concept code? The experts report that they learned about them but not that they are important. Does the mere mention of them mean they are important? Perhaps when they are used in context later in the interview.

Experts also report that their nursing school did not prepare them for the real world. This does align with the literature but I wonder how many alternative conceptions they have about the material. I have not seen papers on nursing specific misconceptions. They are always lumped into the undergraduate category. I feel that Gary made a good point that A&P should be split into future practicing nurses, docs etc. and the academic biologists who take the course for fun or due to interest. (Researcher journal, January, 22, 2014)

After the initial coding was completed, a second round of coding began to condense the open coded concepts into similar categories. This second round of coding condensed the 31 concepts initially identified into nine categories. Examples of these categories were heart physiology, heart anatomy, CVS interaction and vessels. Some of the initial open codes were excluded from the study during this second round of coding due to being irrelevant to the study's research questions. Examples of these were advice, courses taken, course activities,

career trajectory. A third round of coding followed with the condensing of the nine categories into the final five conceptual categories.

Once the final five categories were identified, the interviews were again analyzed using the constant comparative method but this analysis centered on research question 2. This analysis began by using the five important concepts from research question 1 as a guide. Instances of each of the concepts were noted in all of the expert nurses' interviews. These instances were compared and noted in the researcher journal and a synthesis of the application of their knowledge was created. The following excerpt from the researcher journal illustrates the synthesis of this analysis.

Knowing that types of tools to use to get a quick treatment or stabilization of the patient (returning to homeostasis or as close as you can get to homeostasis.) It could be that I just did not stress the need for CVS knowledge and the participants wanted it to be more practice based.

Nurses describe an application of the knowledge but the knowledge they practice often is what they remember, not the specific. They don't need to know how the blood perfuses, just that they need to get it back to homeostasis. They apply their knowledge of why this needs to be a healthy state (learned A&P knowledge) to the situation in conjunction with their pharmacological knowledge to reverse the disease state or the non-homeostasis state. ex. The lungs are full of fluid due to some damage to the heart from CFH. In order to get the lungs clear they use medications such as Lasix. They cannot undo the damage to the heart but they can keep the patient alive and comfortable through medication. Patient manages their new state through the use of long term medication or surgical intervention (Researcher journal, February 8, 2014).

The results from Phase II's scenarios were analyzed using the constant comparative method as well. The nursing students' responses to each question or question set were compared to understand the alternative conceptions for those specific concepts addressed in the scenario. The responses were then grouped into categories based on response similarity. These categories were then condensed into broader categories which were exclusive to the individual scenarios.

The alternative conceptions from each scenario were then compared to produce alternative conception categories for the entire instrument and to identify any overarching alternative conceptions. Comparisons between the results of each phase were not made due to each phase's results answering separate research questions.

Trustworthiness

In any qualitative study it is the job of the researcher to ensure the trustworthiness of the study. Lincoln and Guba (1985) suggest that a trustworthy study will “persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of” (p.290). Within a quantitative paradigm there are four criteria that must be met in order for a rigorous study. These criteria are internal validity, external validity, reliability and objectivity. Qualitative methods also have these criteria but they are labeled as credibility, transferability, dependability and confirmability (Lincoln & Guba, 1985). What follows is a discussion on how this study meets all of these criteria

Credibility. A credible study answers the question “are the results an accurate interpretation of the participants’ meanings” (Creswell, 2007, p. 206)? In order to answer this question the use of triangulation, peer debriefing and member checking were used.

Triangulation (Lincoln & Guba, 1985; Merriam, 1998; Patton, 1990) occurs when the researcher “uses multiple and different sources, methods, investigations and theories to provide corroborating evidence (Creswell, 2007, p. 208). In this study, interviews of multiple expert nurses, the nursing students’ responses to the open-ended scenarios, constant comparative method of analysis and the researcher’s journal, specifically the memo writing, provided corroborating evidence.

During and after the creation of the scenarios peer debriefing with colleagues and doctoral committee members provided an external check of the research process. Lincoln and

Guba (1985) define a peer debriefer as “devil’s advocate” (p. 308) to keep the researcher honest. Member checking (Lincoln & Guba, 1985) of the scenarios and the CVS concepts with the expert nurses also provided credibility to the study.

Transferability. Transferability is the process which “provide[s] only the thick description necessary to enable someone interested in making a transfer to reach a conclusion about whether transfer can be contemplated as a possibility” (Lincoln & Guba, 1985, p. 316). The descriptions need to “describe in detail the participants or setting under study. With such detailed description, the researcher enables readers to transfer information to other settings” (Creswell, 2007, p. 209). The data sources contributed to the description of each of the phases.

Dependability. Multiple data sources previously discussed were used to make the study dependable. Interviews were transcribed verbatim from audio recordings to ensure reliability. Students’ responses to the open-ended questions were left in the voice of the participant.

Confirmability. The use of an audit trail as suggested by Halpern was used to ensure a confirmable study (Lincoln & Guba, 1985). The audit trail for this study is as follows:

1. Raw data- digital interview recordings, researcher’s journal, students’ responses to the open-ended scenario questions.
2. Data reduction and analysis products- memos and hypotheses written in the researcher journal and unitized information coded in NVivo.
3. Data reconstruction and synthesis products- themes, codes and relationships as well as final written product
4. Process notes- notes and memos written in the researchers journal surrounding trustworthiness
5. Materials relating to intentions and disposition- research proposal and predictions or personal notes in research journal.

6. Instrument development- interview protocols and scenario development notes in researcher journal

Based on the above discussion, the study is trustworthy due to making it credible, transferable, dependable and confirmable.

Qualifications of the Researcher

The current study follows the qualitative tradition of research and so the researcher brings their experience to interpret the data. My interest in A&P started in high school when I took it as a science elective during my Junior year. During my undergraduate I took A&P I and A&P II as well as a combined Human Anatomy and Physiology course. The CVS was taught during each course with A&P II providing an in depth focus on the CVS physiology.

During my masters graduate work I took a Vertebrate anatomy course which provided an in depth description of the evolution of the CVS. The course described the single circuit CVS of *Gnathostomes*, *Chondrichthyes* and *Osteichthyes* as well as the double circuit in *Aves*, *Reptilia*, *Amphibia* and *Mammalia*. During this time I became a teaching assistant for the laboratory sections of Vertebrate anatomy and A&P I. I also became the instructor of record for multiple sections of A&P I and II laboratory where I taught the anatomy and physiology of the CVS.

During my doctoral work I was involved with both qualitative research projects and evaluation work which was qualitative in nature. These experiences provided the opportunity to create data collection tools and gain experience in qualitative data analysis. I also enrolled in a two qualitative methods courses which provided me a foundation in the research tradition. The first course required a research project where I further honed my qualitative researching skills.

Chapter Summary

The purpose of this chapter was four-fold. First, the research questions were presented. The study aims to answer three main research questions. The first question deals with identifying the important CVS concepts expert nurses use in their daily practice. The second question investigates how the nurses use the important CVS concepts while the third research question identifies the CVS alternative conceptions nursing students have after instruction.

Second, the participants and context of the study were described. The participants of the first phase of the study were expert nurses who worked in either the cardiac ICU or the ER of two hospitals. The experience level of the nurses varied from 30 years to less than one year. The level of education varied with one participant having a Master's degree in nursing while three had two year degrees.

The second phase of the study involved nursing students enrolled in their final semester of their nursing program at a large, Midwestern university. All of the students have similar preparation in the CVS through a regimented plan of study. A total of 28 nursing students volunteered with 15 filling out the final survey.

Next, a description of the two phases of the study was presented as well as a rationale for a qualitative approach. Data analysis follows the constant comparative method with codes being compared within subjects as well as across the group. Finally, a description of the trustworthiness the study was offered with the areas of credibility, transferability, dependability and confirmability addressed and the qualifications of the researcher were presented.

CHAPTER FOUR: RESULTS

The results of the study are organized by the phases of the study. The first phase of the study involves interviewing expert nurses to understand the important CVS concepts they used in their practice. The second phase of the study centers on nursing students' responses to open-ended scenarios.

Phase I: Interviewing nursing experts

The following will present the five major thematic CVS concepts that the nursing experts use in their daily practice. These concepts are broad categories that the nurses learned during their course work, work experience and continuing education classes. The five major concepts are: a) cardiovascular anatomical concepts; b) cardiovascular physiological concepts; c) homeostasis and diseases of the CVS; d) the interdependence and interaction of the CVS with other organ systems and e) the intersection of the CVS and technology in patient diagnosis and treatment. Each of these concepts contains support from all of the expert nurses.

Cardiovascular anatomy concepts. Nursing experts described common CVS diseases and from those descriptions important anatomical concepts were identified. These anatomical concepts centered on two general areas: a) heart anatomy and b) vessel anatomy. The heart anatomy concept consisted of both sides of the heart, the chambers and valves and the structures responsible for the heart's electrical conduction. The vessel anatomical concept was broken down into coronary vessels and pulmonary vessels. The experts did not specifically mention systemic vessels since many of the common CVS diseases do not involve them. This does not mean that the nursing experts do not deem systemic vessels as important but diseases which involve the coronary or pulmonary vessels are more life threatening than systemic vessels with the exception of the aorta.

The language of anatomy is used throughout all of the major concepts that the nursing experts identified. When referring to diseases or areas of the body, the nurses used their anatomical knowledge to describe the regions or sides of the CVS. The study of anatomy could be considered to have its own language and it is no surprise that the nurses assimilated the language of anatomy into their own vernacular.

Heart Anatomy Concepts. The important heart anatomical concept deals with general structures and areas of the heart that the nursing experts revealed through their stories about fictitious case scenarios. No expert provided a list of specific structures that nursing students should know, but through their stories and descriptions of patients it became clear that knowing the different sides of the heart and where blood went after passing through that side was important. Gary told a story dealing with a patient who had a heart attack. “So if you have damage on the right [side of the] heart what does that look like clinically? If you have damage to the left [side] heart, what does that look like clinically” (Interview, January 20, 2014)? Knowing the clinical appearance of a left or right heart problem is important to Gary because, “where the damage is to the heart and is this a left heart where fluid might be a big issue or is this a right heart problem where they might need fluid to support them” (Interview, January 20, 2014)? Depending on which side of the heart is affected, right or left, from the tissue death during a MI it will present different challenges for nurses.

Tom spoke about understanding heart anatomy because knowing the anatomy of the heart allows him “to dart them to get some of the fluid out. Means you are going to stick something in there and release something in there. The person may have some tamponade in there, might have to stick their pericardial sac” (Interview, January, 27, 2014). The pericardial sac is a structure which protects the heart and has fluid which reduced friction from heart

contractions. In some cases it becomes infected and excess fluid needs to be removed or medication can be injected into the space between the heart and the pericardial sac. Knowing where the pericardial sac is allows Tom to administer the procedure and treat his patients.

Understanding the anatomy of the heart was important for Claire because it allowed her to understand the electrical conduction system of the heart in a disease state. Claire described the difference between the diseases super ventricular tachycardia and atrial fibrillation as “The [sinoatrial] node is firing a lot and the ventricles are responding where as in [atrial fibrillation] they are not” (Interview, February 18, 2014). Claire knows that the SA node is involved with contraction and that the signal is sent to the ventricles where they “respond”.

Sarah referred to heart anatomy, specifically the heart valves, when speaking about a patient presenting signs of a STEMI.

Sarah: They could have a valve issue thrown in on top of [the STEMI] which will complicate that problem. If the muscle isn't pumping the valve is defect[ive] it is not going to get that supply as well.

Interviewer: What are some valve issues that you see?

Sarah: Mitral regurg, tricuspid issues, aortic valve those are the biggies.

Interviewer: When you say tricuspid or aortic is it that they just don't close? Is that the problem?

Sarah: It could be that they are stenotic which means they are stiff, calcified or they could be loose and floppy. Those are problematic. (Interview, January 30, 2014)

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Sarah uses her knowledge of the structures of the heart to understand complications that can occur when a patient has a STEMI. She describes three different valves in the heart: a) mitral, b) tricuspid and c) aortic and how they can become calcified or stiff. The

description of the valves conveys a specific part of the heart which is affected and some potential abnormalities which occur.

Vessel anatomy concepts. An important anatomical concept was the coronary vessels and where they connected to the heart. The reason this was important is because the heart attacks are a common problem that all of the expert nurses spoke about during the interviews. A blockage or occlusion of the coronary vessels is a common cause of a heart attack. The major systemic vessel which was mentioned by the nursing experts was the aorta. Even though a majority of vessels were not mentioned by the nursing experts this does not mean that they are unimportant but that many problems seen in the cardiac ICU or ER are from coronary vessels or the aorta.

One term that many of the expert nurses described was the “widow maker.” Sarah described the widow maker as, “the left anterior descending artery and the left veins supply the left ventricle which is the power house. So those have been named the widow maker. As in if you don't get that treated right away then they are gone” (Interview, January 30, 2014). Tom also mentioned the widow maker when describing a heart attack patient's occluded arteries, “sometimes it is more than one vessel. Sometimes it could be two, three vessels. Or sometimes it is the main vessel that goes down, the widow maker, the big anterior descending” (Interview, January, 27, 2014). In both of these cases the vessel they described was the left descending coronary artery and if problems arise in it, such as an occlusion, then it is a priority to get them to the cath lab because the patient has a high probability of not surviving. Since the widow maker is potentially lethal, it is important for the nurses to understand where the vessel connects and resides anatomically.

Gary spoke of coronary vessels in general when describing important structures to understand while working with cardiac patients who suffered a MI. "If you are talking about heart attacks the big things ones are the vessel, the coronary arteries. Where vessels are, is it right main, left main, circumflex. What are we talking about? What vessels and where they correspond on the heart and different presentations" (Interview, January 20, 2014). Gary is describing how nurses communicate while treating a patient and how it is important for the attending nurses to know where the "circumflex or left main" arteries are because if the nurses do not know where the vessel are housed then it could potentially delay treatment. Later, Gary gave an example explaining the difficulties new nurses encounter when working with patients due to being ill-prepared during nursing school.

As far as nursing school goes I wasn't prepared and I can tell you of my perception of other people, and what other people have said is that...There are seven or eight of us started as new graduate at the time and really you could tell that people are worried and people say 'oh a 100% circumflexion inclusion' people say what is a circumflex? People really don't know that stuff and even for me, I have a limited knowledge based on work experience (Interview, January 20, 2014).

Gary knows that understanding the anatomy of the coronary vessels is important because when communicating with fellow nurses he uses these terms to describe a patient's condition.

The use of anatomical terms and CVS concepts is an important one for understanding diseases and the regions of the heart which are affected. Cardiovascular anatomy is also important for communication between nurses while working on a patient. The expert nurses all incorporate anatomical terms into their vocabulary and daily practice. For Gary, it was difficult at first to remember where specific structures were on the heart. He retold a story of novice nurses not understanding where the circumflex artery was located. He also understood that knowing which side of the heart

was affected in a MI was important because patient will present different symptoms depending on which side is damaged.

Sarah and Tom both spoke of the term “widow maker” in response to coronary vessels which cause major problems to patients. If this vessel is affected than it is a life and death situation since the left descending coronary artery is a major vessel which supplies the heart itself with oxygenated blood. If nurses did not have anatomical knowledge of the CVS then they may not understand the urgency of the situation and treatment could be delayed. The language of CVS anatomy is important because it describes structures in the body which the expert nurses deal with on a daily basis. It also serves as the basis for the nurses’ vocabulary when they are conversing with each other. Sarah summed up how she uses CVS anatomy by stating, “well, you have to know the structure so you can figure out how all of this plays into it, how all the physiology. If you don’t know the structure, the physiology won’t make sense” (Interview, January 30, 2014). This suggests that anatomical concepts form the foundation for other concepts that expert nurses’ use in practice. Throughout this section, more anatomical terms will be used in conjunction with other concepts identified by the nursing experts.

Summary of cardiovascular anatomy concepts. The important CVS anatomy concepts centered on heart anatomy and vessel anatomy. The expert nurses did not list important anatomical concepts for each of these areas but their stories revealed that understanding heart anatomy such as which side of the heart was damaged from a heart attack or that the heart is surrounded by a pericardial sac allowed them to better care for their patients. The expert nurses expressed the importance of knowing the coronary vessel anatomy because one of the major cases they see is a blockage of the

left anterior descending coronary artery or widow maker. A quick diagnosis and understanding of the urgency is of utmost importance in these cases because a blockage in the left anterior descending coronary artery is usually fatal if left untreated.

Cardiovascular physiology concepts. Another important concept that the expert nurses identified centered on some of the physiological mechanisms of the CVS. This concept emerged from the nurses' stories about their patients as well as the nurses' descriptions of diseases which affect the CVS. The nurses did not define the physiological processes but would speak to how they were related to the CVS, particularly in relation to the disease state. This broad concept of CVS physiology is subdivided into two areas: a) heart physiology and b) systemic physiology. This division closely resembles the division seen in the CVS anatomical concept. Heart physiology contains processes which occur in the heart while the systemic concept consists of processes which are found outside the heart in the rest of the body

Heart physiology concepts. The major concept that the expert nurses spoke of pertaining to heart physiology was the notion of the heart's cardiac output (CO). Tom described CO as, "so typically your heart beats and every time it beats and squeezes it sends a burst of blood through your body. That's called cardiac output" (Interview, January, 27, 2014). This process is important because as the blood is being ejected from the heart it circulates throughout the body and delivers oxygen to the surrounding tissues. If a patient's CO is low then complications can arise which the attending physician and nurses need to treat. Tom explained some complications when he described a congestive heart failure patient. "You (the patient) don't have contraction force, your cardiac output is decreased. Your body is being forced to move the fluid somewhere else besides the cardiovascular system. Your heart isn't strong enough to move it and they go into pulmonary edema or start backing fluid up into their lungs"

(Interview, January, 27, 2014). Tom understand the relationship between a strong heart contraction and a normal CO which circulates the blood and prevents edema forming in the lungs.

Sarah feels that CO is important to understand because she uses it to calculate a patient's cardiac index. "Well, you have your cardiac output and it means this. But you need to know your cardiac output is your heart rate times your stroke volume and where does that come from? You can't just pull it out of your hat... your cardiac index is based on your cardiac output divided by your BSA (body surface area)" (Interview, January 30, 2014). The cardiac index relates the performance of the patient's heart to their size, in other words is the patient's heart working well enough to supply blood to their body. If the heart is not performing well enough then the nurses will need to treat the patient with medication to increase the contraction rate of the heart.

Gary brought up other physiological concepts related to CO when relating a story about a heart attack. He briefly mentions the physiological process of pre-load and the Starling effect. "The right heart we talk about preload and the Starling effect, fluid load when our right heart is affected [by a heart attack]" (Interview, January 20, 2014). Preload is the end diastolic pressure that stretches the ventricles to their maximum dimension under the current physiological demand. It is important to understand preload because as more blood enters the heart's myocytes (heart cells) stretch which increases the pressure in the heart and subsequently increases the contractile force of the heart, thus increasing CO. Sarah also mentioned Starling's Law while discussing a patient with an enlarged ventricle. "I know you (the researcher) are familiar with Starling's Law. So if you diurese and get rid of all that fluid that heart cannot pump effectively since it is used to all of that stretch so that is where you have to consider

adding something like dobutamine or something that will help with the pump action of the heart or your contractility of the heart" (Interview, January 30, 2014). In order to understand how to effectively treat a patient Gary and Sarah use their understanding of Starling's Law and preload while administering medication and how the patient is affected by a heart attack.

Systemic physiology concepts. The systemic physiological concepts are processes which take place outside the heart but are related to the CVS. This does not mean that some of the physiological process cannot occur within the heart but the expert nurses identified these as external to the heart itself. Three physiology concepts garnered attention from the nursing experts: a) perfusion in the body; b) blood clotting; and c) blood pressure. Many other processes were discussed in the context of a disease state and will be seen throughout the important thematic concepts

Perfusion in the body. One of the many functions of the CVS is to circulate oxygen-rich blood to the tissues of the body. Nursing experts repeatedly spoke of "supplying oxygen to tissues", "gas exchange" or "perfusion." Tom discussed perfusion in the context of a heart attack as, "when you lose cardiac output [because of a heart attack] your kidneys aren't being fed, aren't being perfused. [During] perfusion a multitude of things are taking place. Your red cells going and dumping oxygen. They are also picking up waste, metabolic waste and toxin and carrying them to the kidneys for disposal" (Interview, January, 27, 2014). Tom relayed that nurses monitor perfusion through the testing of arterial blood gases (ABG). The importance of perfusion can be seen in a story about dealing with a patient during a busy time in the ER. Tom said,

Oh yeah, the other day one of my patients, new patient just came in. Wasn't my patient, I was in triage and I floated back for a second to see if I could help because I wasn't busy. I got a critical patient in room Two and my doctor says 'hey man (referring to the attending physician) I got a bad patient here (Room

two). He (the attending physician) goes ‘Fix’em.’ So I go in there (room two) and I get everything initiated. Guy (Tom’s patient) is on two ivs in here. I want to oxygenation at an adequate level and through the right device. I want RT down here so I need to get an ABG. We need blood cultures. We need these labs, we need to position this patient so she can breathe (Interview, January, 27, 2014).

The first thing Tom does is to measure the oxygen level of the patient to ensure that there is an adequate supply of oxygen. Oxygen is critical for the patient’s survival because the CVS circulates the oxygen and the body needs oxygen to survive. Even though Tom did not specifically mention perfusion it can be implicitly understood that perfusion is a top priority for Tom to treat this patient.

Gary spoke about “relating supply and demand, tissues, and oxygen demands into the clinical picture” as important because “tissue starts dying” (Interview, January 20, 2014). Claire adds, “blood flows everywhere. You are not getting blood flow to heart, not going to get oxygenation anywhere else for much longer” (Interview, February 18, 2014). Sarah said, “it (decreasing the flow of blood to a system) depends on the perfusion the heart can send to those systems. Those are the vital ones (organ systems). The heart will shut down peripherally before it will shut down there (the brain). Like your gut [will shut down first]” (Interview, January 30, 2014). Knowing the process of perfusion, the importance of it and that the body can divert blood towards more vital systems allows the expert nurses to understand how the body is reacting to a disease and how to begin or continue treatment.

Blood clotting. When the CVS is damaged a cascade of chemicals is released to clot the blood. When working with cardiovascular patients it is important to manage this process because if the clot is large enough it can prevent blood from flowing through the vessels or if the clot becomes dislodged it can travel to other systems and cause strokes or pulmonary embolisms. Tom supported the urgency when he spoke about patients he sees in the ER on a regular basis with damaged hearts. “You got white blood cells moving into the area, fibrin and

fibrinogen moving into the area to form clots [be]cause this is a damaged area. You have to get on top of their anti-coagulation to make sure they don't form a clot and throw it off and lodge it in their lungs or their brain and leave them unfortunately dead" (Interview, January, 27, 2014).

Claire emphasized worrying about a patient having blood clots which can lead to a stroke though it was in the context of a patient exhibiting atrial fibrillation.

So the SA (sinoatrial) node is firing, the [atrioventricular] node is not acting correctly. The atrium are just spasming on their own. Not really pumping blood effectively. It (the blood) can pool there and form clots and this is why people are on Coumadin (an anti-coagulant) if they have A fib... Clots can form so a lot of time a fib can lead to a stroke (Interview, February 18, 2014).

Sarah also spoke of "throwing a clot" and blood clots as a possible cause of a heart attack. "They (her patient) either got a clot, sometimes it is a blood clot, sometimes it is a cholesterol, that is narrowing a vessel on the coronary arteries which is what supplies blood to the heart muscle itself. He has muscle dying and time is muscle. So you gotta act quick, got to be quick" (Interview, January 30, 2014). Sarah's summation of "time is muscle" really gets to the crux of working with a cardiac patient because the decisions she makes and the time it takes her to understand the physiology can affect the extent of damage a patient has suffered. If she makes quick decisions she can lessen the damage or if she makes decisions slowly she can increase the damage.

Blood pressure. Monitoring a patient's blood pressure is important and is part of any nurse-driven practice for treating cardiac patients. Understanding blood pressure is important and the nurses spoke candidly about patients being hypotensive or hypertensive. Tom spoke about diabetes and having a "heredity illnesses like hypertension or diabetes" or asking patients if they are "suffering from hypertension and diabetes" (Interview, January, 27, 2014) in his initial health consultations. This allowed Tom to gain an understanding on their current conditions of his patient and how this would affect his healthcare decisions.

Gary used the terms as descriptors when describing his fictitious patient scenarios. "CHF patient is coming we almost immediately think breathing because they normally are hypertensive... We can decrease pulmonary hypertension, we can make them better for a little while but what is the ultimate care for people with this disease" (Interview, January 20, 2014)? Sarah also used blood pressure in describing a patient "his bp is up, down, whatever" (Interview, January 30, 2014). Claire also views blood pressure as a descriptor as seen in the following portion of her interview about atrial fibrillation:

Interviewer: Is their BP elevated, are their lungs wet?

Claire: Usually not, no. They come in with the same symptoms as a STEMI.

Interviewer: So they are not hypertensive or hypotensive.

Claire: Usually not (Interview, February 18, 2014).

Claire's responses to the questions suggest that she would have taken the patient's blood pressure but it was not abnormal. This reinforces the notion that taking a patient's blood pressure is a nurse-driven practice and understanding the measurement and how that relates to physiology is important.

Summary of Cardiovascular Physiology Concepts. The important CVS physiological concepts centered on two areas, the heart itself and the systemic portion of the CVS. Similar to the important anatomical concepts, the nursing experts did not explicitly define these concepts but through their descriptions of their fictitious patients several processes were important. The nurses use their understanding of these processes to understand their patient's individual symptoms and to plan a course of treatment for them. Two general areas arose from the nursing experts' stories: Heart physiology concepts and systemic physiology concepts. The heart physiology consisted of cardiac output, Starlings Law (effect) and pre-load while the systemic concepts focused on blood clotting, blood pressure and perfusion of the body.

Homeostasis and diseases of the cardiovascular system. The third concept that the expert nurses deemed important was normal physiological conditions (homeostasis) of the CVS and how diseases cause deviation. The nurses viewed the patients as having a normal (disease-free) state and their job is to identify the deviations from this normal state (problem patients were describing or exhibiting) and returning them to homeostasis or that normal state. This view coincides with Cannon's definition of homeostasis as "the stabilization of bodily states" (Cooper, 2008, p. 424).

Through the interview process none of the expert nurses specified knowing specific numbers, such as normal blood pressure being 120/80, but to quickly assess a patient's state and understanding that their blood pressure was elevated followed by deciding what interventions needed to be done to lower the patient's blood pressure. In other words, nurses need to interpret patient's test results or symptoms in the context of known standards to ascertain interventions to return patient to homeostasis through those interventions.

Claire demonstrated her knowledge of CVS homeostasis and a disease when she disclosed information pertaining to super ventricular tachycardia during a particularly difficult case to treat.

Claire: I had one of these today actually. It is where the ventricles are pumping way too fast or are just out of control and usually their heart rate is sometimes being close to 200. It is an emergency.

Interviewer: How do you treat them?

Claire: Same [symptoms] that we did for the others. EKG, chest x-ray, IVs. Usually with those we get bilateral IVs because you are shocking them and you have to give them some drugs which stop their heart for a few seconds and then restart it.

Interviewer: With the Super Ventricular Tachycardia, besides having your heart pumping fast what else is going on in the cardiovascular system? Is there anything else?

Claire: As far as the electrical system?

Interviewer: Yeah if that is involved then you can talk about that.

Claire: I don't really remember honestly. The SA node is firing a lot and the ventricles are responding... We shock them or we push a drug called adenosine. That stops the heart for a few minutes and hopefully restarts it in a nice sinus rhythm. Most of the time they do go home, sometimes they stay for observation overnight. Mine were young people who went home. they were in their 20s.

Interviewer: Do you know what cause this to happen?

Claire: I don't. I really don't. I think there might be a genetic factor to it. I am not for sure on that at all (Interview, February 18, 2014).

Here Claire understands that having a patient present a heart rate of 200 is abnormal (the body is not in homeostasis) and is something she needs to address quickly to successfully treat the patient. Claire uses her knowledge of what a normal heart rate should be to devise treatment methods, in this case the use of an EKG, chest X-ray and IVs. She also knows that one way to regain a normal sinus rhythm is to shock the heart with a defibrillator. She may not completely understand exactly how the disease progresses or a reason why the patient has super ventricular tachycardia but she knows that getting the patient back into homeostasis is her first priority.

The notion of homeostasis and disease was reiterated when Claire spoke about common disease she sees in the ER. She brought up a STEMI as a common disease and the associated symptoms she sees in patients.

Interviewer: What is a STEMI?

Claire: A heart attack, there is a blockage and the heart is not getting oxygen. ST elevation. [The patient] need[s] to get to cath lab. Usually [symptoms] are pressure radiation to the left arm, jaw, neck, sweaty, short of breath, nausea.

Interviewer: In this STEMI, what is going on in the CVS?

Claire: There is a blockage of some kind and the heart itself is not getting good blood flow, oxygenation. it is getting ischemic (Interview, February 18, 2014).

Claire understands that when patient enter the ER they present symptoms that people in homeostasis do not. These include pain in the left arm, a blockage in a vessel and lowered oxygen levels in the heart tissue. The knowledge of the symptoms for a person who has had a STEMI combined with her CVS knowledge of perfusion, flow of blood and a blocked vessel allow her to treat this patient effectively.

Tom spoke of homeostasis and diseases for a specific disease, congestive heart failure, as well as on a more holistic or systemic level. Tom uses his knowledge and experience as an ER nurse to describe what is going on in the CVS when a patient is diagnosed with congestive heart failure and how the disease affects cardiovascular physiological processes in the following interview passage.

Interviewer: Let's focus on the congestive heart failure. When you are thinking congestive heart failure what is going on in the CVS?

Tom: There pump is pooped. their heart muscles have been stretched out so long over a lifetime of abuse because of fluid overloaded some folks have had some drug interactions like cocaine to cause the heart to crank down to stretch those striation out they don't have good contraction. They get those boggy hearts. Those patients are very weak. These patients are fragile for lack of a better word. Water can kill them because they heart can't move it in their vascular space. You don't have contraction force; your cardiac output is decreased. Your body is being forced to move the fluid somewhere else besides the CVS. Your heart isn't strong enough to move it and they go into pulmonary edema or start backing fluid up into their lungs. Third spacing that fluid, putting fluid where they can put other than in the CVS. This causes other problems.

Interviewer: When you see this type of patient what are some treatments you would go through. They are admitted to the ER, what is the first thing you would do?

Tom: We are going to want to get some fluid off of them. give them some Lasix, long term medication to help with that. With good ionotropic and chronotropic effects would be like put them on Digoxin to increase the force of contraction. Slow their rate down. They may end up themselves on antidysrhythmias depending on whether their heart has changed rhythm or not because of the force that has been put upon them. Everything wears out in the body so I am

going to look for measure, oxygenation issues, are they perfusing well, are their pressures holding because the cardiac out is decreased or their BP is keeping a good mean of 60 so we can profuse the rest of the organs. We are going to look at moving the fluid off with diuretic therapies, life style changes (Interview, January, 27, 2014).

This illustrates how Tom uses his knowledge of the normal CVS conditions and the deviations from this to understand the patient's condition. He speaks about having weak heart contractions due to over stretching of the ventricles from increased fluid volume and having decreased cardiac output. Since the heart is not ejecting enough blood with each contraction the patient is moving fluid elsewhere in the body such as the lungs. He then describes a regimen of treatment options for this patient such as a diuretic, life style changes or anti-dysrhythmia to bring the body back to homeostatic (normal) conditions.

A list of important concepts generated by academic physiologist was presented to Tom and he was asked to rate which concept was the most important in regards to the CVS (See Appendix E). Tom ranked homeostasis as the most important concept and described how it pertains to not just the CVS, but to other systems as well.

Tom: A lot of this stuff (the concept list) is very important. I believe that I will go with those six.

Interviewer: You said homeostasis is probably your number one.

Tom: Absolutely.

Interviewer: How does that pertain to the CVS in your line of work?

Tom: Homeostasis is an equilibrium that is met to achieve a perfectly tuned instrument. Everyone needs to be in exact homeostasis. Not one part of that engine can be off. If your renal system is off, you cannot have cardiac homeostasis. If your liver is off you can't have good cardiac homeostasis. If your lungs are down, you certainly cannot have good and if you're obese you have heredity illnesses like hypertension or diabetes all of that stuff affects your homeostatic condition of the body. It really starts with the CVS so the first thing that is affected a lot of times is your CVS. Luckily it is such a grand system it compensates and hides all of this stuff for years. Your renal system is going

down and it see that and goes ‘hell, well we (the heart) will pump a little harder and force that fluid out of the vascular space’, you’ll have swelled up feet but you’ll have good homeostasis (Interview, January, 27, 2014).

Tom views homeostasis as a normal, healthy state in which it is his job to return them to this state by treating their symptoms. He uses the example of how deviations in other organ systems can affect the CVS. If the renal system is not working properly (homeostasis) then the CVS will increase contraction and move the fluid out of the vessels and into the feet. Through the use of the engine analogy it illustrates that Tom views his job as returning a patient back to a normal, homeostatic state similar to how a mechanic works on an engine.

Gary’s view of homeostasis and the CVS reiterates the notion that homeostasis is a normal standard state and nurses need to identify deviations from this normal state. Gary, similar to Tom, also ranked homeostasis as the most important concept from the list of major concepts that academic physiologist valued in regards to body physiology .

Interviewer: Looks like you have 5 of them. Let’s start with the number one. This is the most important and give me an example and how it relates to the CVS for you.

Gary: Homeostasis. Everything we talk about, the physiological function is based around homeostasis. So when people are sick is because something is not right. Not the status quo anymore. (Homeostasis is) probably the most important [concept] for people to understand. How do thing normally function and then when there is not homeostasis there is a problem.

Interviewer: How does that relate to the CVS? Can you give me an example for the CVS? You have touched on it but let’s reiterate it.

Gary: When you talk about fluid status, when fluid status is normal good flow and everything. [Nurses] talk about imbalances. So the heart is pumping okay, homeostasis. Left heart pump fails so we don’t have homeostasis anymore (abnormal state) causing fluid backup and that kind of thing (Interview, January 20, 2014)

Gary understands that when the heart is not contracting correctly the body is not in homeostasis so the body will modify function to compensate for these deviations. He describes understanding the normal physiology (homeostasis) of the CVS in order to understand diseases to aid him in successfully practicing as a nurse. The overarching concept of understanding deviations of normal body function is important in nursing practice.

Sarah spoke of homeostasis while ranking the important academic physiologist concepts. Sarah spoke of her learning and how she incorporates homeostasis into her practice and learning.

Well, you have to know the structure so you can figure out how all of this [physiology] plays into it. If you don't know the structures (anatomy), the physiology won't make sense and the whole deal of these two (anatomy and physiology) working together drives your causality and homeostasis. These are the basics [anatomy and physiology] and this [homeostasis and causality] is what comes from all of that (Interview, January 30, 2014).

Sarah sees anatomy and physiology knowledge as how the body functions normally, "the basics". She uses her knowledge of anatomy and physiology as the normal state of the body (homeostasis) and the deviations she sees in her patients are compared to this state. She then uses her knowledge of causality to understand what could be responsible for the patient's symptoms.

Summary of Homeostasis and Diseases of the Cardiovascular System. The notion of homeostasis was ranked by three of the four expert nurses as an important concept from the list of 15 important concepts generated by academic physiologist. All of the nurses viewed homeostasis as the normal, healthy state of the body. Patients enter either the cardiac ICU or ER describing symptoms from a cardiac condition. The nurses view these descriptions as deviations from the normal state and treat their patient to correct the abnormal state back to homeostasis.

All the expert nurses implicitly refer to their anatomical and physiological knowledge as the standard for a normal body. They then make decisions based off of evidence from tests such as x-rays, physical examinations and blood work to devise a treatment regimen.

The interdependence and interaction of the cardiovascular system and other organ systems. The fourth major concept which nursing experts relayed was the importance of how the CVS was connected to other organ systems. During the interviews, experts would disclose common patient diagnoses that they would see on a daily basis. The two systems most frequently mentioned were the respiratory system and the renal system. Physiologically, these two systems regulate the amount of fluid and waste products that are circulated in the body. The respiratory system lies adjacent to the CVS and plays an integral role in the pulmonary loop of the CVS. The renal system is the body's way of regulating fluid osmolarity and blood pressure through excretion of urine.

During the interviews the nurses were asked to reiterate some of their common patient cases or cases that they see on a daily basis. The nurses relayed stories of their time in either the cardiac ICU or ER specifically focusing on patient symptoms and the CVS.

Sarah described a patient who came into the cardiac ICU with a ST elevated myocardial infarction (STEMI) and was asked what systems besides the CVS are involved with this patient.

Sarah: The respiratory system is the initial one. [The patient's] shortness of breath and depending on how long they are having this [chest] pain. Some people wait way too long. I am having this pain for two weeks by then they could be having some respiratory system [involvement] based on which part of the heart is affected and which heart muscle is weakened as to where that fluid is going.

Interviewer: Could you describe for me the when the right side is weakened?

Sarah: The right side is weakened then for the most part they are going to be getting peripheral edema and their breathing is going to be bad cause it is backing up. Either side but more so the right side (Interview, January 30, 2014).

Here Sarah describes how if the right side of the heart is weakened or damaged that the blood will pool in the body and the fluid will third space into the tissues causing edema. The patient breathing is going to be hastened due to this fluid building up in their lungs.

Sarah also described a patient who came into the cardiac ICU with pneumonia which was brought on by the patient's congestive heart failure and third spacing fluid into the lungs which became infected.

Initially they (the doctors) are thinking pneumonia and I am thinking well this pneumonia could very well be driven by a bad heart. I always put the two together. One does not operate without the other and I always tell my patients that if your heart is not working well your lungs are going to be compromised and try to work with it. But in this case you don't know which came first. Quite honestly, the heart has led to the fluid buildup causing the pneumonia and the pleural effusion which is causing the friction run and the pain there...the combo of all of it is causing pain anyway. So your initial problem you are actually going to physically see is this patient struggling to breathe...You can't always go by the diagnosis they are telling you they are coming in with. You have to look at the whole picture. Just because they are having trouble breathing doesn't mean it is just pneumonia (Interview, January 30, 2014).

This patient's most pressing concern was the congestive heart failure but it was masked by the presence of pneumonia so looking at how the CVS and respiratory system are connected allowed her to order an x-ray which revealed both the pneumonia and congestive heart failure. She summed up the example by saying "You can't always go by the diagnosis they are telling you they are coming in with. You have to look at the whole picture. Just because they are having trouble breathing doesn't mean it is just pneumonia." The idea of looking at the "whole picture" gets to the point that all of the body systems depend on one another and when one system is affected by a disease the affects can be seen elsewhere in the body.

Tom reiterated the interdependence of organ systems and the CVS when describing a patient with congestive heart failure.

Problems like very edeminoous legs, weeping sores and blisters, shortness of breath, fatigue, slow hemoglobin and hematocrit because when you poop your heart out that much your heart beats for the rest of your body. You slow your thought process because your brain is being affected as well. Your kidneys aren't being fed as well. Your blood is shunted to your kidneys but your kidneys are no longer functioning at a high level because they are not being perfused with that great [mean arterial pressure] that we were able to produce when our heart had good striate and good forceful contractions. Their toxin build up in their body (Interview, January, 27, 2014).

Tom describes that the CVS is the key system in keeping the body alive. If the renal system does not get enough blood supply then toxin will build up in the body which will cause further problems. Here Tom also indicates that the nervous system, specifically the brain and thought processes will be slow since oxygen is not being delivered in large enough quantities. This reinforces the close association the respiratory system and the CVS have in delivering oxygen to the body.

Tom went on to describe the knowledge a nurse would need to care for a patient with CHF.

You need to have a whole gambit of knowledge to care for that patient. Not just CVS, that's the minimum. Fluid and electrolyte balance because these patients are fluid bloated and their electrolytes are out of whack. You need good pulmonary knowledge because they are backing up fluid into their lungs and essentially drowning themselves because their heart isn't strong enough and it is third spacing sometimes (Interview, January, 27, 2014).

Here Tom specifically indicates that the heart dictates the amount of fluid going into the respiratory system and if it is not strong enough to pump the blood out of the lungs then the fluid will third space and cause breathing problems. This corroborates Sarah's

comment of how patients will have breathing issues when the CVS is damaged from a STEMI.

Tom also described the interdependence of the renal system and the CVS during his time working in the dialysis floor of the hospital. His training during this time helped him understand how the renal system and the CVS interact.

My dialysis experience was extremely helpful to me. Dialysis is something that not everyone knows about but fluid and electrolyte balance is the core of almost any measures that affect the body. Unless you have a great fluid and electrolyte balance [knowledge] then you are not going to understand diffusion, osmosis, active versus passive transport. What the kidneys do that can affect the heart. What the heart does that can affect your kidneys. Everything is tied together without a base knowledge of everything the prior understanding of the entire system and each individual system and a great understanding of how they all come together. [Beginning nurses] really should be cautiously released on patients (Interview, January, 27, 2014).

This suggests that Tom understands that the renal system and the CVS are connected and to understand the physiology of one system can help with understanding other bodily processes. Later, Tom also suggested that knowing how the body is interdependent is a difficult concept for beginning nurses.

...putting it all together. Understanding the need to be focused on the heart and the lungs and the kidneys. The heart because it is the cause of the problem because the heart is “pooped out”. How much cardiac output do we have, normally 60-70. What are we down to 40,50,20,10? The lungs, how well are we filtrating fluids and how well we are eliminating wastes? Are we collecting water are we collecting toxins and are they coming out in an adequate manner. The lungs, what are the ABG (arterial blood gases)? Are we oxygenating and having good gas exchange at the alveolar level or just breathing and not exhaling much gas because we are full of fluid from here (points to his armpit level) down. Other issues such as skin and integumentary. How is their skin and integumentary? Do we have an infected process? Mental status. What is the patient's mental status and the outliers such as what is their current physical condition? Are they suffering from hypertension and diabetes? Have they had strokes in the past? So putting it all together and taking it all into consideration. Do we have any current infected process? Have they had a heart attack two

weeks ago and didn't come in for it and that is why their shit is in the crapper
(Interview, January, 27, 2014).

This is a common situation when working with a patient as a nurse since if the CVS is not supplying enough oxygen then the other systems are affected. Here Tom mentioned the respiratory, renal, integumentary and nervous systems and what readings a nurse must take into consideration when treating a patient.

Gary responded in a similar manner to Tom and Sarah even though he did not have as much experience. In his time in the cardiac ICU, Gary has worked on many patients who have had a myocardial infarction (MI). Gary describes how the CVS interacts with a multitude of other systems.

Interviewer: How is this [MI] interacting with other systems?

Gary: So a lot of times, when you decrease pumping power of the heart, you have decreased oxygenation of the heart muscle so it doesn't pump as well or tissue starts dying or doesn't move as well. You have heart wall a kinesis and so you get fluid backed up. In addition, you have higher demand (of oxygen) so other parts of the heart have to work harder. Or the heart wants more oxygen so you see people with shortness of breath, we see people with fluid in their lungs. Pulmonary edema because the left side of the heart isn't pumping well so it (fluid) starts to back up [into the lungs]. People that are chronic 'oh I have had chest pain for 3 or 4 weeks' they start to get edema in their feet because now the right [side of the] heart cannot keep up because it is back up so far. A lot of other things too, depending on what arteries are occluded the right heart could be affected. The right heart we talk about pre-load and the Starling effect, fluid load when our right heart is affected and you don't have good right ventricular function then people are usually severely hypotensive so you know that [you are] balancing fluid and good pressure with am I going to overload their lungs with fluid. Those are the things that we think about or relate to pathophysiology
(Interview, January 20, 2014).

Gary's response supported many of the same ideas of how the renal, respiratory and CVS are interdependent on one another. If the heart is damaged from a MI then there is a possibility of having fluid buildup in the lungs or extremities which suggest involvement with the respiratory system. Gary surmised the interdependence of the systems by stating

It is this circular thing for these patients. So their heart gets sick, then their breathing gets bad, and then that causes their heart to get sicker and so we think airway, breathing circulation and we need to supply oxygen to these people with wet lungs.... If you hear a CHF patient is coming we (he and his co-workers) almost immediately think breathing because they normally are hypertensive, they normally have adequate circulation when they come to us and [it] usually manifests itself as this breathing problem" (Interview, January 20, 2014).

This indicates that Gary associates both the CVS and respiratory system together and patients that he treats in the cardiac ICU usually have breathing troubles when their heart is involved.

The idea of interdependence was a concept that Claire brought up in regards to the function of the CVS. For Claire, the CVS was the major system to be concerned about when caring for a patient.

With the CVS, because so many other parts of the body are dependent on the heart. It is carrying oxygen and nutrients to your entire body. So everything needs your heart. Yeah everything is connected. If the heart is damaged then it is only a matter of time until everything else is (Interview, February 18, 2014).

Claire knows that when caring for patients in the ER if the CVS is not working properly and getting oxygen to the other body systems they will stop working and cause more problems.

Claire mentioned the respiratory and nervous systems as two systems which are affected by a MI and where low oxygen levels will first be noticed. "Yeah, lungs everything really. Your brain of course. Blood flows everywhere. You are not getting blood flow to the heart [from a MI], [you are] not going to get oxygenation anywhere else for much longer if you don't take care of it" (Interview, February 18, 2014). This suggests that Claire understand the urgency of a patient coming into the ER with a MI. If she does not get the patient stable then it is only a matter of time before other systems are affected which will escalate the situation by causing more health problems.

Claire also supports Sarah and Tom's notion of "putting it all together" or looking at the "whole picture" when treating a patient by using the statement of "seeing the bigger picture" when caring for ER patients. During Claire's interview she thought that the concept of interdependence was the main concept she used in her practice but it was not stressed during her course work as identified in the following excerpt.

Interviewer: Did [college instructors] go over interdependence?

Claire: No, they didn't go over any of that

Interviewer: Where did you learn it? Why do you think that is the number one concept if you didn't learn it in school?

Claire: I just think it shows the bigger picture. It is important to see the bigger picture and see how one thing affects the other. Also to see what is going to happen down the line to predict what is going to happen and know how to treat somebody. I think it is shows the bigger pictures of things (Interview, February 18, 2014).

A nurses' main focus in the ER is to stabilize the patients so they can get the treatment they need. Claire views understanding how each of the body systems interact as a way to predict possible future complications or how the patient's current state could change depending on which systems are involved.

Summary of the Interdependence and Interaction of the cardiovascular system and other organ systems. The patients these nurses treat are complex where changes or abnormalities in the CVS have systemic consequences. All of the expert nurses view interdependence through the lens of patient care or understanding what can go wrong if the CVS isn't functioning normally. It could be surmised from the expert nurses' responses that understanding how the interconnectedness of the CVS with other systems is critical to their daily practice and patient care. For example, if a patient presents fluid in the lungs then it is quite possible that the heart is involved since blood

may not be circulating effectively in the pulmonary circuit. On possible path of treatment would be ordering a regiment of diuretics to remove the excess fluid through the renal system. The increase in frequency of urination then affects the CVS by lowering the patient's blood pressure and hopefully will improve respiratory function.

The intersection of the cardiovascular system and technology in patient diagnosis and treatment. In order for practicing nurses to identify, diagnose and treat patients they rely on their CVS physiology knowledge as well as their knowledge of technologies available. This concept is a blending of test results, knowledge gained during nursing courses and their patient's current condition. It is also a concept which draws ideas from all of the previously discussed concepts. Some examples of technology that the expert nurses identified they use to treat patients are electrocardiograms (EKG), several types of medications and x-rays.

Diagnosing patients with an Electrocardiogram. The technology that all expert nurses repeatedly spoke about was the EKG, in particular the 12-lead EKG. Sarah described the 12-lead EKG as follows:

It basically gives you 12 different snapshots. Each lead is looking at a different angle of the heart. That is why 2,3, avf we are looking at this part (right side of the heart). V5 V6 is looking at the septum... From that you can get not only the rhythm, you can see what we see on the regular 3 or 5 [lead EKG]. Is it a conduction issue? You see rhythm conduction issue based on waves, part of heart in trouble also to a certain extent valve issues. Certain disease processes will show signs on [the 12-lead EKG]. Digitoxicity, different stuff, U-waves here and there. Different things if you have been trained you can tell a lot about the heart from the 12-lead.

Interviewer: What type of output does it give? Are there multiple monitors that give all of these different signs or the standard waves?

Sarah: You'll have a v1 through v6 [electrodes]. 1 and 2 are [placed near the] collarbones and the remaining three wrap around the heart (placed on the left side of the chest}. You will have the limb leads 1, 2, 3. So you got 12 different [leads], think of the electrodes are (points to body)1,2,3,4,5,6, (points to her

chest), each leg. Think of those as cameras so it is look at this part and this one. All around the heart, you can also do, everyone thinks of it being right over the heart, you can also do a right sided heart EKG; you can do one from the back. So you can move the camera anyway you want and see whatever part of the heart you want. The EKG machine will spit out an interpretation but you cannot always go by that and it is a short little, basically three or four beat, picture. You can also do like a big long strip of each picture if you want or rhythm strip of each particular lead as well (Interview, January 30, 2014).

Sarah's description encompasses her knowledge of the technology along with reiterating notions emphasized in the concept of homeostasis and CVS diseases when commenting about "conduction issues" and "parts of the heart in trouble" (Interview, January 30, 2014). All of the nurses said this was the main diagnostic tool used in any cardiac patient they see at the hospital. Tom put it succinctly by stating "You have to have an excellent knowledge of EKG interpretation knowledge. Look at those 12 leads and say 'hmmm, my patient is having an inferior infarc or jeez this guy may have a widow maker (anterior descending coronary artery)" (Interview, January, 27, 2014).

Tom also described the benefits of a 12-lead EKG as compared to a 3 or 5 lead EKG.

The 12 leads adds to that is the whole area of the heart. You are looking at the electrical activity of the whole heart. The 3 lead won't tell you the information it will show you that [draws and points to a cardiac cycle diagram]. With a 12 lead I can look at the 12 lead and say exactly what part of my heart is infarcting, what part is in trouble? Am I in right sided failure? I can expect pulmonary issues. Am I in left side failure? I can expect pulmonary issues and death. It (EKG results) gears me up for the level of care I need to provide. If [the patient] is (*sic*) in left sided failure I'm going to the cath lab immediately. If we are in right sided failure, we may or may not be going to cath lab. If [the patient] is in left sided failure, we are probably going to the OR for open heart right away because time is heart muscle (Interview, January, 27, 2014).

Tom's description of the 12-lead EKG is an example of how important CVS concepts are applied seamlessly to understand the intersection of the CVS and technology. He uses anatomical concepts to understand "what part of the heart is infarcting, what part is in

trouble" or "left side failure." He draws on interdependence with the respiratory system since he describes "expect[ing] pulmonary issues" as well as homeostasis and diseases when giving the example of a "widow maker."

Both Gary and Claire expressed how EKG interpretation was emphasized in their course work but did not understand its importance until they were working in a hospital.

People (new nurses) really don't know that stuff (EKG interpretation) and even for me I have a limited knowledge based on work experience. For nursing school and pathophysiology, we talk about EKG in Pathophys. Here is a P wave, here is a QRS, and here is what it corresponds to. You look at [a portion of the EKG wave] and it corresponds to [a part of the cardiac cycle]. Well what does it mean in the real world? When you get into a room with a patient and their QRS is big or their T wave is big or they don't have a T wave, but a U wave or whatever. That disease state and the changes to the EKG those are the practical things that you miss [in course work]. You know the QRS and the P and you could probably translate it if you went back to your notes but how does it translate to a patient sitting there (Interview, January 20, 2014)?

For Gary, course work taught him what an EKG represents and the anatomical portion of the heart which the different waves corresponds to but, for him, it is entirely different when he is working with a patient. Gary also elaborated on how he uses an EKG to help understand what is going on in a patient when discussing a patient with a MI. Gary began the example discussing the common symptoms and CVS physiology when a patient has a MI and then described his EKG interpretation as follows:

The right heart we talk about pre-load and the Starling effect, fluid load when our right heart is affected and you (the patient) don't have good right ventricular function then people are usually severely hypotensive. So, you [are] balancing fluid and good pressure with am I going to overload their lungs with fluid. Those are the things that we think about or relate to pathophysiology. EKG is specific. Where are the SD segment changes or other EKG changes on it (the EKG printout) and where they lead to? If you see changes of leads 2, 3, and AVF the 12 lead we know it is right heart. We know it is inferior and technically, probably right and you say 'do I need to give them fluids or do I need to not give them nitroglycerin' and so those are the considerations that you don't get until you are out of school. You might see an EKG but it doesn't make sense yet (Interview, January 20, 2014).

Gary combines the concepts of CVS anatomy, “right heart”, and CVS physiology, “good ventricular function”, with how the CVS and respiratory system are interdependent, “overload their lungs with fluid”, with EKG interpretation to guide his clinical practice.

The mastering of EKG interpretation with the other concepts was difficult for Claire. Claire is early in her career and she spoke of new ideas she has been exposed to during her time in the ER and she later offered advice to new nurses in regards to EKG interpretation and the CVS. When discussing her new experiences she said, EKGs are just hard to read in general. I’m getting better at reading EKG and comparing with old one... what they show you in the book [are] not what they usually look like in real life. They look completely different. Just getting real life EKG, seeing that is not the perfect wave” (Interview, February 18, 2014). Her advice for nursing students in regards to the difficulty of reading an EKG was,

Make sure to study EKG and understand what is actually going on. Not just this is a STEMI. Understand what is going on in the heart and why you are doing what you are doing. What the nitro[glycerin] is doing to the vessels. Why are you giving morphine and oxygen. To understand why you are doing what you are doing. Understanding what the EKG actually means. What the heart is doing during those abnormal EKGs” (Interview, February 18, 2014).

Claire’s advice and experiences are similar to what Gary expressed because that they both understand the importance of connecting the EKG to their CVS knowledge, yet were not confident in their ability due to their coursework preparation and limited work experience.

Medications used while treating patients. A second area where technology and the CVS intersect is the administration of medications through the course of treating a patient. All of the experts have taken a pharmacology course during their nursing course work and need to use this knowledge when working with cardiac patient on a daily

basis. Several types of medication were discussed during the interviews with the most prevalent examples being diuretics, anti-dysrhythmias, and vasodilators. Each medication is used in response to the signs and symptoms that a specific patient is exhibiting.

The expert nurses all described a MI as a common disease and a variety of medications are used in treating these patients. The regimen for treating an MI was very similar, regardless of the hospital or department. Claire mentioned the protocol during her description of a STEMI. "You need to act fast and do the whole morphine, O₂, nitro, and aspirin. Get them to cath lab. They (cardiac physicians) do the whole balloon to door, door to balloon" (Interview, February 18, 2014). Claire also described other medications she has encountered while working in the ER. She has used anti-dysrhythmia, Diltiazem, while treating patients with atrial fibrillation. She described the action of the drug as "[it] slows the heart rate down, gets them out of a fib. It can be used to cardiovert too" (Interview, February 18, 2014). Claire knows that being in atrial fibrillation is an abnormal cardiovascular state and if she uses this medication it can help return the heart rate back to a normal level (homeostasis).

Gary described these standing treatment orders as PRN in the follow excerpt when asked about the autonomous nature of being a practicing nurse:

Interviewer: It is more of relying on your knowledge to be autonomous with a general order.

Gary: Right.

Interviewer: So you really have to dig into your nursing knowledge?

Gary: Right so same thing even on the floor the patient might have an order for nitroglycerin, sublingual nitroglycerin with chest pains. PRN for chest pains.

Interviewer: What is PRN?

Gary: As required. PRN so if they have chest pains give them nitroglycerin. So if the patient has chest pains and you automatically think there is an order for

nitroglycerin or wait to give the nitroglycerin until you have an EKG to see. I think a smart nurse or paramedic will say 'okay, let's get the EKG and make sure it is not a right side heart attack and their BP is low' and we make it a lot lower by decreasing preload. So those are things that I think a nurse with a basic education out of school doesn't connect the dots, preload and what is this pharmacological agent going to do in this situation if the right side of the heart is affected. I keep going back to that one because we make that mistake a lot. The doctor wrote that if there is chest pain we give them nitroglycerin so here is your nitroglycerin. But a prudent nurse would say 'well the EKG shows that the damage might be their right side. And their BP is already low is a bit low. So I am going to withhold the nitroglycerin and I am rightful in doing that. Is doing the right thing by doing that? Some nurses, especially who are not knowledgeable will say 'well the doctor wrote it so I cannot get in trouble for it' well that is true but is in the best interest of the patient. So nurse discretion based on knowledge is huge and so the more knowledge you have the better nurse. The more you can relate it to what is actually happening (Interview, January 20, 2014).

Gary describes being a prudent nurse in thinking about the results of tests, an EKG, and using a prescribed medication to treat the patient. Gary thinks about how the drug action will affect his patient as well as CVS physiological concepts of preload and blood pressure to withhold the nitroglycerin. If this fictitious patient would have right heart damage the vasodilation from the nitroglycerin would decrease blood pressure and preload which would not bode well since the patient may be hypotensive due to the heart damage.

Tom was asked to describe how he treats a MI patient when they arrive to the ER. What follows is a standard treatment for patients who are treated by Tom and Jefferson hospital:

A STEMI get a whole work up. I like to bring them into the ER and within 15 minutes and have them in the cath lab. The standard is 25 and I like to beat that by 10. So, the patient comes in the door. Big lines on both sides (both arms), big bore IV, by big bore I mean 16 to 18 gauge needles. Fluids running, medications pharmacological wise. We are going to hang him on a nitro drip, expand those coronary arteries. We have to open those coronary arteries because what causes a myocardial infarction is lack of oxygen to the myocardium, the heart muscle. So we are going to open those vessels up and put [the patient] on oxygen, oxygen therapy. These patients are usually awake, we put them on a

non-rebreather if they are failing too badly. The minimal, the least invasive. If they are still awake and talking and sometimes they are, I put them on 2-4L nasal cannula. A good review of medications, anticoagulants, baby aspirin times four. A shot of Lubinox (an anticoagulant) we don't want to throw a clot and have a stroke. Hypertension control, usually these patients are hypotensive because their heart is dying. Their heart's dying so we want an immediate intervention and that is why we go to the cath lab and do percutaneous angiography angioplasty (commonly known as a coronary angioplasty). Get in there and open the vessels that are closed, open it and restore blood flow to the heart muscle that is being effected. Sometimes it is more than one vessel. Sometimes it could be two to three vessels or sometimes it is the main vessel that goes down, the widow maker, the big anterior descending [coronary artery] (Interview, January, 27, 2014).

Tom's example shows his understanding of the different medications that he is using to treat this MI. He uses nitroglycerin, a vasodilator, to expand the coronary arteries and aspirin along with anticoagulant so they do not have a stroke from the clotting cascade started by the damaged heart muscles. Tom's understanding of the CVS is combined with his pharmacological knowledge to help treat the patient. Tom's anatomical knowledge also allows him to understand which portions of the CVS and associated systems (respiratory) will be affected by the medication.

The intersection of Tom's CVS concepts and medication was also explained during a discussion of advanced cardiac life support (ACLS). This type of knowledge is a requirement to work in Jefferson's ER and Tom used the researcher having a heart attack as an example of what ACLS is and the interventions he would use to treat his patient.

ACLS is a quick understanding of your situation and an extremely quick understanding of how to reverse that situation. So, if you are sitting here and you fall on the floor and lay down. The first thing I am going to do is feel your pulse. If I feel your heart fibrillating I am going to yell out Hey do you guys have an AED (automated external defibrillator) here anywhere? I know you are in V fib and I am going to shock you and get you out of that. You are going to wake up and maybe even talk to me 'Damn what happened to me. Get this shit off of me.' Why am I burning here (points to chest where the AED paddles were placed)? It is also a pharmacological intervention. I know that if you are in atrial fibrillation, that you have lost your atrial fib and your cardiac output is

decreased so therefore your energy is decreased and your oxygenation ability is also decreased. So I can give you something to kick your pump up a little bit to increase your cardiac output or shock you out of that rhythm and throw you back to a normal sinus rhythm. If you are in ventricular tachycardia I can use different medication like amiodarone which is an anti-arrhythmia or epinephrine to restart your heart and shock you . in the presence of those medications you dramatically increase your chances of survival whereas if I just shocked you I wouldn't increase your chances very much. With the epinephrine and the amiodarone onboard I'll probably going to save your ass (Interview, January, 27, 2014).

Tom's knowledge of how to use the AED and medications for correcting the ventricular fibrillation support how important having an understanding of pharmacological interventions can have on a patient, especially when it is an emergency. Tom describes the drug action when he speaks of the ant-arrhythmia medication in his example. Tom knows that stopping the ventricles from contracting uncontrollably is critical to help the patient survive. This example also reinforces his understanding of homeostasis and diseases as well as his anatomical and physiological knowledge of the CVS. He also understands that cardiac output has a direct effect on the respiratory system and oxygenation levels in the body.

Diuretics, such as Lasix, are another class of drugs which the expert nurses spoke of when describing patients they treat. The purpose of a diuretic is to cause the renal system to excrete more fluid from the body. This in turn can cause blood pressure to lower since less volume of liquid is present in the CVS and can help reduce fluids in the respiratory system. This treatment regime has been alluded to in connection to the previous concepts: a) homeostasis and disease of the cardiovascular system; and b)the interdependence and interaction of the CVS and other organ system.

Sarah discussed a treatment using diuretics when she described a patient with congestive heart failure. She spoke of how her experience has taught her that you need to understand the patient's condition and how the medication will affect their damaged organs. Specific to the case of congestive heart failure Sarah spoke of how the heart muscle has been

stretched out from pumping extra fluid so treating with a diuretic may not be the best course of action.

You also need some diuresis but be careful how you do it cause if that heart is big and stretched and you diurese them to get rid of the fluid. I know you are familiar with Starling's Law. so if you diurese and get rid of all that fluid that heart cannot pump effectively since it is used to all of that stretch so that is where you have to consider adding something like dobutemine or something that will help with the pump action of the heart or your contractility of the heart, which is not a nursing deal. It is physician driven but you need to know, yeah you are diuresesing them, we are going to lose their pressure because we don't have the kick we need (Interview, January 30, 2014).

Sarah understands that the damage to the heart has modified the functioning of this fictitious patient's CVS so she needs to be a prudent nurse when using a diuretic because it will reduce blood volume and the heart will not be able to contract with enough force on its own to circulate the blood. This means that she need to also use a medication that will cause the heart to contract with more force to get adequate circulation.

Tom also spoke of a patient with congestive heart failure and that he would use Lasix, a diuretic, since he needs "to get some fluid off of them. Give them some Lasix" (Interview, January, 27, 2014). This reinforces the idea that the renal system and the CVS are interdependent and that changes in one system will affect the other. In the case of the Lasix, the excretion of fluid will lower blood pressure.

Even though technology plays a large role in a nurse's treatment regime Sarah feels that understanding the concepts behind the technology is critical for nursing students. Sarah is a preceptor for nursing students so she educates nursing students during either their clinical practicum or if they are doing a fellowship in the cardiac ICU. Sarah spoke of the educational training of nursing students today versus when she was a student and how technology has changed the field, perhaps not for the better.

Interviewer: We have talked about the important concepts; the 3 or 4 scenarios are there any other concepts specific to the CVs that are very important for nurses to know?

Sarah: So many of the nurses are dependent on technology. So we have the cardiac output, put a swan ganz in, which is a catheter which measures the pressures in the heart. It automatically calculates the systemic vascular resistance, the peripheral vascular resistance(PVR) the cardiac output, the cardiac index. All those factors for you and the monitors show the pulmonary artery, diastolic, systolic calculates the mean. Does the same for BP and CVP (central venous pressure). All these numbers are calculated for them [nursing students]. They need to know that to get your SVR (systemic vascular resistance). You need these factors and your cardiac output is driven by these factors. And your [cardiac] index is driven by these factors so when one is out of whack you know how to fix the rest of it. Your SVO₂ is your reserve bank of O₂. What do I need to do to get that where it needs to be to optimize these numbers? You have to know the factors that are going into this equation. [Nursing students] don't know how to put it all together. If my SVO₂ is low, what is driving that? My hemoglobin is low, I am only on 2L O₂, and maybe I need to be on 4 or 6. How am I going to fix it? But you don't know how to fix this if you don't know the factors that are playing into it. They (nursing students) aren't getting it.

Interviewer: Is it more of experience thing or school thing that needs to be reinforced?

Sarah: I think it is a school thing they need to teach. Well, you have your cardiac output and it means this. But you need to know your cardiac output is your heart rate times your stroke volume and where does that come from? You can't just pull it out of your hat. They [nursing students] need to know. When I started, we had to hand calculate everything. Plug numbers in and if you didn't have the number you have to go get it. Your cardiac index is based on your cardiac output divided by your BSA (body surface area).Well were did your BSA come from? Why are we more interested in the index rather than the output? Well, the index is patient specific for height and weight and I try to explain all of this to them (the students she supervises) and they are like 'Oh, didn't know that.' I think that is the crux of the whole thing. you can teach them all of the anatomy and physiology you want, but give them the equation for the numbers they are going to call the doc and say my cardiac index is this or my SVO₂ is this but if you don't know what goes into it (the equation), you will not know that the guy who was admitted was a med student yesterday and knows what he is talking about. You have to in the ICUs, you need to know what intervention you are anticipating when you call a doc or you're going to delay treatments.

Interviewer: That is patient time and life and death.

Sarah: Mmhmm. I am very firm in the idea that they need to know what goes into the equations and give them these numbers they are throwing around because if you don't know that the SVO_2 you need to look at how much oxygen you're giving them, how much hemoglobin they have, what is their temperature. All those factors go into making that number. You need to know. You can't fix it if you don't know what is involved. Well, the technology is so advanced they (nursing students) don't have to think that in order to get my SVR, I need the mean and the CVP and in order to get my SVR and PVR I need to have a wedge and a CVP and put all of it into the right equation. Since I learned it that way (hand calculating the equations), 'oh I know I need to fix this. Not just the protocols that we have. If your CVP is less than 10 give two units of albumin. That is the way the new people are taught, you go by the protocols but you don't know why, what is driving that (the equation and physiology)

(Interview, January 30, 2014).

Sarah understands that the Swan Ganz makes the job of nurses easier by calculating all of the values (i.e. SVR, PVR, cardiac output, cardiac index etc.) that nurses need to treat patients but understanding what all of those values mean is just as important. The values are not just numbers on an instrument but interrelated factors that indicate what is going on in their patient's body. Sarah alludes to having students understand what each value represents and how it relates to patient care when she said "And your [cardiac] index is driven by these factors so when one is out of whack you know how to fix the rest of it" (Interview, January 30, 2014). Having an in-depth understanding of what physiological concepts the technology is measuring was important to Sarah for predicting what course of treatment doctors would advise so nurses do not "delay treatment." Sarah also believes that knowing these functions will enable nurses to "know how to fix it" which allows for better treatment for patients and lowers the delay in treatment because the time nurses use understand the physiology could be better used treating the patient because "time is muscle" (Interview, January, 30, 2014)

Summary of the intersection of the CVS and technology in patient diagnosis and treatment. All of the expert nurses use technology in conjunction with their CVS knowledge to

treat patients. Specifically, when dealing with cardiac patients an EKG is the most powerful diagnostic instrument. Each of the four experts relayed they use EKG but the more novice nurses, Gary and Claire, said that they are still learning to understand the results. The two veteran nurses displayed a vast knowledge for the diagnostic power of the EKG. Both Tom and Sarah described what a 12-lead EKG does and how it is a “camera” to look at the heart. Combined, Sarah and Tom have close to 50 years of experience with cardiac patients which translate to extensive experience with EKG interpretation.

Another prevalent form of technology is the use of medications to treat cardiac issues. The nurses expressed having experience using diuretics, anti-dysrhythmia, anti-coagulants and vasodilators frequently. All of the experts have taken a pharmacology course during nursing school which reinforced CVS concepts learned in previous courses. When treating a patient the nurses need to understand and combine ideas from three areas. The nurses need to understand the symptoms their patient is expressing, how these symptoms differ from normal CVS function and the type of the drug to reverse these abnormal symptoms.

Summary of Phase I

The results of phase I identified five broad concepts which nursing experts use in their daily practice. Nursing experts use anatomical and physiological concepts to understand their individual patient's needs to effectively treat and care for them. Both of these concepts form a foundation of understanding and language they use in the hospital. All of the experts viewed their role in the hospital as providing care to get the patient back to homeostasis (normal state). Treating a patient effectively means the expert nurses need to understand how the body's systems are interdependent. Other systems, such as the respiratory, depend on the CVS to function normally and deviations from this can cause fluid to build up in the lungs. The expert

nurses use EKG results and pharmacological agents such as diuretics or anti-dysrhythmia drugs and their understanding of CVS anatomy and physiology to successfully treat their patients.

Scenario Development

Originally, six scenarios were created at the conclusion of phase I. Scenarios creation started by consulting the researcher's journal and written memos. Short descriptions of patients were documents during initial data analysis and then aligned with the major concepts identified by the expert nurses. At least three of the five major concepts identified by the nursing experts were included into each of the scenarios. Learning objectives were also created for each of the scenarios which helped align the content covered by each scenario (see Table 6). This method is similar to a specification grid which is used in creating concept inventories and diagnostic tests (Treagust, 1988).

All scenarios were reviewed by measurement experts, nurse experts, science education experts, nursing educators and content experts (n=13). Revisions were made following each of the expert's remarks which strengthen the scenarios. Some experts chose to answer the questions to provide feedback on the questions. These answers provided insights into the type of responses to expect from the students. Next, nursing educators suggested combining some of the scenarios in order to shorten the amount of time nursing students would need to complete the scenarios. A total of four authentic scenarios emerged from the revision process (See Appendix C)

Table 6

Summary of important concepts and learning objectives for the four authentic scenarios

Scenario	Important expert content	Learning objectives
1	<ol style="list-style-type: none"> 1. Homeostasis and disease of CVS <ol style="list-style-type: none"> a. Heart Attack 2. Intersection of Technology and CVS Knowledge: <ol style="list-style-type: none"> a. Medications (nitroglycerin) 3. CVS physiology: <ol style="list-style-type: none"> a. Perfusion b. Blood pressure and Blood flow 4. Interdependence and interaction between CVS and other systems <ol style="list-style-type: none"> a. Respiratory system 	<ol style="list-style-type: none"> 1. Demonstrate an understanding of vasodilation and its effect on BP 2. Apply knowledge of low oxygen saturation's effect on the cardiopulmonary system 3. Justify answers using their knowledge of the CVS
2	<ol style="list-style-type: none"> 1. Intersection of Technology and CVS Knowledge: <ol style="list-style-type: none"> a. Echo cardiogram 2. CVS Anatomy: <ol style="list-style-type: none"> a. Vessel anatomy 3. CVS Physiology: <ol style="list-style-type: none"> a. Perfusion to skin 4. Homeostasis and Disease of CVS <ol style="list-style-type: none"> a. Atrial fibrillation b. Valve stenosis 1. Interdependence and interaction of CVS with other organ systems <ol style="list-style-type: none"> a. Respiratory 2. CVS Anatomy <ol style="list-style-type: none"> a. Heart anatomy b. Vessel Anatomy 	<ol style="list-style-type: none"> 1. Explain the relationship between blood flow and heart valve physiology 2. Apply their knowledge of EKG diagnostics and effect on blood flow 3. Justify answer using CVS knowledge
3	<ol style="list-style-type: none"> 1. Interdependence and interaction of CVS with other organ systems <ol style="list-style-type: none"> a. Respiratory 2. CVS Anatomy <ol style="list-style-type: none"> a. Heart anatomy b. Vessel Anatomy 3. Intersection of Technology and CVS Knowledge <ol style="list-style-type: none"> a. X-ray 4. CVS Physiology <ol style="list-style-type: none"> a. Cardiac Output 5. Homeostasis and Disease <ol style="list-style-type: none"> a. Ventricular failure 	<ol style="list-style-type: none"> 1. Describe the pathway of a blood cell using knowledge of CVS anatomy. 2. Derive connections between the CVS and respiratory system based on diagnostic information 3. Justify answers with knowledge of the cardiovascular system

Continued

4	<ol style="list-style-type: none"> 1. CVS Anatomy <ol style="list-style-type: none"> a. Coronary Arteries 2. CVS Physiology <ol style="list-style-type: none"> a. Blood pressure 3. Interdependence and interaction of CVs and other organ systems <ol style="list-style-type: none"> a. Renal system 4. Intersection of Technology and CVS Knowledge <ol style="list-style-type: none"> a. Medications (Furosemide) 	<ol style="list-style-type: none"> 1. Apply their knowledge of cardiovascular vessel anatomy to disease states and patient diagnosis 2. Identify key features in the relationship between the CVS and the renal system in regulating blood pressure 3. Justify their answer using their knowledge of the cardiovascular system
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How the expert nurses use these important concepts in practice

The expert nurses used each of the different concepts separately and collaboratively during their practice in the cardiac ICU or ERs. The model can be thought of as a tiered system with knowledge from previous tiers being incorporated into successive tiers with the final outcome of treating the patient (see Figure 2). The tiers do not represent importance of the concepts because the previous tiers (e.g. CVS Anatomy and CVS Physiology) can be accessed by the nurses when new patient information is received. The process also follows as a linear series of steps with the nurses' knowledge being refined by accessing new CVS anatomy and physiology knowledge as it pertains to their knowledge of the patient's disease, other organ systems involved (interdependence) and test results (technology) to develop a treatment regime for the patient (see Figure 3). A complete understanding of the expert nurses' CVS knowledge is a combination of the tiered model with the linear model. A general description of the both models will be presented followed by excerpts from each excerpt nurse using the five concepts when describing a patient who is having a heart attack.

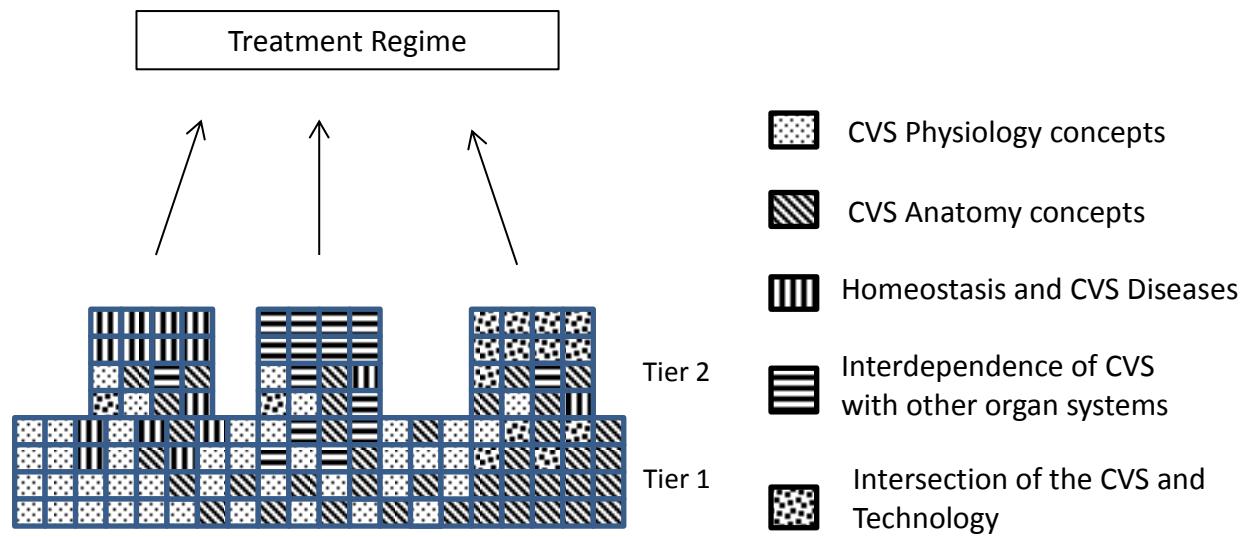


Figure 2. A tiered model of how expert nurses use the five important CVS concepts in their daily practice

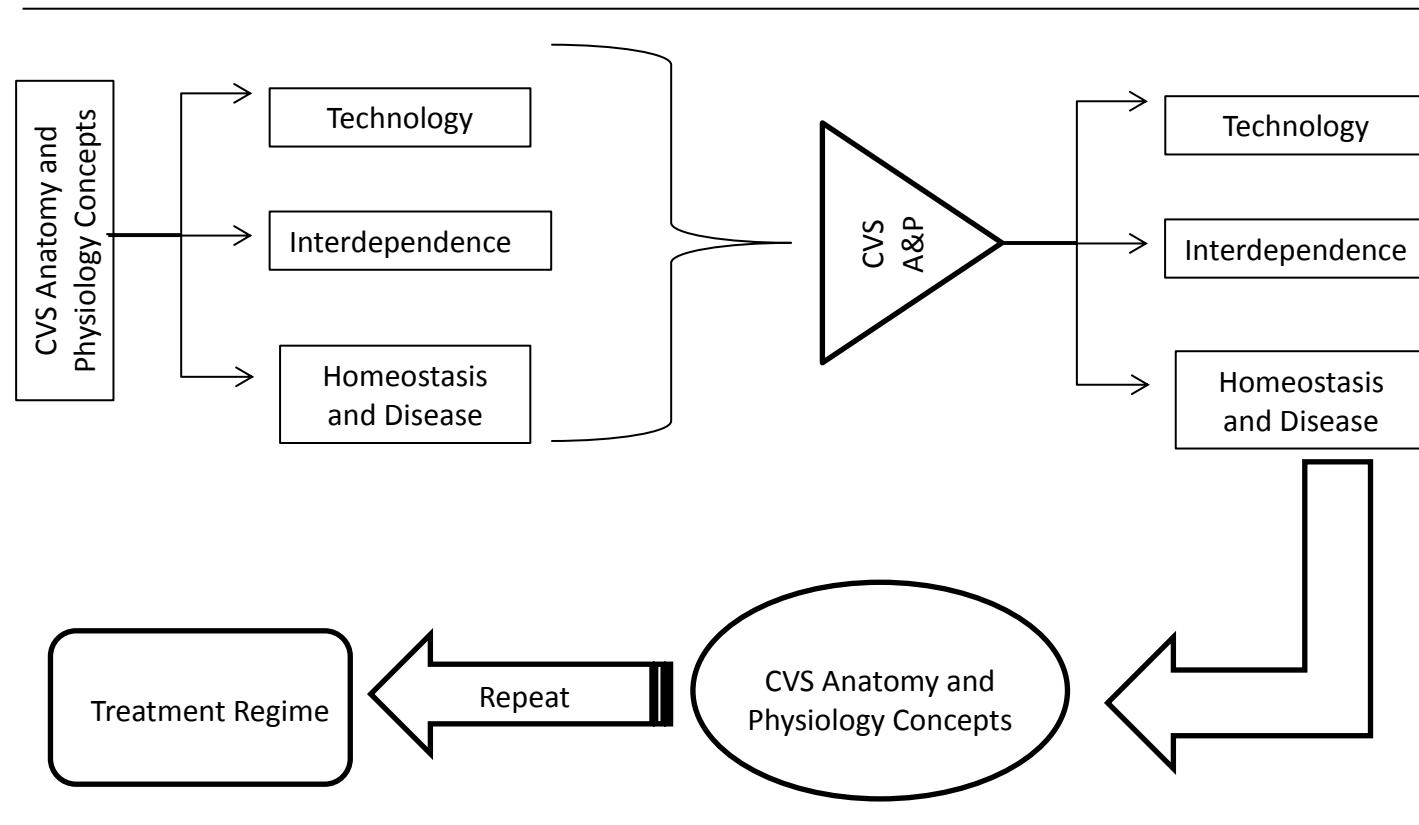


Figure 3. A series model depicting how nurses refine their treatment of patients

General model description. The expert nurses begin by drawing on the anatomical and physiological concepts that pertain to the patient's initial description or condition. This knowledge serves as the base tier for treatment because both the anatomy and physiology concepts are used by successive tiers to and serve as a baseline for a normal state or the patient being in 'homeostasis' because this knowledge is not influenced by a disease state. In this model, each of the important concepts is represented by a different patterned box. The boxes represent aspects of the knowledge the expert nurses have for the different concepts. The CVS anatomy and CVS physiology concepts appear on both sides of the first tier because there is a relationship between CVS anatomy and CVS physiology.

For example, if the expert nurse is dealing with a MI from an occlusion of the coronary vessels then they draw on their anatomical knowledge of the coronary vessels and which portions of the heart they supply. The physiological concepts the nurse would use to understand a heart attack would be Starling's Law because the damage to the heart would cause a decrease in cardiac output among other symptoms. The two concepts are closely related because in many instances the structure (anatomy) dictates the function (physiology).

Next, the nurses apply the tier one concepts to a second tier of new concepts. These second tier concepts are: a) interdependence and interaction of the CVS and other systems; b) homeostasis and the disease of the CVS; and c) the intersection of technology and the CVS. This application is represented by the appearance of CVS anatomy and CVS physiology concepts in the second tier. The concepts exclusive to the second tier do interact with each other, though not as much as the interaction from tier 1, hence why fewer concepts exclusive to tier 2 appear in other areas of the second tier while more tier 2 concepts appear in tier 1.

The first section of the second tier, the section farthest to the left, takes into consideration the disease which their patient is presenting. The "normal" anatomical features

and accompanying physiology, accessed from the first tier, are used as reference points. In this tier the nurses incorporate the disease and how this compares with a normal functioning system. At this point, a revision in their thinking can be made based on input from external sources such as attending physicians and other nurses working collaboratively on the patient.

The middle section of the second tier of the model represents the concept of interdependence with other organ systems. It is accessed simultaneously and is somewhat influenced by the concepts accessed while trying to understand the patient's disease. In this section, the nurses consider if other systems are involved and should be considered in the overall treatment regime of the patient. The CVS supplies other body systems with oxygen so if it is affected by some disease then complications can arise in other systems. A common example of this is the presence of fluid in the lungs. Having fluid in the patient's lungs is not normal so a revision of their thinking can be made moving the treatment from the third tier to the fourth.

The last section of the second tier deals with the technology such as medications and/or diagnostic tests the nurses use to further refine their treatment. For example, if the nurses want to get rid of the excess fluid from the lungs with Furosemide (a diuretic) then they know that the renal system will be involved which draws on their physiology knowledge outside of the CVS, even though the complication arose from the CVS itself. The concepts of this tier do influence the treatment regime which is portrayed by the arrows leading to the final tier, the treatment regime.

Along with accessing these different concepts, the expert nurses also refine their knowledge as the concepts interact. Initially, the expert nurses use their CVS anatomy and physiology concepts when a patient arrives for care which is represented by the rectangle in Figure 3. This knowledge is passed along and interacts with their knowledge of CVS diseases, interdependence with other organ systems and technology. Through this interaction the initial

CVS anatomy and physiology knowledge is modified, represented by the triangle. Next, a second iteration of this process begins with new, refined CVS anatomy and physiology knowledge being integrated with new knowledge of CVS diseases, interdependence with other organ systems and technology. Once again, there is an interaction and their CVS anatomy and physiology knowledge is modified, represented by the circle.

When the two processes (Figures 2 and 3) are combined there is an interaction between the concepts (Figure 2) and a refinement of the knowledge based on how the concepts interact (Figure 3). This iterative, cognitive process continues until a treatment regime for the patient is established based on all the available evidence. Due to the urgency of individual patient cases this process can take place in a very short span of time. For an excerpt from each of the expert nurses' interview depicting instances where the nurses use each concept see Appendix G.

Phase II: Nursing students' CVS alternative concepts

The second phase of the study centered on the nursing students' responses to the scenarios. This section will begin by reporting the response rate of the survey, followed by two subsections dealing with the students' alternative conceptions. The first subsection will present the student responses to each question with the second subsection describing results from across the entire student sample.

Response to the survey. The survey was distributed electronically to the nursing students. Of the 28 students who consented to the study, 19 completed the survey. However, two of the 19 responses lacked answers to any of the questions so they were excluded from analysis. Of the 17 students who provided responses, some did not finish the survey in its entirety (See Table 7).

Student responses were divided into six different categories. These categories are as follows: a) students hold no alternative conceptions (NA); b) students held no alternative

conceptions but stated they guessed and provided a correct rationale (NG); c) students held no alternative conceptions but lacked knowledge on a portion of the question (NLK); d) students pose a correct answer but have an alternative conception in their reasoning (CA); e) students held alternative conceptions (IA); and f) students had a lack of knowledge (LK).

Student responses to the individual scenarios. Each of the scenarios contained either four or five questions for student responses. All scenarios contain questions presented as a paired set with the student responding to a questions followed by a second questions where the students provide a rationale or reason for their answer. Two of the four scenarios (scenario 3 and 4) had an additional question which did not intend for the students to justify their response with a rationale. This section will present the results of each scenario with examples from each of the five previously stated student response categories. For the NA category both “best” and “bare minimum” response will be provided when possible which encompass all of the responses for that category. For the remaining four categories all of the student responses will be provided

Student responses to scenario 1. The first scenario consisted of two paired items or four total questions. For the patient description and complete scenario see Appendix C. The students' had a total of two alternative conceptions for the first question set. The second question set provided 6 alternative conceptions. For individual response categories of scenario 1 see Table 8 and for a summation of the each category see Table 9.

Table 7
Response rate of students per question

Student	Scenario 1				Scenario 2				Scenario 3					Scenario 4				
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X	O	X	X	O	X	X	X	X
4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O
10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
11	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X	X
13	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O
15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
17	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

X indicates a response. O indicates no response.

Student responses to Scenario 1: Question Set 1. The first question set for scenario 1 asked the students to predict the effects of nitroglycerin on a patient's blood pressure. Of the 17 student 15 had no alternative conceptions whose answers aligned with the scientifically accepted answer. The most comprehensive answers for the question set were, "Nitroglycerin will lower [Maggie'] blood pressure. Nitroglycerin is a vasodilator. This means that it relaxes the smooth muscle of the vasculature, which thereby lowers blood pressure and decreases preload and afterload" (Student 13). Another valid, comprehensive answer was "Nitroglycerin is a vasodilator so it will lower Maggie's blood pressure. Vasodilation is [the] expanding [of] the spaces in the arteries and veins that the blood travels through. If there is more space the blood will exert less pressure on the walls of the vasculature therefore causing a lowered blood pressure reading" (Student 14). To be considered to not exhibit an alternative conceptions a response must specify that blood pressure will be lowered and provide a rationale indicating that the vessels will dilate thus exerting less pressure.

Table 8
Individual student responses to scenario 1 by response category

Student	Question set 1	Question set 2
1	NA	NLK
2	CA	NA
3	NA	CA
4	NA	NLK
5	NA	NLK
6	NA	NLK
7	NA	CA
8	NA	IA
9	NA	CA
10	NA	NLK
11	NA	NA
12	NA	NA
13	NA	CA
14	NA	CA
15	CA	NA
16	NA	NA
17	NA	NA
Total Alternative Conceptions	2	6

Note: Alternative conceptions include both CA,IA

Table 9

Total responses for Scenario 1 by response category (n=17)

Category	Question set 1	Percent (%)	Question set 2	Percent (%)
No Alternative Conceptions (NA)	15	88	6	35
No Alternative Conceptions but Guessed (NG)	0	0	0	0
No Alternative Conception but Lacked Knowledge (NLK)	0	0	5	29
Correct Answer but Alternative Conception in reasoning (CA)	2	12	5	29
Incorrect Answer and Held an Alternative Conceptions (IA)	0	0	1	5
Student Lacked Knowledge (LK)	0	0	0	0

Two students provided responses with different alternative conceptions in their reasoning. The first student thought that the arteries will dilate and lower blood pressure but did not include all vasculature in their answer.

Nitroglycerin causes vasodilation of arteries, including the coronary arteries which are partially or fully blocked by plaque. It is used for [coronary artery disease because] of this, by vasodilating the coronary arteries hopefully more blood will be able to perfuse the heart. It also causes vasodilation of all of the arteries in the body, however, which will cause a decrease in blood pressure (Student 2).

This student did not include veins as being affected by the nitroglycerin. This suggests that the student does not understand that vasodilation from nitroglycerin is a systemic wide phenomenon or that only arteries vasodilate while veins do not. A second student provided an answer which displayed a second alternative conception. “The nitroglycerin is given to help Maggie's heart not work so hard. It is used to relax it and it will decrease her blood pressure. Nitro dilates blood vessels making them more productive” (Student 15). This statement suggests

that they believe the relaxation of the heart, caused by the administration of the nitroglycerin, will lower the blood pressure in combination with making all the vasculature dilate. It is unclear as to what a “more productive” blood vessel pertains to.

Summary of Student responses to Scenario 1: question set 1. The two students who held alternative conceptions for this question set understood that nitroglycerin would lower the blood pressure but through different means. Student 2 thought that only vasodilation of the arteries contributed to the decrease in systemic blood pressure. Student 15 expressed that the relaxation of the heart muscle in tandem with more productive blood vessels caused the decrease in blood pressure. This suggests that the student’s pharmacological knowledge of nitroglycerin was correct but their physiological knowledge of blood pressure was inadequate.

Student responses to Scenario 1: Question set 2. The second question set for this scenario followed an update to the condition of the patient where they exhibited low oxygen saturation which led to hypoxia. Students were more challenged by this question set than the prior set and exhibited more alternative conceptions (See Tables 8 and 9). A total of 6 students held at least one alternative conception for this question set. A majority of the alternative conceptions came from the student’s reasoning for either question in this set.

The nine students who did not exhibit alternative conceptions were divided into two groups. One group containing four students provided responses which centered on constriction of the coronary arteries either through the formation of a plaque or vasoconstriction as well as an increase in heart rate (see Table 10). The heart rate will increase when oxygen is deprived to an area of the body in order to get more oxygen to the affected tissue. The body will also constrict the vasculature to increase the flow of blood. Both of these physiological changes will increase the blood pressure.

The second group of five students provided answers which did not contain alternative conceptions but they did not provide an effect on the blood vessels included in the prompt. It was not possible to distinguish whether the students forgot to answer the question, did not have the knowledge or had an alternative conception for the effect of hypoxia on blood vessels

Table 10
Representative student responses displaying no alternative conceptions for Scenario 1: question set 2(n=9)

Student	Response
2	The coronary artery disease is plaque built up in the arteries feeding the heart. Without blood, the heart cannot pump effectively. Also, plaque increases blood pressure in the arteries the heart is trying to pump blood through, which causes the heart to work harder, and become less effective as well.
11	Coronary artery disease is caused by a plaque building up inside the vessel walls over time. This fatty plaque is a result of a poor diet and lack of exercise. The plaque makes it difficult for the body to pump blood to the areas of the body which the damaged vessels feed. Overtime this increased work load of the heart can begin to cause heart failure. Left sided heart failure causes fluid to back up into the lungs, which is why there are coarse crackles in the base of her lungs on auscultation. If the heart failure continues, it will progress to right heart failure as well.
12	Her heart will work harder to oxygenate her body which places extra stress on an already damaged heart. Her blood vessels will constrict to try to get blood to the places it needs to go quicker and more efficiently which could in turn causes an increase in blood pressure.
16	Maggie's heart will become more damaged and even could die in areas that are not getting enough oxygen. Her heart rate will increase in order to pump more blood to the lungs for oxygen. Her blood vessels will continue to constrict in an effort to get blood to the heart quickly.

The remaining six students held alternative conceptions for question set 2. Four students identified that hypoxia would increase the patient's heart rate but thought this condition would lower blood pressure (see Table 11).

Table 11

Student responses displaying reasoning alternative conceptions for Scenario 1: question set 2(n=6)

Student	Response
3	When the body's tissues are hypoxic, the heart rate is increased. The heart rate increases as it tries to compensate for the low levels of oxygen in the blood. The increased heart rate will lower the pressure in the blood vessels, causing a drop in arterial blood pressure. These changes are happening because the body is working hard to compensate for the low serum oxygen levels.
7	hypoxia will cause the heart to not receive the amount of oxygen it needs. This could lead to chest pain, as well as the heart not functioning as well, and both of these can lead to more hypoxia to the rest of the body. Decreased oxygen to the heart can cause areas of the heart to be damaged and could cause necrosis, permanently damaging the heart tissue. Hypoxia affects all the organs. I'm not sure exactly what the affect is of hypoxia on blood vessels. I could imagine they would dilate to try and get more oxygen through the vasculature system
9	To compensate for the hypoxia, the heart muscle begins to contract faster in an effort to circulate more blood to the lungs and vital organs. Blood vessels also begin to dilate to help send more blood to the tissues that need it.
14	heart rate will increase in an effort to circulate and oxygenate more blood. Peripheral vasculature will vasodilate, and pulmonary vasculature will vasoconstrict.

The remaining two students provided answers which did show alternative conceptions that differed drastically from all other students. One student did not exhibit an alternative conception but they provided a unique reason.

Hypoxia causes vasoconstriction of the vasculature in an effort to shunt oxygenated blood to vital organs like the heart and brain. Hypoxia causes the heart to beat faster for the same reason. These changes are part of the body's adaptations to survive with low amounts of oxygen (Student 13).

This student understands that vasoconstriction will occur to all vessels and the heart rate will be increased due to the hypoxia but aligns her reasoning to an adaptation expressing that the

patient will do this in order to survive. It is unclear if the student is using the term adaptation in an evolutionary sense or in the lay sense, meaning a change to an acute condition.

The second student does not provide a physiological response to the prompt and provides a different response, equally unique, as the previous student. "not enough oxygen getting to her main organs. Her body is not sufficiently making enough oxygen to supply O₂ to her body. Her metabolic demands are too high" (Student 8). This student presents the definition of hypoxia, lack of oxygen to a body region, but this is due to the body not making enough oxygen. This suggests that the student believes the body goes through a process, similar to photosynthesis, to create oxygen when the demand is low when in fact processes involving the respiratory system and cardiovascular system take place when oxygen demand is low. None of these processes involve the creation of oxygen by the body.

Summary of Student responses to Scenario 1: Question set 2. This question set probed the students' understanding of hypoxia's effect on the heart and blood vessels. The majority of the students (n=11) provided answers with no alternative conceptions, though almost half of the students lacked knowledge of how low oxygen affects the blood vessels. The remaining students (n=6) held an alternative conception in either their reasoning or, in two cases, a unique perspective on the physiological processes. The alternative conceptions centered on increased heart rate causing a decrease in blood pressure, the body adapting to or producing oxygen to increase oxygen levels.

Summary of Scenario 1. The first scenario asked the students to describe the effects of nitroglycerin on the patient's blood pressure and how hypoxia affects the CVS. Eight students (47%) held alternative conceptions for this scenario. Two students (12%) held alternative conceptions pertaining to nitroglycerin's effect on the CVS. These students understood that

nitroglycerin would lower blood pressure but their understanding of the pharmacological mechanisms was incorrect. Six students (34%) held alternative conceptions for the second half of the scenario. Four of the students believed that hypoxia would cause a decrease in blood pressure. The remaining two reported unique alternative conceptions suggesting that the adaptation is the reason for the physiological changes from the disease state or that the body produces oxygen in response to hypoxia. No student held alternative conceptions to both question sets for this scenario.

Student responses to Scenario 2. The second scenario consisted of two paired items or four total questions. The scenario centered on a patient with poor circulation, atrial fibrillation and valve stenosis. The students were asked to explain why the patient's extremities changed color upon being raised and lowered and what affect their diseases had on the CVS. The students' had a total of three alternative conceptions for the first question set. The second question set provided five alternative conceptions as well. For individual response categories of scenario 2 see Table 12 and for a summation of the each category see Table 13.

Table 12

Individual student responses to Scenario 2 by response category

Student	Question set 1	Question set 2
1	NA	NA
2	NA	NA
3	NA	NA
4	NA	NA
5	NA	NA
6	NG	CA
7	LK	LK
8	NA	LK
9	LK	LK
10	CA	IA
11	NA	NA
12	CA	IA
13	NA	NA
14	LK	LK
15	NA	NA

Continued

16	NA	IA
17	NA	NA
Total Alternative Conceptions	3	4

Note: Alternative conceptions include IA and CA

Table 13

Total responses for Scenario 2 by response category (n=17)

Category	Question set 1	Percent (%)	Question set 2	Percent (%)
No Alternative Conceptions (NA)	11	65	9	53
No Alternative Conceptions but Guessed (NG)	1	5	0	0
No Alternative Conception but Lacked Knowledge (NLK)	0	0	0	0
Correct Answer but Alternative Conception in reasoning (CA)	2	12	1	5
Incorrect Answer and Held an Alternative Conceptions (IA)	0	0	3	18
Students Lacked Knowledge (LK)	2	12	4	24

Student responses to Scenario 2: Question Set 1. The first question set for the Scenario 2 dealt with color changes in the extremities of a patient who exhibits peripheral artery disease. The students are asked to explain the color change and how it relates to the patient's blood pressure. Of the 17 students, 12 did not hold any alternative conceptions with one student

guessing. Two students held an alternative conception for this question set in their reasoning to one of the questions in the set. Three students lacked knowledge for this question set.

A student needed to describe the reason for the color change in the patient's extremities and mention constriction of the vessels in order to not have an alternative conception for this question set. The constriction of the vessels could have been described as either through the creation of a plaque or the physiological mechanism of vasoconstriction. For examples of the most comprehensive questions see Table 14.

Table14
Representative student responses displaying no alternative conceptions for Scenario 2: question set 1(n=12)

Student	Response
3	The color change is due to lack of circulation in the lower extremities. This is a characteristic of peripheral artery disease. I believe peripheral artery disease would increase her blood pressure because of the narrowed vessels.
11	When Louise's legs are elevated she is not getting adequate perfusion to her extremities and they will turn a whitish color. Then when puts them in the dependent position there will be a sudden return of blood flow causing the feet to flush red again. This also can be very painful. Peripheral artery disease would increase blood pressure because the heart must pump harder to get blood through the narrowed vessels.
13	PAD is reducing the amount of blood her extremities receive when elevated, so they turn a pale, dusky color. When they are lowered they become bright red because of the surge in blood flow to the limb. PAD would increase her blood pressure because of the vasoconstriction in her extremities.

The two students who responded with an alternative conceptions both thought that the vessels playing an active role in blood transportion. Their responses were:

Student 10: PAD causes narrow arteries in the extremities. This would cause her extremities to be cold and blue, not red. Red would mean that blood is pooling in the lower extremities and the veins are not effectively taking the blood back to the heart.

Student 12: When her feet are lowered, there is less vascular resistance and blood can flow more easily to her extremities. When her feet are higher, the arteries have a harder time pumping blood to them. It can cause an increase in blood pressure as the heart works harder to get the blood to where it needs to be.

Student 10 presents the idea of veins taking blood back to the heart which suggests that the veins use some mechanism to actively take blood back to the heart and without a further qualifier as to what “taking the blood back” it is interpreted as an active process and not as a conduit for blood transportation. Student 12 explicitly suggests that the arteries are actively “pumping blood” to the extremities and does not return to the heart through the veins.

Student responses to Scenario 2: Question Set 2. The second question set for Scenario 2 was preceded by additional information which informed the students with updated patient symptoms that included atrial fibrillation and mitral valve stenosis. The question set dealt with how atrial fibrillation and valve stenosis effected blood flow. While 9 of the 17 students did not hold any alternative conceptions (see Table 15) and four lacked knowledge. Four students held alternative conceptions for the questions set with one student having an alternative conception in their reasoning with the remaining three having views that do not align with scientifically valid explanations (see Table 16). For individual answers and response categories see Tables 12 and 13.

Table 15

Representative student responses displaying no alternative conceptions for Scenario 2: question set 2(n=9)

Student	Response
5	With atrial fibrillation, the atria are "quivering." This means that they are not pumping effectively and blood is not being ejected from the atria properly. This can cause emboli which can cause [pulmonary edema], stroke, or an MI. Valve stenosis puts an increased workload on the heart muscle to pump effectively. When the valves are stenotic, they are hard and non-compliant. The heart is having to force blood through the valves and therefore is having to work harder just to pump blood. In a-fib her blood is pooling in her atria and not getting to the ventricles and out of the heart. Valve stenosis is creating a difficult path for the blood to travel which increases myocardial workload and in turn myocardial demand.

Continued

- 11 In atrial fibrillation the atria are not contracting properly and are just “quivering”, thus they do not effectively pump blood into the ventricles. There can be a pooling of blood in the atria which makes patients more likely to form clots. In mitral valve stenosis, the mitral valve gets a plaque buildup on it and becomes more stiff. This stiffness does not allow for the mitral valve to close all the way during systole and thus there is a backward flow of blood into the atria when the ventricles are contracting. Both of these conditions decrease cardiac output, and together they can greatly decrease the amount of blood circulating to the body, which increases the work load of the heart to maintain adequate perfusion. The stenosis and atrial fibrillation are causing the heart to pump inefficiently. Improper contraction and valve closure cause the flow of blood to be disrupted.
- 13 Atrial fibrillation and mitral valve stenosis reduce the forward flow of blood through the heart. Atrial fibrillation causes blood to pool and stay in the atria, because not all of the blood is able to exit per atrial contraction because the contractions are impaired by the fast atrial contraction rate. Mitral valve stenosis further reduces the amount of blood that is able to leave the left atria and move into the left ventricle. The heart must pump harder to overcome the stenosis and force all of the blood into the left ventricle.
-

Responses that did not contain an alternative conception displayed an understanding of diseases, both atrial fibrillation and valve stenosis, that were described in the scenario. The responses also included reference to a decrease in blood flow through the heart and body due to the atria contracting abnormally either by “quivering” or increasing their contraction rate.

Table 16

Student responses displaying alternative conceptions for Scenario 2: question set 2

Student	Response
6	Both conditions will decrease the flow of blood through the heart. A. Fib. does not allow the heart to fully fill or contract so the cardiac output is decreased. This happens because a fib is a condition where the heart's electrical activity is randomly stimulated. Mitral valve stenosis decreases blood flow through the heart as the opening by the valve is decreased due to stenosis.
10	Valve stenosis and A fib increase the preload of the heart. Valve stenosis also decreases the force of blood ejection. During A fib, the atrium is constantly shuddering. That means that even after systole, blood is left in the atria, increasing the risk of clots and increasing preload for the next beat. A stenosed valve is hard and stiff. Thus, some blood may be left behind during after systole. Also, the heart has to beat harder to eject blood through the stenosed valve, increasing its oxygen demands.

Continued

- 12 The atria are quivering and not delivering a steady flow of blood throughout the heart. The stenosed valve can account for reduced blood flow as well as it greatly reduces the amount of blood able to pass through the valve. It is harder for the heart to pump blood when a valve that should be open has greatly reduced space for blood to flow through. The atrial fibrillation also accounts for extra stress on the heart. Both of these things make it harder for the heart to get the blood to the rest of the body.
- 16 Blood is not being ejected efficiently. Blood is not able to move to the different chambers due to the fibrillation of the atria and the mitral valve not opening wide enough.
-

The four students who hold alternative conceptions for the second question set can be separate into three groups: a) alternative conceptions dealing with valve function in a disease state; b) alternative conceptions in blood flow; and c) preload alternative conceptions. Students 6, 12 and 16 held alternative conceptions surrounding valve function. Student 6 refers to a decrease in blood flow due to a decreased opening of the mitral valve while Student 12 believes that the mitral valve has “a greatly reduced space for blood.” Student 16 suggests that the mitral valve cannot “open wide enough”. Both of these responses suggest that the students believe that the valve closes properly, yet fails to open to its full diameter. In valve stenosis the chordae tendonae become calcified and the valves do not fully close. This causes what is commonly referred to as a leaky valve. The blood flow is reduced in the heart because it flows back into the left atrium.

Student 16 holds the alternative conception in the flow of blood. In the beginning of their response they state that the “blood is not able to move to the different chambers.” It is unclear if they mean that blood has stopped flowing completely or if blood flows between all chambers of the heart. If the latter is suggested, then the student does not display knowledge of a separate right and left side of the heart and blood freely flows between atria and ventricles. Blood flow does not completely halt in the presence of atrial fibrillation and valve stenosis

because this would result in death. Likewise, the septum of the heart separates the two sides of the heart and does not allow blood to flow between the sides.

The final alternative conception present in Student 10 revolves around the topic of preload. They stated that, "Valve stenosis and A fib increase the preload of the heart... that even after systole, blood is left in the atria, increasing the risk of clots and increasing preload for the next beat " This suggests that the student understands preload as the amount of blood in the atria and not as the diastolic pressure which stretches the ventricles. Atrial fibrillation decreases preload because the volume of blood which enters the ventricles from the atria is decreased due to the uncontrolled contraction of the atria. The stretch of the ventricle myocardium from the volume of blood is reduced hence, preload is decreased.

Summary of Student responses to Scenario 2: Question Set 2. Overall the sample of nursing students held few alternative conceptions for the second question set though four students lacked knowledge for the set. Of the 17 student, only 4 held alternative conceptions. These alternative conceptions centered on the function of the mitral valve, flow of blood in the heart and preload.

Summary of Scenario 2. The second scenario tested the student's knowledge of how peripheral artery disease, valve stenosis and atrial fibrillation affected a patient's CVS. A total of six students (35%) held alternative conceptions to this scenario. Two students (12%) held alternative conceptions dealing with vessels having an active role in blood flow. One student thought that arteries contracting cause the blood to flow through the CVS and the second thought veins actively take blood back to the heart.

Four students (23%) held alternative conceptions about the affect valve stenosis and atrial fibrillation had on the CVS. Students held alternative conceptions centered on valve

function (12%), blood flow (5%) and preload (5%). Alternative conceptions dealing with heart valves suggest that students believe stenosis allows the valve to close normally but reduces the diameter of the valve when it is open. Blood flow alternative conceptions centered on blood being unable to move properly in the heart chambers. Preload alternative conceptions suggested that the student believed preload is the term used for the blood that is entering the atria and not the amount of blood which stretches the myocardium. Two students (10 and 12) held alternative conceptions to both of the scenario's question sets.

Student responses to Scenario 3. The third scenario consisted of two paired items and a standalone question or five total questions. The sequence of questions is question set 1, stand alone question 1, question set 2. The students' had a total of six alternative conceptions for the first question set. The stand alone question had a total of six alternative conceptions. A majority of the students had alternative conceptions for the second question set which provided ten. For individual response categories of scenario 3 see Table 17 and for a summation of the each category see Table 18.

Table 17
Individual student responses to Scenario 3 by response category

Student	Question set 1	Standalone Question 1	Question set 2
1	NA	NA	CA
2	NA	NA	NA
3	IA	LK	NA
4	LK	IA	CA
5	NA	NA	NA
6	NA	NG	CA
7	LK	LK	LK
8	IA	IA	CA
9	LK	LK	LK

Continued

10	NA	IA	CA
11	IA	CA	CA
12	IA	NA	CA
13	NA	NA	CA
14	LK	LK	LK
15	NA	NA	CA
16	IA	IA	LK
17	CA	CA	CA
Total Alternative Conceptions	6	6	10

Note: Alternative conceptions include both CA,IA

Table 18

Total responses for Scenario 3 by response category (n=17)

Category	Question Set 1	Percent (%)	Standalone Question 1	Percent (%)	Question Set 2	Percent (%)
No Alternative Conceptions (NA)	7	41	6	35	3	18
No Alternative Conceptions but Guessed (NG)	0	0	1	5	0	0
No Alternative Conception but Lacked Knowledge (NLK)	0	0	0	0	0	0
Correct Answer but Alternative Conception in reasoning (CA)	1	5	2	12	10	58
Incorrect Answer and Held an Alternative Conceptions (IA)	5	29	4	23	0	0

Continued

Students Lacked Knowledge (LK)	4	23	4	23	4	23
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Student responses to Scenario 3: Question Set 1. The first question set for the Scenario 3 dealt with a patient who had an enlarged heart and fluid buildup in his lungs. The students are asked to explain how the enlarged heart contributes to the excess fluid in his lungs and providing a reason for their answer. Of the 17 students eight did not hold any alternative conceptions on the question set (See Table 19). Six students held an alternative conception for this question set. Of the six, one had alternative conceptions in their reasoning to one of the questions in the set while the remaining five students were incorrect (See Table 20). Four students lacked knowledge for this question set with one response being a tautology.

Students who did not harbor any alternative conceptions for this question set provided answers stating that the enlargement or weakening of the left side of the heart was responsible for the excess buildup of fluid in the patient's lungs. The students could also speak to the inefficient nature of an enlarged ventricle and its systemic effects, specifically focusing on the pulmonary vessels and lungs. When the ventricles enlarge they cannot contain the same volume of blood since the myocardium is hypertrophic and has decreased the area of the ventricles. The left side of the heart received blood from the pulmonary circuit and then the left ventricle ejects the oxygenated blood into the systemic circuit. If less volume is being ejected than normal from the left ventricle then the excess fluid will be third spaced into the lungs.

Table 19

Representative student responses displaying no alternative conceptions for Scenario 3: question set 1(n=8)

Student	Response
1	When there is a failure to pump the blood through the heart it tends to back up. This patient has had fluid back up into his lungs from the left side of his heart and most likely will have other signs of right sided heart failure like increased JVD and generalized edema. When the ventricle is enlarged whether it is dilated or hypertrophy it cannot push out the same amount of blood which it was healthy. This causes the back of blood and from the left ventricle this fluid backs into the lungs and the right ventricle backs into the vasculature.
6	When the ventricles enlarge they do not contract as efficiently as normal. The ventricles not contracting lead to a backup of blood (the left backs up to the lungs) causing fluid to build up in the lungs.
13	If Joe's left ventricle is enlarged it could be causing a backup of blood into the pulmonary veins and into the pulmonary vasculature, causing excess fluid in the lungs. When blood is backed up into the pulmonary veins, this causes an increased amount of pressure in the veins. As a function of osmosis, the fluid will move into the pulmonary tissue. However, because blood will continue to back up into the veins because of the enlarged and weakened left ventricle, the pressure in the pulmonary veins will remain high and movement of fluid into the lung tissue will continue.
15	Right sided heart failure could eventually lead to left sided heart failure due to it making it work harder. with left sided heart failure, fluid will accumulate in the lungs. with enlarged ventricles, the pumping is not as effective which slows the rest of the system up (the lungs are right after the right ventricles).

Table 20

Student responses displaying alternative conceptions for Scenario 3: question set 1

Student	Response
3	Joe's ventricles can cause fluid buildup in the lungs because the right ventricle is responsible for transporting blood to the lungs. If the right ventricle is ineffectively doing so, fluid becomes backed up in the lungs.
8	Back flow into the lungs. Heart is working too hard...once it is tired there can be a back flow into the lungs
11	The increased work load of the heart has caused Joe's heart muscle to grow larger over time. This prolonged elevation in work load causes the heart to get tired and not pump as effectively (there will be blood left in the heart at the end of systole), which in turn causes fluid to back up into the lungs.

Continued

- 12 When the heart cannot adequately pump, the kidneys respond by releasing angiotensin to increase the blood pressure in order to facilitate more efficient flow to the organs. This increase in blood pressure can also be accounted for by an increase in retention of fluids. These fluids can accumulate in the lungs. This is what I deduced from my current knowledge.
- 16 His ventricles are not able to push the blood out of the heart so there is a backup of fluid into the lungs. The ventricles are so large that they cannot move efficiently. Because of this lack of movement, more blood stays in the ventricles when it should be leaving the heart. The blood then backs up into the atria which then back up into the lungs and the rest of the body.
- 17 The stretching of the ventricles make it harder for them to forcibly contract and meet normal cardiac output. This left over blood will flow backwards into the lungs with time. The blood will spill from the left atria into the lungs.
-

Six students held alternative conceptions for this question set. These alternative conceptions were separated into four categories: a) the heart itself is tired so blood does not circulate effectively; b) the kidneys are responsible for the retention of fluid; c) circulation or flow of blood and d) heart and vessel anatomical alternative conceptions. Five students' response fell into a single response category with the remaining student having alternative conceptions in two categories. Two students held the single alternative conception that the heart gets tired or they held an anthropomorphic view of the heart when it decreases its contractile strength. This alternative conception was represented by stating, "the heart is working to hard...once it gets tired there can be backflow into the lungs" (Student 8) or "This prolonged elevation in work load causes the heart to get tired and not pump as effectively (there will be blood left in the heart at the end of systole), which in turn causes fluid to back up into the lungs" (Student 11). When the heart loses contractile strength the amount of blood ejected from the left ventricle will decrease, thus allowing fluid to be third spaced into the lungs.

The second group of alternative conceptions for this question set involved the kidneys which release angiotensin to increase blood pressure. Student 12 mentioned that angiotensin is responsible for increasing blood pressure and it also helps in fluid retention. This retention of fluids is responsible for the third spacing of the fluid in the lungs. Angiotensin is a class of hormones with five different angiotensin molecules (I-V) which serve several functions in the body. Specific to the CVS it raises blood pressure through vasoconstriction but it does not cause third spacing or fluid retention.

Three students held the third alternative conception dealing with blood flow or circulation. This alternative conception is different than the first alternative conception because the students do not impose anthropomorphic characteristics on the heart. Student 3 expressed that the right ventricle sends blood to the lungs so it is responsible for the backup.. Similarly, Students 16 and 17 believe that the ventricles cannot circulate blood effectively, yet do not distinguish between ventricles or take for granted the arteries which connect the right and left ventricle to their respective areas of the CVS. Student 3 is correct in that the right ventricle does contract and force blood into the pulmonary circuit which eventually enters the lungs but a slowdown of circulation would happen prior to the right ventricle or third spacing into portions of the body, not the lungs. Student 16 and 17's responses suggest that they believe both ventricles circulate blood that goes to the lungs and the body. The heart contains two ventricles and with each contraction it circulates blood into a distinct area of the CVS.

Finally, one student held alternative conceptions centered on anatomical features of the CVS. Student 17 stated that the reason for the overflow of blood into the lungs was that the "blood will spill from the left atria into the lungs." This suggests that they think the CVS is an open system and that the left atrium connects directly to the lungs. The left atrium connects to

the pulmonary veins which transport blood from the lungs to the heart. The entire CVS is a closed system with blood flowing in a system of arteries, capillaries and veins.

Summary of Student responses to Scenario 3: Question set 1. Only six of the 17 students held alternative conceptions for this question set. The alternative conceptions were split into four categories. Overall, students had difficulties with how blood circulates and anatomical features of the CVS. One student expressed difficulty with fluid dynamics or back flow of blood distal from the right ventricle. Some students failed to differentiate the left and right ventricle as well as how the pulmonary circuit connects to the heart.

Student responses to Scenario 3: Standalone Question 1. This question asked the students to trace a drop of blood from the superior vena cava to the right hand. While seven of the 17 students held no alternative conceptions for this question, one student guessed (see Table 21). Six students held alternative conceptions for the question (see Table 22) while four lacked knowledge. For individual response categories for the question see Table 17 and for a summation of the question's categories see Table 18.

Responses needed to include gross anatomy of the heart and a description of the major vessels in the pulmonary and systemic circuit of the CVS to not hold an alternative conception. The question did not require the students to trace the drop of blood back to the superior vena cava. The responses could be in paragraph form or in a list format featuring arrows between anatomical terms.

Table 21
Representative student responses displaying no alternative conceptions for Scenario 3: standalone question 1(n=7)

Student	Response
2	The red blood cells goes through the superior vena cava, into the right atria, through the tricuspid valve, into the right ventricle, through a pulmonary valve, into the pulmonary arteries, to the pulmonary arterioles, through capillaries where it will lose CO ₂ and pick up O ₂ , into the pulmonary venules, into the pulmonary veins, back through a pulmonary valve into the left atria, through the mitral valve, into the left ventricle, into the aorta (ascending, transverse), into the brachial artery, which will go through other arteries depending on the area of the hand the red blood cell is going too.
6	The blood vessel enters the superior vena cave, then goes into the right atrium, the tricuspid valve, the right ventricle, the pulmonary valve, the pulmonary artery, the pulmonary arterioles, the pulmonary capillaries, the pulmonary venules, the pulmonary vein, the left atrium, the mitral valve, the left ventricles, the aortic valve, the brachial artery, to the smaller vessels of the hand. (I always get confused on mitral and tricuspid valve...so those might be backwards but I believe that is right like 85% sure)
13	SVC -> Right atrium-> tricuspid valve->Right ventricle->pulmonic valve->pulmonary arteries->arterioles->pulmonary capillaries->pulmonary venules->pulmonary veins->Left atrium->mitral valve->left ventricle->aortic valve->aorta->arteries->arterioles->capillary beds in left hand
15	The blood enters his superior vena cave and enters the right atrium, which passes through the tricuspid valve, enters right ventricles, passes pulmonic valve, passes through pulmonary artery, then arterioles, then capillaries then hits lungs, pulmonic vein, then left atrium, passes through mitral valve, left ventricle, aortic valve, ascending, aortic arch, descending aorta, arteries, arterioles, capillaries of hand.

Table 22

Student responses displaying alternative conceptions for Scenario 3: standalone question 1

Student	Response
4	Right atrium, right ventricle, lungs, left atrium, left ventricle, not exactly sure of the rest?
8	rt atrium, rt ventricle, into lungs, pulmonary artery back to heart, into left atrium, to left ventricle and out into aorta to the rest of the body. To get to the left hand it travels through carotid and clavilucar arteries
10	Superior vena cava into the right atrium through the tricuspid valve and into the right atrium. During systole, blood is pumped from the right atrium through the pulmonic valves and into the lungs to be oxygenated. Then it enters the left atrium in an open system. Blood travels through the mitral valve and into the left ventricle where it is pumped through the arterial branch. It enters the brachiocephalic artery, travels down to the hand, and enters the arterioles, then to capillaries to deposit oxygen.
11	Blood goes from the superior vena cava into the right atria, right ventricles, pulmonary arteries, pulmonary capillaries, pulmonary veins, left atria, left ventricle, ascending aorta, brachiocephalic artery, left brachial complex, and radial and ulnar arteries into the left hand.
16	Right atrium, then right ventricle, then lungs, then the pulmonary veins, then the left atria, then the left ventricle, then the aorta, to the arteries of the body, then the arterioles, then finally the capillary beds
17	The blood enters the right atria, then to the right ventricle, then through pulmonary circulation to receive oxygenation, then to the left atria, left ventricle where it is ejected into systemic circulation where it eventually reaches the capillary beds through arterial circulation.

Alternative conceptions appeared in a single category of excluding an anatomical structure(s) which leads to a flawed circulation pathway. This alternative conception is quite diverse because it is unclear if the students excluded the structure or if they believe the preceding structure is a conduit for the blood to the successive structure in their pathway.

Comparing Student 4's response with Student 16 illustrates this diversity. Student 4 excluded the entire pulmonary and systemic circuit vasculature whereas Student 16 excludes the pulmonary artery which suggests two possible reasons for each student's alternative

conception. Student 4 could believe that the lungs and right ventricle are connected directly, likewise, for the lungs and left ventricle or it also could suggest they excluded the pulmonary circuit. Student 16's response displays a similar, yet different, alternative conception since they exclude the pulmonary arteries, yet include the pulmonary veins. This suggests that Student 16 is aware of a pulmonary conduit, but excluded the artery portion of the pulmonary circuit.

The valves of the heart were a common exclusion (Student 4, 8, 10, 11, 16 and 17) across the students with an alternative conception to this question. The valves, both in the heart and in vessels play an intricate role in the flow of blood. The tricuspid and mitral valve prevent backflow between the chambers of the heart whereas the semilunar valves prevent backflow from pulmonary arteries and veins and the aorta.

Student 10 gave a unique response stating that the right atrium pumps blood into the lungs to receive oxygen. They excluded the right ventricle in their pathway and they also state that the pathway is the "superior vena cava into the right atrium through the tricuspid valve and into the right atrium. During systole, blood is pumped from the right atrium through the pulmonic valves and into the lungs to be oxygenated." This suggests that tricuspid valve divides the right atrium into two halves with the first half pumping blood to the second half of the right atrium which then transports blood through the pulmonic valve to the lungs directly. The tricuspid valve separates the right atrium and right ventricle. The right ventricle contracts and blood is transported through the pulmonic valve to the pulmonary circuit of the CVS.

Summary of Student responses to Scenario 3: Standalone Question 1. This question was shown to be challenging for the students. If the students who showed a lack of knowledge for the question are excluded then almost half of the students ($n=6$) hold alternative conceptions. The alternative conceptions were placed into a single, diverse category in which the students

excluded a structure or believed the successive structure attached directly to one another. It is unclear which individuals held the former or later version of the alternative conception.

Student responses to Scenario 3: Question set 2. The second question set for Scenario 3 tasked the students with explaining the effect of the patient's enlarged heart on his cardiac output and providing a reason for their claim. Of the 17 students, three did not hold any alternative conceptions on the question set (See Table 23). Ten students held an alternative conception for this question set. All ten had alternative conceptions in their reasoning to one of the questions in the set (See Table 24). Four students lacked knowledge for this question set with one student using a tautological argument. For individual answers and response categories see Tables 17 &18.

Table 23

Student responses displaying no alternative conceptions for Scenario 3: question set 2

Student	Response
2	As mentioned before, an enlarged heart does not pump effectively, which means less blood is pumped with each heartbeat, which decreases cardiac output. An enlarged heart does not pump effectively, which means less blood is pumped with each beat, which decreases cardiac output.
3	His cardiac output is decreased. If the ventricles are failing, they do not effectively eject blood to the body. The weakened ventricle is unable to eject enough blood to the body's tissues, which causes low cardiac output.
5	Decreases his cardiac output. An enlarged heart is unable to pump blood as effectively. The ventricles are smaller which decreases the amount of blood they can hold and pump. Also, they have poor contractility, making cardiac output decrease.

Table 24

Student responses displaying alternative conceptions for Scenario 3: question set 2

Student	Response
1	Decrease CO. The dilation of the heart allows more blood to fill but the heart cannot give a strong enough contraction. When the contraction is not strong enough to eject an adequate amount of blood it decrease the CO.
4	Cardiac output is decreased. The heart is enlarged because the ventricles are having to work hard to meet the bodies demands
6	the enlarged heart decreases his cardiac output. The enlarged heart does not allow for the heart to contract fully so the heart does not push as much blood out during the contractions
8	tries to work harder at first, but eventually CO will decrease because demands are too high and the heart becomes tired.
10	It decreases cardiac output. The muscles are tired, so they bulk up from extra work. They are now not as efficient and push less blood out of the heart.
11	If the ventricle walls are enlarged (the actual cardiac muscle) it is because it has been over worked for an extended period of time. It will start to not pump as effectively because it is fatigued. There will be blood left over at the end of systole because the heart is not fully contracting. This causes decreased cardiac output.
12	His cardiac output is reduced. His heart has a harder time pumping blood and is less efficient.
13	It reduces his cardiac output because the heart is weakened. The enlarged ventricles are unable to contract with the same efficiency as a heart of normal size. The muscle in an enlarged heart has overgrown to accommodate for other insufficiencies. It cannot contract and produce the same ejection fraction as a normal heart.
15	Decreases cardiac output due to the decreased pumping ability. The muscle is hypertrophied and the pumping ability is lost. With decreased pumping ability, the cardiac output is decreased.
17	Decreases it. The heart cannot adequately contract to meet the body's demands.

The four students who did not hold alternative conceptions for this question set noted that the cardiac output of the heart would be decreased by the enlarged ventricles. The reasoning for this had to surround the idea of the amount or volume of blood being ejected

from the heart. The reason for this is that when a ventricle becomes enlarged the area of the ventricular cavity becomes smaller and holds a smaller volume of blood. Due to the smaller volume the CO is decreased. Each of the student's responses contains these reasons and no other alternative conceptions. Synonymous terms or statements such as "an enlarged heart does not pump effectively, which means less blood is pumped with each heartbeat" (Student 2) or "the weakened ventricle is unable to eject enough blood to the body's tissues, which causes low cardiac output" (Student 3) were used.

Ten of the students held an alternative conception for this question set. All of the students understood that the patients CO would be decreased but their reasoning for this varied. Three general areas of alternative conceptions emerged from the student's responses: a) the heart itself dilates; b) alternative conceptions about contractility or pumping ability of the heart contraction and c) anthropomorphic views suggesting alternative conceptions. Student 1 was the only student who held the alternative conception that as the heart becomes enlarged it dilates and the volume it can contain increases. This increase in volume then decreases CO. When the heart muscle enlarges its myocardium gets thicker or increases in diameter. This increase in size reduces the area for blood to fill and reduces CO. The heart does not dilate to become enlarged.

Seven of the students had alternative conceptions about the contractility of the heart. This could either be misunderstandings that enlargement "does not allow for the heart to contract fully" (students 6, 11 and 13), "had a harder time contracting" (Student 12) or contract with the "same or adequate efficiency" (Students 13, 15 and 17). These students have views where the heart's contractions cease or are interrupted in some manner or there is an ideal contraction of the myocardium. In reality, the force of the contraction is dictated by the amount

of blood that enters the heart which stretches the myocardium. As the volume of blood the ventricles can hold decreases due to myocardial hypertrophy the ‘stretch’ decreases leading to decreased CO.

The final type of alternative conception for this question set is similar to an alternative conception from this scenario’s question set 1; that of an alternative conception spawning from an anthropomorphic view of the heart. Not surprising is that the two student who held an anthropomorphic view in question set 1 (students 8 and 11) appear here as well. These students are joined by students 4 and 10 in responding that the heart gets “tired” or “works too hard.” Student 10 also states that the heart “bulks up” similar to how lifting weights helps to increase skeletal muscle mass. These statements suggest that these students do not understand that the enlargement of the heart reduces the ventricular cavity size, which reduces the amount of blood enters the ventricles and stretches the myocardium and that reduces CO.

Summary of Student responses to Scenario 3: Question set 2. A majority (n=10) of the students who responded to question set 2 held at least one alternative conception. Only three students did not hold any alternative conceptions. All students who responded to the question understood that the enlargement of the ventricles would reduce CO but three categories of alternative conceptions in their reasoning emerged. First, students believed that ventricular diameter increased with enlargement of the ventricles. Second, the enlargement either ceased or interrupted heart contraction which decreased CO. Lastly, anthropomorphic views of the heart suggests a form of an alternative conception such as the heart becoming tired or overworked and this resulted in a decrease in CO.

Summary of Scenario 3. This scenario asked the students to describe the effect an enlarged heart would have on the patient’s cardiac output and how it contributes to fluid on

their lungs. The scenario also had the students describe the pathway a blood cell would travel from the right atrium to the left hand. Overall, this scenario was challenging for students and only two students (12%) did not respond with at least one alternative conception. Four students (23%) responded with alternative conceptions to each portion of the scenario. Students held alternative conceptions centered on blood circulation (12%), fluid dynamics (6%), CVS anatomy specifically excluding features or incorrect connections in the blood pathway (71%), ventricular diameter size in a disease state (6%), heart contractility (41%), alternative conceptions about the interdependence between the renal system (6%) and CVS and anthropomorphic views that the heart gets tired (24%).

Student responses to Scenario 4. The fourth scenario consisted of two paired items and a standalone question or five total questions. The sequence of questions is question set 1, standalone question 1, question set 2. The students' had a total of four alternative conceptions for the first question set. The standalone question had a total of six alternative conceptions. Question set 2 had two students having alternative conceptions in their reasoning. For individual response categories of scenario 4 (see Table 25) and for a summation of the each category (see Table 26).

Table 25
Individual student responses to Scenario 4 by response category

Student	Question set 1	Standalone Question 1	Question set 2
1	NA	IA	NA
2	NG	IA	NA
3	LK	NA	LK
4	IA	NA	NA
5	NLK	LK	NA
6	LK	IA	NA
7	LK	LK	LK
8	IA	NA	NA
9	LK	LK	LK
10	IA	CA	NA
11	NG	NA	NA
12	LK	NA	LK
13	NG	IA	NA
14	LK	LK	LK
15	NA	IA	CA
16	NA	CA	NA
17	IA	NA	CA
Total Alternative Conceptions	4	7	2

Note: Alternative conceptions include both CA,IA

Table 26
Total responses for Scenario 4 by response category (n=17)

Category	Question Set 1	Percent (%)	Standalone Question 1	Percent (%)	Question Set 2	Percent (%)
No Alternative Conceptions (NA)	3	18	7	39	11	65
No Alternative Conceptions but Guessed (NG)	3	18	0	0	0	0
No Alternative Conception but Lacked Knowledge (NLK)	1	5	0	0	0	0
Correct Answer but Alternative Conception in reasoning (CA)	0	0	2	12	2	12
Incorrect Answer and Held an Alternative Conceptions (IA)	4	24	4	24	0	0
Students Lacked Knowledge (LK)	6	35	5	29	4	24

Student responses to Scenario 4: Question set 1. The students were asked to identify which side of the heart was most likely damaged from an occlusion of the circumflex artery. This attempted to challenge the student's anatomical knowledge of the coronary vessels and the areas of the heart they supply with blood. The students then need to supply an explanation for why they chose the respective side of the heart. There were seven students who did not hold any alternative conceptions for this question set (Table 27). While three of these seven supplied responses in which they correctly answered the question, yet disclosed that they guessed. Four students held alternative conceptions that did not involve their reasoning (see Table 28). Six students lacked knowledge for the question set with one having the correct side of the heart identified and stated they guessed. "I want to say left side of his heart, but I'm not sure. Just a guess, honestly" (Student 5).

Table 27

Student responses displaying no alternative conceptions for Scenario 4: question set 1(n=7)

Student	Response
1	Left Ventricle. The circumflex artery feeds the posterior aspect of left ventricle
2	I am not 100% sure but I believe the circumflex feeds the left ventricle. We just studied the arteries this past semester in [a nursing course]. I think the right ventricle is only fed by the right coronary artery
15	The left side of the heart. Anatomy

To be considered to not hold an alternative conception for this question set the student must state that the circumflex artery brings blood to the left side or left ventricle. The response must also state a reason including a discussion of the coronary vessel anatomy. Each of the three students (1, 2 and 15) included the minimum requirement needed to be considered to not hold an alternative conception.

Table 28

Student responses displaying alternative conceptions for Scenario 4: question set 1

Student	Response
4	Right sided heart failure. The blood is backing up into the peripheral system.
8	Right side. He has edema in his peripheries.
10	Right side. Left would lead to a backup into the lungs. Right shows that the venous system is getting backed up. That is why his legs are swollen. Also, his kidneys are not receiving blood, thus no water is being filtered.
17	Right side. Type of edema is a good indicator. I don't necessarily know based on which artery. But edema in the feet suggest right side damage.

Four students held alternative conceptions for the first question set. All of the students responded that the right side of the heart was being affected by the occlusion in the circumflex artery. This is incorrect because this vessel transports blood to the left ventricle. Each of the students also stated that the presence of edema in his feet or peripherals is why the right side of the heart is involved. This suggests that the students focused in on the patient's description, instead of their anatomical knowledge to respond to the question which specifically states this. Student 17 alluded to their anatomical knowledge when they stated, "I don't necessarily know based on which artery." This suggests that they lack knowledge of the coronary vessel anatomy but answered the question using other indicators.

If the circumflex artery has an occlusion then the left ventricle will be primarily affected. If the vessel is not fully occluded, which would cause an MI, eventually the right side of the heart may be compromised. If the right side of the heart is involved than these student's understanding is correct but for the purposes of the question set they hold an anatomical misconception.

Summary of student responses to Scenario 4: question set 1. This question set examined the coronary vessel anatomical knowledge of students. Three of the students did not hold

alternative conceptions while four did hold some alternative conceptions. Ten students either guessed correctly that the left side was involved without supplying a reason or lacked knowledge for the question set. The students who did hold an alternative conception believed that the right side of the heart was involved when the circumflex artery has an occlusion. If the students who guessed or lacked knowledge are removed from the sample than there a majority of students hold alternative conceptions about the coronary vasculature.

Student responses to Scenario 4: standalone question 1. The standalone question for this scenario deals with the effects of the vessel occlusion on the patient's blood pressure. For individual responses to this question see Table 25 and for a summation of each response category see Table 26. Even though the question did not explicitly ask for a reason for their answer, many students did supply one. Seven students did not hold any alternative conceptions for this question (see Table 29). Six students held alternative conceptions for the question with one having an alternative conception in their reasoning (see Table 30). Four students lacked knowledge for this question.

Table 29

Representative student responses displaying no alternative conceptions for Scenario 4: Standalone question 1(n=7)

Student	Response
8	Increase
11	Blood pressure will be increased because the heart must work harder to try and get blood past the occlusion.
12	His blood pressure would be raised.
15	Blood pressure will be increased because of decreased blood flow

Table 30

Student responses displaying alternative conceptions for Scenario 4: Standalone question 1

Student	Response
1	If the occlusion were to damage all of the cells this would decrease his pressure due to the damage to the left ventricle.
2	His blood pressure would decrease because the lack of oxygen to the left ventricle will cause the left ventricle to not pump as effectively.
6	His blood pressure would be decreased as part of the heart is damaged decreasing the ability of the heart to pump out blood efficiently.
10	The vessel occlusion will raise the blood pressure as the vessels work to push through the blockage.
13	His blood pressure would decrease, because part of the heart is not getting blood and therefore is not contracting with the same force that it does normally. This reduces the contractile strength of the heart and, therefore, the blood pressure.
16	His blood pressure would increase because the blood has to be pushed harder in order to move past the occlusion.

To not hold an alternative conception for this question a student response needed to state that blood pressure would increase or rise. The blood pressure will increase because the body is trying to get oxygenated blood to the occluded area. This is done by increasing the heart rate and constricting the vessels. All of the seven students stated as such.

Six students held alternative conceptions for the question. Although two of the six who harbored alternative conceptions correctly identified that blood pressure would increase but had alternative conceptions in their reasoning. The alternative conceptions can be separated into 2 categories: a) damage to heart decreases its function which dramatically decreases blood pressure and b) blood pressure increases due to the heart forcing blood through the occlusion. Student 2 suggests that damage to the left ventricle will cause blood pressure to decrease because the left ventricles will not pump effectively with damage. This suggests that the

students understand that an occlusion will cause damage to the heart but damage happens quickly and the entire heart does not contribute to blood pressure. The major contributor to the systemic blood pressure is the left ventricle but the circumflex artery is not the only vessel which supplies it with blood. Even with some occlusion, the left ventricle will contract and in order to get blood to itself it will increase contractions, albeit labored, which increases blood pressure. Students 1, 6 and 16 have responses which are similar to this as well.

Two students (10 and 16) hold the alternative conception that the heart will try to force blood through the occlusion in the unobscured vessel as well as increase blood pressure. This alternative conception stems from an anthropomorphic view of the heart. The occlusion could be dislodged but the heart is not “trying” to actively do this. Fluid will pool behind an obstruction in a fluid filled system has an obstruction in it and if enough pressure is put on the obstruction it will dislodge. This is a passive consequence of the increase in pressure which does occur when large vessels are partially occluded which in some cases results in strokes or pulmonary embolisms.

Summary of Student responses to Scenario 4: stand alone question 1. This question asked students for an understanding of how a vessel occlusion would affect a patient's blood pressure. Seven of the students did not hold any alternative conceptions while six did. The alternative conceptions that emerged centered on two areas. The first area dealt with blood pressure being decreased from the occlusion while the second alternative conceptions came from an anthropomorphic view of the heart. This resulted in approximately half of the students who responded to the question exhibiting an alternative conception.

Student responses to Scenario 4: Question set 2. The second question set for Scenario 4 tasked the students with explaining the effect of a diuretic (furosemide) on the patient's blood

pressure. For individual responses to this question see Table 25 and for a summation of each response category see Table 26. Of the 17 students, 10 did not hold any alternative conceptions on the question set (Table 31). None of the students held an alternative conception for this question set. Five students lacked knowledge for this question set.

The students needed to identify that Furosemide will decrease the patient's blood pressure due to causing the body to excrete more fluid through urination in order to not hold an alternative conception for this question set. The students could use colloquial terms such as water as a synonym for fluid since the kidneys filter a large volume of fluid which consists of mostly water. They also used terms such as "taking off excess" (Student 10), "extracting" (Student 15) and "force fluid out" (Student 17) when describing how the kidneys filter the fluid. These terms are colloquial terms for the function of the renal system. From the context of the student's responses it could be inferred what were meant by each of the terms in relation to the Furosemide's effect on the CVS.

Table 31

Student responses displaying no alternative conceptions for Scenario 4: Question set 2(n=12)

Student	Response
1	This will decrease his blood pressure because as a loop diuretic this medication removes fluid from the vasculature. It is a loop diuretic which removes fluid from the body in the kidneys in the loop of Henle.
2	It will decrease his blood pressure. Furosemide is a diuretic, which increases the amount of water the kidneys release into urine. Less water in the vascular system means less volume which decreases blood pressure.
4	Furosemide would decrease his blood pressure. Furosemide will get rid of water because it is a diuretic.
5	It will decrease his blood pressure. Furosemide or Lasix is a diuretic. This gets rid of the fluid in the vascular system which decreases the amount of fluid in the vessels which decreases his blood pressure.
6	Furosemide will decrease the blood pressure further. Furosemide is a diuretic leading to the patient urinating out excess fluid. When the patient loses fluid he loses volume, and thus his blood pressure would decrease due to less volume circulating through the system
8	Decrease. Gets water out of system...Lasix.
10	It would lower the blood pressure by taking off the excess fluid.
11	Furosemide will lower blood pressure. Lasix decreases the amount of fluid in the vasculature by increasing absorption at the loop of Henle and causing an increase in urine production.
13	The furosemide will further reduce his blood pressure. Furosemide is a potent diuretic. By reducing the circulating blood volume, the blood pressure will be reduced
15	Furosemide will make him lost fluid which will decrease his blood pressure. Furosemide (Lasix) is a diuretic and will cause his body to extract fluids. When fluids are taken from the body, his vascular system has fluid taken from it which will cause a blood pressure decrease.
16	The furosemide will decrease his blood pressure. The furosemide will get rid of the excess fluid in Ron's body. This reduction in fluid will decrease the amount of fluid in the blood so not as much blood is being pushed into the vessels. Since not as much blood is being pushed, a reduction in pressure will occur.
17	Decrease it. Furosemide forces fluid out of the body which will reduce blood volume

Summary of Student responses to Scenario 4: Question set 2. The question set asked student to describe the effect Furosemide would have on the patient's blood pressure. Furosemide is a diuretic which would increase the frequency of urination. The increased frequency of urination causes the fluid levels in the blood to decrease which in turn decreases blood pressure. None of the nursing students held any alternative conceptions to this question set.

Summary of Scenario 4. The final scenario asked students to use their anatomical knowledge to describe which side of the heart was damaged from an occlusion as well as what affect the occlusion had on the patient's blood pressure. Two students (12%) held no alternative conceptions for this scenario and no student had alternative conceptions to all questions. Four students (23%) held alternative conceptions about which side of the heart would be affected by the occlusion. All of these students believe that the circumflex artery attaches to the right side of the heart instead of the left ventricle.

Only six students (35%) held alternative conceptions dealing with the occlusions effect on blood pressure. Four of these students thought that the presence of an occlusion would decrease blood pressure. Two students thought that blood pressure would increase because the heart is trying to force blood past the occlusion. No students held alternative conceptions pertaining to how a diuretic affects blood pressure.

Comparison of student responses across the assessment. The assessment asked students to apply their CVS knowledge to four different scenarios with a total of 18 questions. The 18 questions consisted of eight questions sets and two standalone questions. Individual student results to each question can be seen in Appendix H. Overall, every student except Student 5 had at least one alternative conception with the most alternative conceptions being held by Student 8 (Table 32). The mean number of alternative conceptions held by the students

was 2.64 ($SD = 1.32$). The mean number of questions where the students held no alternative conceptions was 4.76 ($SD = 2.12$).

The alternative conceptions which were held by the students can be placed into 4 categories. These categories were: a) CVS anatomy, b) blood flow and pressure, c) anthropomorphic views and d) miscellaneous alternative conceptions. A general description of the alternative conception followed by the section of the assessment which supports this category will be given. This will be done because individual student responses were discussed in the previous section.

Nursing Students CVS anatomy alternative conceptions. This alternative conception was exemplified by student responses to Scenario 3: Question set 1, Scenario 3: Standalone question 1 and Scenario 4: question set 1. These questions had responses from students which suggest that they incorrectly believe certain structures lie adjacent or connect to one another. Answers to Scenario 3: Standalone question 1 were perhaps the most revealing with students not understanding the structures a blood cell travels through on its journey in the body despite having multiple courses reinforce this concept.

Nursing Students blood flow and pressure alternative conceptions. Alternative conceptions in this category were very diverse and it is the largest represented category examples across the sample of nursing students. Students who held alternative conceptions in this category responded that the vessels (both arteries and veins) contract to transport blood throughout the body (Scenario 1: question set 1; Scenario 2: question set 1); blood pressure decreases due to the increase in heart rate (Scenario 1: question set 2); valves close completely but have a decreases opening diameter which restricts blood flow when stenotic (Scenario 2: question set 2); conditions which cause back flow in the CVS are present prior to the affected

Table 32

Summary of each student's response category for the entire instrument.

Student	Total NA	Total NG	Total NLK	Total Alt conceptions	Total LK
1	7	0	1	2	0
2	7	0	0	3	0
3	5	0	0	2	3
4	5	0	1	3	1
5	7	0	2	0	1
6	3	2	1	3	1
7	1	0	0	1	8
8	4	0	0	5	1
9	1	0	0	1	8
10	5	0	1	4	0
11	6	1	0	3	0
12	4	0	0	4	2
13	6	1	0	3	0
14	1	0	0	1	8
15	8	0	0	2	0
16	5	0	0	4	1
17	6	0	0	4	0
Mean	4.76	.23	.35	2.64	2
Standard Deviation	2.12	.545	.352	1.32	2.89

Note: Total Alternative conceptions include IA and CA

organ instead of after the affected organ (Scenario 3: questions set 1). Many of these alternative conceptions can be linked to the student's not understanding fluid dynamics or hemodynamics.

Nursing students anthropomorphic view alternative conceptions. An anthropomorphic view of an object is caused when the nursing students impose human characteristics on to it. These views cause the students to respond that the CVS has some sort of sentient intelligence which allows it to perform certain actions. Such actions are that the heart becomes tired (Scenario 3: question set 1) or that the heart tries to force blood through an occlusion (Scenario 4: Standalone question 1). The heart does not increase its heart rate consciously to help clear out occlusions but instead a person's heart rate increases because areas of the body are in need of oxygenated blood or vessel diameter is decreased. The contraction strength of the heart does diminish in some diseases but in the case of the an enlarged heart (as depicted in scenario 3) the cardiac output of the patient's heart is decreased due to the smaller volume of blood the ventricles can hold and not due to it becoming tired.

Miscellaneous alternative conceptions. Finally, the last group of alternative conceptions included students' responses with unique answers that did not fit into any other category. These responses only appeared once in the instrument. Some examples of the responses were that the body adapts to hypoxia or creates its own oxygen (Scenario 1: questions set 2) and the kidneys were responsible for fluid retention (Scenario 3: question set 1). All of these examples do not align with any scientifically valid explanation of CVS phenomena or other areas of biology.

Chapter Summary

This chapter presented the results of the study. The study was divided into two phases. The first phase began by interviewing four expert nurses about their understanding of the CVS. At the conclusion of the phase five important concepts were identified that the expert nurses

used in their daily practice. These concepts were: a) cardiovascular anatomical concepts; b) cardiovascular physiological concepts; c) homeostasis and diseases of the CVS; d) the interdependence and interaction of the CVS with other organ systems and e) the intersection of the CVS and technology in patient diagnosis and treatment.

Next, a model for how the expert nurses used the five concepts was presented. The proposed model suggests that the expert nurses use the anatomical and physiological concepts of the CVS as a base tier to guide their practice. In the second tier the nurses apply the concepts from the previous tier to their individual patients needs expressed in three different regions of the second tier. These regions represent the final three concepts identified from the interviews.

Four scenarios were developed based off of the expert nurses' important concepts. The scenarios were reviewed by measurement experts, nurse experts, science education experts, nursing educators and content experts (n=13). Revisions were made following each of the expert's remarks which strengthen the scenarios. The scenarios were administered electronically to a group of nursing students.

The second half of the study involves nursing students who provided responses to four scenarios created based on the important concepts identified from the expert nurses. The purpose of this phase was to identify if the nursing students harbored any alternative conceptions about the CVS, especially within the five areas identified by the expert nurses. The results of the study suggest that the nursing students do indeed have alternative conceptions about the CVS, particularly in the areas of blood flow, blood pressure and CVS anatomy. Other alternative conceptions were identified but they were not prevalent in the group as a whole.

CHAPTER FIVE: DISCUSSION AND IMPLICATIONS

This chapter is organized into four sections. The first section will summarize the study.

Next, four assertions will be described. The chapter culminates with a discussion contextualized in the relevant literature and concludes with recommendations for future research and practice.

Summary of the Study

For the last two decades nursing researchers (Corlett, 2000; Jordan, 1994) have suggested that there is theory-practice gap in nursing. One reason for this gap is that nursing programs tend to focus more on the psychosocial aspects of nursing instead of focusing on bioscience content (Wynne et al., 1997). Bioscience courses have been suggested to be the foundational courses for the health professions (Schoon, 2001) with nurses' bioscience knowledge linked to increasing patient outcomes (Prowse & Lyne, 2000a; Prowse & Lyne, 2000b). In addition, nurses play a significant role in patient education as a source of information for the patient during the course of their treatment (Newens et al., 1997) and nurses draw upon their bioscience knowledge to make judgments about treatment in their daily practice(Boore, 1981; Jordan & Reid, 1997).

Compounding this problem is that nursing students perceive bioscience courses as difficult (Barclay & Neill, 1987), lack a link to practice (Davies et al., 2000; Davis, 2010), as a source of anxiety (Gresty & Cotton, 2003; Nicoll & Butler, 1996) and nursing curriculum inadequately prepares them for practice (Clancy et al., 2000; McVicar et al., 2010). One bioscience course which nursing students find essential for their success as a nurse is A&P (Wynne et al., 1997) with the CVS being one of the most challenging systems due to the presence of a multitude of student alternative conceptions (Michael et al., 2002).

Currently, there are relatively few studies (Ahopelto et al., 2011; López-Manjón & Angón, 2009; Michael et al., 2002; Özgür, 2013; Palizvan et al., 2013; Pelaez et al., 2005) which focus on undergraduates' CVS understanding with a lack of studies explicitly focusing on nursing students. These studies indicate that undergraduates hold persistent CVS alternative conceptions in the following areas about a) the flow of blood, specifically the role of the lungs in circulation, b) the relationship between blood pressure and flow, c) the structure and function of the heart and d) the effect of exercise on the cardiovascular system. In addition, no study has compared practicing nurses' knowledge of the CVS with nursing student knowledge as a potential source of a theory-practice gap. Current studies dealing with the theory-practice gap suggests that the nursing curriculum itself contributes to this gap (Akinsanya, 1987; Eraut et al., 1995; Trnobrański, 1993) and overlook student knowledge as a possible source.

This study addresses these two areas. Foremost, it links practicing nurses ideas to student understanding as a way to identify if there is indeed a theory-practice gap as suggested by several studies (Akinsanya, 1987; Akinsanya & Hayward, 1980; Courtenay, 1991; Jordan, 1994). What is unique about this study is that it centers on student understanding of an individual organ system, specifically identifying CVS alternative conceptions as a possible source of a disconnect between CVS theory-practice, instead of focusing on how course material is presented (Clancy et al., 2000; MacNeil, 1997) or how well nursing education prepares students for entering the workforce (McVicar et al., 2010; Wynne et al., 1997). The use of the expert nurses answers the call of Jordan et al. (1999) of identifying relevant, clinical based bioscience knowledge as well as Phillips et al. (1996) to link theory- practice.

The study is the first to explicitly look at nursing students' understanding of CVS concepts although practicing nurses' knowledge has been investigated (Angus et al., 2012;

Newens et al., 1996; Newens et al., 1997) but fails to identify alternative conceptions. The current research base for student understanding of the CVS is sparse with the studies combining undergraduates from multiple disciplines such as biology majors (Michael et al., 2002) to non-majors who are taking the science course(s) as electives (López-Manjón & Angón, 2009; Özgür, 2013; Pelaez et al., 2005; Yip, 1998). This study specifically focuses on nursing students in their last semester of coursework before becoming practicing nurses. This group of nursing students brings a unique temporal component to the discussion because the nursing students have completed all of their bioscience courses and are in clinical practicums working with patients. The identification of alternative conceptions at this point in the students' program of study sheds light on alternative conceptions which are resistant to change.

The study consists of two phases with different participants used in each phase. The first phase of the study centered on interviewing expert nurses who worked with cardiac patients on a daily basis in either cardiac ICUs or ERs at two local hospitals. Each interview was transcribed verbatim and analyzed using the constant comparative method (Boeije, 2002; Denzin & Lincoln, 2000; Glaser & Strauss, 1967). The results of the interviews identified five general CVS concepts that are important to nursing practice. This use of expert nurses begins to uncover the relationship between CVS theory and nursing practices. Scenarios underpinned by these important CVS concepts were developed to establish a link between CVS theory and practice and provides a bridge between each phase of the study. Each scenario consisted of a short description of a fictitious patient followed by a set of questions pertaining to the description. Each of the four scenarios was reviewed by a panel of 13 experts to ensure authenticity. This panel consisted of measurement experts, validity experts, nurse experts, science education experts, nursing educators and content experts.

The second phase of the study involved nursing students (n=28) enrolled in their final semester of nursing school. The course chosen for the study was a clinical practicum in the traditional program of study. Students in the course met once a week in class to discuss content with the remaining course time dedicated to students completing their clinical practicum rotations. Seventeen nursing students responded to the open-ended scenarios electronically. Responses were analyzed using the constant comparative method. Results indicate that the nursing students do hold a diverse group of CVS alternative conceptions with many centering in on a) CVS anatomy, b) blood flow and pressure, c) anthropomorphic views and d) miscellaneous alternative conceptions.

Assertions

A total of four assertions were made following analysis of data.

Assertion 1: The five important cardiovascular system concepts identified by expert nurses are used to varying degrees when treating a patient. Five categories of concepts important to practice emerged from the four expert nurses. These concepts are: a) cardiovascular anatomical concepts; b) cardiovascular physiological concepts; c) homeostasis and diseases of the CVS; d) the interdependence and interaction of the CVS with other organ systems and e) the intersection of the CVS and technology in patient diagnosis and treatment. Each concept influences the other four concepts in the course of treating a patient with some of the concepts, specifically CVS anatomical and physiological concepts, having a greater influence than others.

The first two concepts, cardiovascular anatomical and cardiovascular physiological, are perhaps the most important concepts because they form the foundation of the expert's knowledge. Understanding the basic anatomy and physiology of the CVS is important when

treating patients because deviations from the normal function dictate how the nurses respond to the patient's individual case. The expert nurses provided several examples of CVS anatomy that are important. These examples included knowing the different sides of the heart and where coronary vessels connect to the heart. The most prevalent example was the location of the coronary vessels, in particular the circumflex artery, since they are commonly involved with STEMI with all four nursing experts relating stories of treating patients with either a MI or a STEMI. Sarah illustrated this concept when speaking about the widow maker or "the left anterior descending artery and the left veins supply the left ventricle which is the power house. So those have been named the widow maker. As in if you don't get that treated right away then they are gone" (Interview, January 30, 2014). Since the widow maker is potentially lethal, it is important for the nurses to understand where the vessel connects and resides anatomically.

Another anatomical feature that is important to understand is which side of the heart is affected in a disease state. Gary stressed knowing this because "where the damage is to the heart and is this a left heart where fluid might be a big issue or is this a right heart problem where they might need fluid to support them" (Interview, January 20, 2014). Complications arise in the body depending on which side of the heart is involved such as pulmonary edema or peripheral edema.

Perfusion, cardiac output and blood pressure were some of the more common examples of CVS physiological concepts that were deemed important by the expert nurses. Understanding the relationship between these three physiological processes is important for the expert nurses when treating a patient. The expert nurses understand that having a good cardiac output will increase perfusion rates and it is dictated by the patient's blood pressure and blood flow. Tom stressed the importance of perfusion because "when you lose cardiac output your kidneys

aren't being fed, aren't being perfused. [During] perfusion a multitude of things are taking place. Your red cells going and dumping oxygen, they are also picking up waste, metabolic waste and toxins and carrying them to the kidneys for disposal (Interview, January 27, 2014). If the kidneys are not removing waste or lack blood supply them diseases such as kidney failure can manifest.

The last three important concepts, homeostasis and CVS diseases, interdependence between CVS and organ systems and the intersection of technology and CVS knowledge, build off the expert nurses' knowledge of CVS anatomy and physiology. Understanding normal physiological conditions helps the nurses understand patient symptoms and diseases. The expert nurses consider homeostasis as the body's normal condition and deviations from this occur in a disease state. All of the nurses described similar symptoms for a MI with Claire being the most succinct. "A heart attack, there is a blockage and the heart is not getting oxygen, ST elevation. [The patient] need(s) to get to the cath lab. Usually, [symptoms] are pressure radiation to the left arm, jaw, neck, sweaty, shortness of breath [and] nausea" (Interview, February 18, 2014). The nurses, illustrated here by Claire, understand that certain diseases have telltale signs which people in homeostasis do not have.

Physiological concepts also underpin the interdependence of other organ systems with the CVS as well as how to interpret EKG or why to administer certain medications. Tom described how these two concepts are used in his daily practice when describing how he would report a patient's condition and treatment regime to a physician.

I've got a patient here heart rate is 86/40. Patient is light headed and dizzy. Isn't seeing very straight oxygen saturation is 88% on rhumare. She is huffing, her lungs are both wet bilaterally in her lower and middle lobes. Her right side upper lobe is also wet. Vital signs are good. No bowel or bladder issues because she pees regularly. Has not taken her Lasix for three days because she is fatigued when she has to get up all the time. She got two to three plus pitting edema bilateral lower extremities. I'm going to get a line in her to get some

ABG's I am going to order the appropriate lab to include a BNP which is to check specifically for CHF. And we are going to put her on CPAP or BiPAP (Interview, January 27, 2014).

Tom reinforces the idea of interdependence when he reports that the patient has edema, fluid on their lungs and her bowels are working properly. By ordering a BNP he is using technology to get a better diagnosis for his patient.

Assertion 2: Nursing students hold a diverse set of cardiovascular system alternative conceptions. The nursing students as a whole do hold several alternative conceptions but each individual student holds relatively few alternative conceptions and varies by individual. Three alternative conceptions were held on average by the group with the most alternative conceptions being five (Student 8). Relatively few students held alternative conceptions to an entire scenario when comparing across the nursing students response however, the same can be said for hold no alternative conceptions for an entire scenario (Table 33).

Table 33

Comparison of number of students who held no alternative conceptions to a scenario with students who held alternative conceptions to the entire scenario (n=17)

Scenario	Held no alternative conceptions	Percent (%)	Held alternative conceptions to entire scenario	Percent (%)
1	4	24	0	0
2	9	52	2	12
3	2	12	4	24
4	2	12	0	0

Collectively, the nursing students exhibited alternative conceptions to all five of the important CVS concepts from phase I of the study. The alternative conceptions which were held by the students can be placed into four categories. These categories were: a) CVS anatomy, b) blood flow and pressure, c) anthropomorphic views and d) miscellaneous or unique alternative

conceptions. The nursing students who held alternative conceptions in CVS anatomy did not seem to understand the vascular route which transports blood throughout the body. This was represented by responding with an incorrect circulation pathway as well as being indecisive as to the anatomy of the coronary vessels. Thirty-five percent of the nursing students failed to include the correct pulmonary circuit or omitted it altogether and 24% of the nursing students believed that the circumflex artery transported blood to the right side of the heart.

Cardiovascular physiology had the largest number of alternative conceptions for the nursing students. Thirty-five percent of the students held alternative conceptions that a) increases in heart rate would decrease blood pressure; b) a smaller diameter of a valve would cause a restriction in blood flow as well as; c) fluid dynamic alternative conceptions with students believing that complication from an occlusion would arise in areas of the CVS prior to the occlusion it instead of after. For example, Student 3 (Scenario 3: Question set 1) thought that if fluid built up on the lungs it was due to damage to the right ventricle instead of the left ventricle.

Patients exhibiting enlarged ventricles were also a source of physiology alternative conceptions for the nursing students. The nursing students correctly identified that an enlarged heart would result in decreased cardiac output but a variety of reasons were given as to why this would occur. Some student responses included that the cardiac output would be decreased from the ventricles dilating in an enlarged heart, the heart does not fully contract or eject all of the blood or that the enlarged heart would cease contracting and decrease CO.

Two students held alternative conceptions which involved the interdependence of the CVs and other organ systems and intersection of technology and the CVS. These alternative conceptions centered on the interdependence of the renal system with the CVS as well as the

pharmacological action of nitroglycerin. Student 12 (Scenario 3: Question set 1) who used the renal system as an example discussed angiotensin causing fluid retention. Student 15 (Scenario 1: Question set 1) thought that nitroglycerin relaxed the heart itself which caused blood pressure to decrease.

Assertion 3: Some of the cardiovascular system alternative conceptions stem from student's imprecise use of biological terms or lay usage. Many nursing student alternative conceptions contained imprecise use of scientific terms. Student 12 (Scenario 2: Question set 1) described that arteries "have a harder time pumping blood" instead of them being a conduit with blood being moved by the contracting heart. It may be that the term pumping was meant to mean transport but the student is incorrect physiologically. Student 10 (Scenario 2: Question set 1) also describe the veins not effectively taking blood back to the heart. In this instance, the student presents an answer where the veins have an active role in transportation instead of a conduit. This answer is vague and the student may have not meant it as an active role but the surrounding context of their responses supports the notion of contracting to transport blood. Student 13 (Scenario1: Question set 2) exhibited a unique alternative conception when using the term adaptation incorrectly. Student 13 responded that the increase in heart rate due to hypoxia was the "body's adaptations to survive with low amounts of oxygen."

Finally, many nursing students used anthropomorphic descriptors such as the heart getting tired (Scenario 3: Question set 1) or the ventricles enlarge or "bulk up from extra work" (Student 10, Scenario 3: question set 2). This response suggests that Student 10 views increasing heart rate leading to an increase in the heart size similar to how exercising a skeletal muscle leads to an increase in its size. Using terms such as getting tired as a synonym for a less strong

contraction is incorrect and inferences could not be made from the surrounding context of their response to indicate different interpretations.

Assertion 4: There is a misalignment between expert nurses' and nursing students' knowledge which could potentially contribute to the theory-practice gap. The misalignment of the two groups appears when comparing the expert nurses' CVS knowledge the alternative conceptions in the nursing students in this study. The model purposed in this study uses the concepts of cardiovascular anatomy and physiology as the foundation for the expert nurses knowledge. There is support that nursing students have alternative conceptions in their basic CVS anatomy and physiology so, by extension, these alternative conceptions could impact decisions made in practice. Some of the CVS anatomy and physiology alternative conceptions present in the group of nursing students are unclear blood flow pathways (Scenario 3: Stand alone question), relationship between pressure and flow (Scenario 1: Question set 2) and hemodynamics (Scenario 3: Question set 1).

Discussion

This section of the chapter provides in depth discussions of the results in context of the literature. Each phase of the study will be discussed independently.

Phase I. This study is one of the few studies (Michael, 2007; Michael & McFarland, 2011) which attempts to uncover important anatomical and physiological concepts. What makes this study unique is that the important concepts were not solicited from members of academia but from practicing nurses specializing in the CVS. Michael and McFarland (2011) identified broad concepts which span the entire breadth of anatomy and physiology while a smaller scope, investigating only the CVS, was used in this study. Even though the scopes of the studies differ, the results are similar. Both the current study and Michael and McFarland (2011) identify

homeostasis, structure function and interdependence between organ systems as among the most important concepts. Several other studies (Gellert, 1962; Ozsevgec, 2007; Reiss & Tunnicliffe, 2001) suggest that students have an inadequate or limited understanding of how our body systems are interrelated and each of the expert nurses in the current study reinforced how the CVS interacts with other organ systems.

The nursing experts also stressed the importance of understanding the intersection of the cardiovascular system and technology, specifically the 12 lead EKG and medications. Drew, Ide, and Sparacino (1991) investigated the accuracy of practicing nurses use of the 12 lead EKG and found that 63% of the 302 nurses improperly placed the electrodes. This reinforces that practicing nurses and nursing students need to be able to properly incorporate technology into their practice. The expert nurses also mentioned many types of medication, such as diuretics, vasodilators and anticoagulants, that they administer to patients and stressed the importance of understanding the pharmacological action of these medications. Several studies suggest that both practicing nurses (King, 2004; Latter, Rycroft-Malone, Yerrell, & Shaw, 2001; Manias & Bullock, 2002a) and nursing students (Latter, Rycroft-Malone, Yerrell, & Shaw, 2000; Manias & Bullock, 2002b) have difficulties in explaining and understanding the actions of medications they administer. In addition, having a strong understanding of pharmacological knowledge has been suggested by the Nursing and Midwifery Council (2002) since nurses are becoming more autonomous in their practice and often educate their patients about medications.

The five important concepts identified by the expert nurses have the potential to begin a discussion about introductory curriculum for nursing students similar to what is proposed in *Vision and Change* (AAAS, 2009). *Vision and Change* suggests five major concepts to be emphasized throughout the course which provide students with a framework to better support

their learning of introductory biology content . *Vision and Change's* (AAAS, 2009) proposed curriculum approach reduces the amount of content and emphasizes application and problem solving instead of rote learning.

There is potential from the findings in phase I to start to reduce content and to give students a framework based on important concepts in practice. The expert nurses in this study suggested that interdependence of the CVS with other organs systems as well as the intersection of technology and the CVS aid in treating a patient. If these areas were incorporated into introductory courses' curriculum it would give students an opportunity to apply their CVS knowledge early in their program of study instead of later in their program as was the case with the group of nursing students in the current study.

Phase II. The nursing students involved in the study hold alternative conceptions in categories which are similar to areas identified as difficult for students from K-12 through post-secondary courses. The scenario which the nursing students held the most alternative conceptions was scenario 3. This scenario addressed the pathway of blood, interdependence between CVS and respiratory and cardiac output. All of these concepts have been shown to be difficult for students (Arnaudin & Mintzes, 1985; Cliff, 2006; Michael et al., 2002) with the most alternative conceptions appearing in the nursing students blood pathways.

The nursing students presented pathways which omitted vessels, specifically the pulmonary circuit, or believed that the structure were incorrectly connected (i.e. the lungs connect to the right atrium). Similar alternative conceptions about the CVS have been reported in elementary (Arnaudin & Mintzes, 1985, 1986), high school (Alkhawaldeh, 2007; López-Manjón & Angón, 2009), undergraduate (Pelaez et al., 2005; Windschitl & Andre, 1998) and professional students (Ahopelto et al., 2011; Mikkilä-Erdmann et al., 2012; Palizvan et al., 2013).

Other alternative conceptions present in the nursing students related to the pressure and flow of blood and having difficulties reasoning why fluid would third space into specific areas of the body (Scenario 3: Question set 1). Michael et al. (2002) found similar alternative conceptions and related the alternative conceptions to students having a misunderstanding of hemodynamics. In Michael and colleagues' study, a pair of multiple choice questions was presented with a diagram showing a tube being pinched and asked the students how the pressure would change in the tube. They found that 46% of the students incorrectly identified that pressure would decrease following the pinch in the tube although 26% of these students correctly answering a similar question in the context of the CVS.

Other areas of the CVS where the literature suggests undergraduates hold alternative conceptions were the anatomy of the heart (Ahopelto et al., 2011; Michael et al., 2002; Mikkilä-Erdmann et al., 2012; Palizvan et al., 2013), yet the nursing student in this study did not hold any alternative conceptions pertaining to the anatomy of the heart. The anatomical alternative conceptions held by the nursing students related to exclusion of portions of the CVS that a blood cell travels through or valves' function within the heart.

Some alternative conceptions were unique to this group of nursing students and were not found in the CVS alternative conception literature. One example of this was the alternative conception was that the body creates its own oxygen in response to hypoxia (Student 8, Scenario 1: Question set 2). This particular alternative conception has not been a documented alternative conception and may be unique to this individual.

Several of the nursing students' responses contained responses using lay terms such as vessels pumping or contracting and the heart getting tired. Student 13 (Scenario1: Question set 2) exhibited an alternative conception when they used the term adaptation in their response.

This individual believed that the body adapts to hypoxia by constricting vessels and increasing its heart rate. The use of imprecise or lay terms by students is not uncommon when learning a science topic. One area where imprecise use of terms can lead to alternative conceptions is evolution. Even though this alternative conception is not CVS centric, it illustrates the point that imprecise use of scientific terms is a potential source of alternative conceptions. Specifically, many non-major biology students inaccurately use the term adaptation when describing the origin and role of variations (Anderson, Fisher, & Norman, 2002; Bishop & Anderson, 1990; Demastes, Good, & Peebles, 1995; Nehm & Reilly, 2007).

Finally, the knowledge that an expert nurse holds differs from nursing students (Benner, 1982). This difference is predominantly due to experiences the nurses have in the workplace and not “the mere passage of time but by encountering many actual practical situations that add nuances or shades to theory” (p. 407) and is consistent with studies done on expert and novices (Bruer, 1993). The presence of these alternative conceptions in the nursing students could contribute to a CVS theory-practice gap because it suggests that individuals lack strong bioscience knowledge which has been linked to increased patient outcomes (Prowse & Lyne, 2000a). If nursing students follow the same proposed model as expert nurses for treating patients then alternative conceptions can potentially cause a cascade of problems.

According to Ausubel (1968) learning new information is dependent on relevant, existing ideas in a person’s cognitive structure. Successive learning is therefore hinged onto these existing cognitive structures when building a person’s knowledge base for a topic. These relevant cognitive structures may not always align with scientifically valid ideas but must make sense to the individual. Therefore, if a nursing student harbors an alternative conception all successive learning can be askew since it is being built on an incorrect foundational idea. For

example, Student 3 believed that as heart rate increases, blood pressure decreases (Scenario 1: Question set 2). This idea does not align with the acceptable idea that as heart rate increases, blood pressure increase as well. This creates a potential starting point where Student 3's notion of blood pressure starts to deviate from the scientifically valid understanding (see Figure 4). All additions to the concept of blood pressure following this deviation could potentially widen the gap between the two pathways and potentially contribute to a theory-practice gap in this individual.

In order to combat this, the two hospitals in this study require newly hired nurses to take additional specialty coursework through the hospital. Jefferson Hospital require ACLS courses for nurses working in the ER (Claire, personal communication, February 18, 2014) and Davis requires multiple courses including a cardiac educator course during orientation, a one day trauma course with a review course every year thereafter (Sarah, personal communication, May 12, 2014). Each of these courses reviews basic CVS anatomy and physiology as well as effective nurse driven practices for the respective hospitals. Additionally, many nursing programs have introduced the lecturer-practitioner (Fairbrother & Ford, 1998; Quinn, 2000).

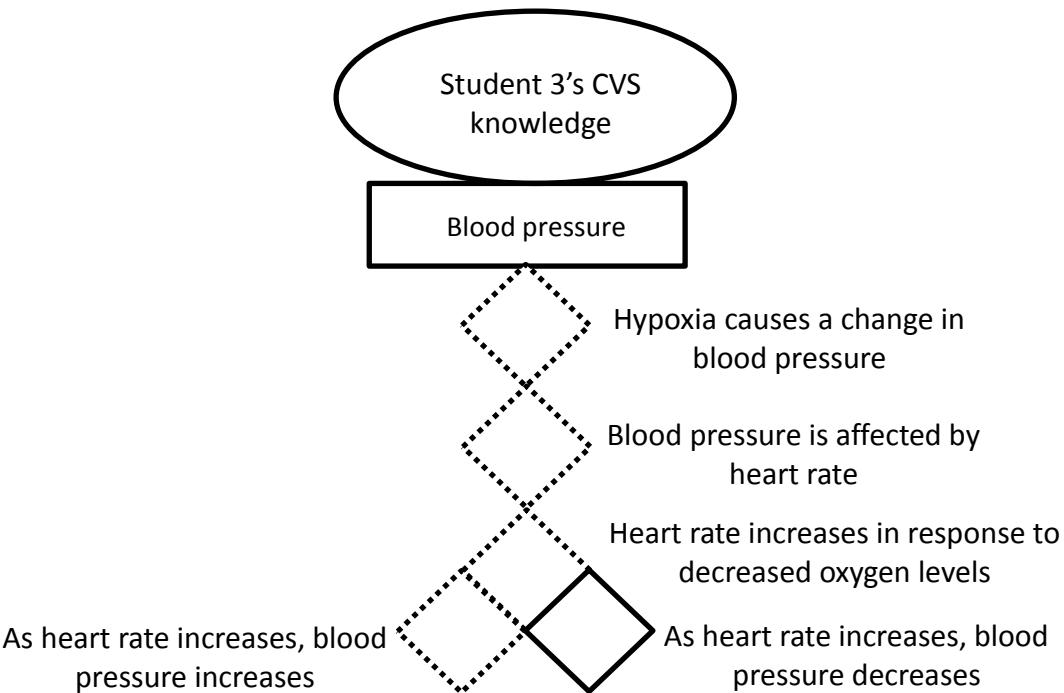


Figure 4: An illustrative example of a potential CVS theory-practice gap between scientifically valid notions and alternative conceptions about blood pressure. Solid lines indicate notions held by Participant 3 while dashed lines indicate scientifically valid ideas.

These positions consist of people who work both in a hospital setting and are nursing educators. The hope is that due to them continuing to practice while instructing that the nursing students will have a resource for insights into where theory and practice merge (Landers, 2000) thus having more experiences and opportunities to alleviate any alternative conceptions.

Recommendations for future studies

This study has implications for future research involving aspects of both nursing students and educational practices of nursing educators. The results of this study inform how CVS content is taught in grades 13-16, specifically focusing on how instructors teach and how they assess. Suggestions for future research related to student learning and instruction of CVS content are made as well.

Recommendations for nursing educator studies. This study give support that a possible source of alternative conceptions was the students' imprecise use of scientific terms. Instructors need to be mindful of the colloquial terms they use during instruction. For example, when teaching about the function of the vessels instructors need to avoid using terms such as pumping or anthropomorphic statements such as the heart trying to force blood to areas. Reinforcing the physiological mechanisms using correct scientific terminology may seem trivial since instructors clearly understand the correct function of the CVS; yet, assuming students have the same understanding of these colloquial terms could be an oversight by the instructor. A possible study could involve aspects of pedagogical content knowledge (PCK) (Magnusson, Krajcik, & Borko, 1999) of nursing educators specifically focusing on their knowledge of student learning. One study (Rovick et al., 1999) dealing with students' respiratory system knowledge suggests that there is indeed a misalignment of what instructors think students know and what the students actually know. This also meets the call of Abell (2008) for strong descriptions of science teacher PCK.

Instructors in foundational bioscience courses, such as A&P, need to begin to incorporate reform based teaching practices into their courses since research has shown that student centered instructional practices are one way to alleviate alternative conceptions (Wandersee et al., 1994). Studies outside of nursing curriculum have shown that when students construct their own understanding through student centered instruction they develop a more robust understanding of body systems (Brown, 2010; Carvalho, 2009; Goldberg & Dintzis, 2007; Hughes, 2011; Krontiris-Litowitz, 2009). Currently, some successful student centered activities in nursing courses are the use of simulation dummies (Hoadley, 2009; Rauen, 2004) to help bridge the gap between theory and practice with more student centered instructional techniques such

as kinesthetic learning (Wagner, 2014) and problem based learning (Rideout et al., 2002) to understand blood circulation becoming available.

Another possible approach to understanding nurse educator's instructional practices is to investigate their use of formative assessment. Formative assessment allows the instructor to monitor student learning and provides a way for students to monitor their own learning through a metacognitive approach (Pellegrino et al., 2001). Understanding current formative assessment practices of nursing educators will begin to provide insight into how, or if, instructors use formative assessment to target students' alternative conceptions and potentially lessen their prevalence (Sadler, 1989). The scenarios created in this study could be incorporated as a formative assessment tool to investigate faculty perceptions about the scenarios.

Finally, this study begins to uncover the CVS areas that nurses use in their daily practice. These areas are included in the current curriculum for nursing students but instructors need to focus more on how the CVS and other organs systems interrelate instead of the current organ system approach (Silverthorn, 2002a) in foundational courses. Nursing students consider A&P as the most important course for their success (Wynne et al., 1997) so making it more cohesive and meaningful to them at the beginning of their studies has the potential to lessen student anxiety (Gresty & Cotton, 2003) and alleviate student's perceived lack of a link between theory and practice (Davies et al., 2000). This would also meet the call for more meaningful classroom experiences which link theory and practice proposed by Crotty (1992) and Corlett (2000) as well as suggestions from *Vision and Change* (AAAS, 2009) for emphasizing application and problem solving.

Recommendations for nursing student studies. This study investigated the alignment between concepts that expert nurses deem important and the alternative conceptions that

nursing students hold for those concepts. The study includes a small sample of expert nurses from cardiac ICUs and ERs. Multiple wards or floors of a hospital, such as NICUs and surgical wards, deal with cardiac patients and there is a potential to add more concepts to the one identified here. In addition, a larger sample of nurses and nursing students from diverse backgrounds needs to be undertaken in order to corroborate the findings of this study. This will also allow for further support and modifications to the model of how the expert nurses use their CVS knowledge.

Researchers should try to establish a solid relationship with practicing nurses in order to effectively facilitate recruitment. Recruitment of expert nurses for this study was impeded due to recruitment being done through a research flyer, as per the request of the hospitals, which limited contact between the researcher and the practicing nurses. Expert nurses may have been hesitant to participate since the researcher was an unknown to them so forming a relationship to the nurses is critical for recruitment and model refinement. The same can be said for the use of an electronic survey. Nursing student participant retention from the time of recruitment and administration of the scenarios was lower than expected so giving pen and paper scenarios to students might aid in uncovering more nursing student alternative conceptions.

The scenarios created for this study did access multiple alternative conceptions held by the nursing students but in some instances the responses were unclear. Administering the instrument to a new sample of nursing students with a follow up interview targeting specific students who hold alternative conceptions would allow for more robust explanations of these alternative conceptions. The interview process could also be used as a way to refine the instrument based on student responses. The instrument was created and revised based on expert feedback but the students themselves did not have the opportunity to provide feedback.

Along the same lines, the scenarios were given to all students in the same order. It may be possible that the scenario order contributed to the presence or absence of alternative conceptions. Students may have modified their answers off of previous responses since some topics were asked in multiple scenarios. For example, Scenario 1 and 4 both asked students about blood pressure so alternative conception responses from one could potential influence responses on the other. With this in mind, a study investigating the effect of scenario order on the presence of alternative conceptions is needed.

The nursing students in the study were at the end of their program of study and still harbor CVS alternative conceptions. Research is needed on nursing student at different time intervals in their education to track which alternative conceptions are most resistant to change. This study involved students who have had multiple bioscience courses dealing with CVS content and they harbor CVS alternative conceptions. A longitudinal, qualitative study may enlighten a progression of different types of alternative conceptions at different points in the nursing program of study. A potential trajectory for sampling could be at the beginning of their coursework, after anatomy and physiology and at the end of their nursing program.

This study suggests that alternative conceptions that nursing students hold may potentially add to the CVS theory-practice gap. A study is needed to address this by following a group of nursing students from their last semester of course work into the first year of practice. The students could have their CVS alternative conceptions identified through the scenarios as they exit school followed by a second administration of the scenarios during their first year of practice. Stimulated recall questions using their first responses while in nursing school could help access differences between their previous and current thinking as a possible way to access a theory-practice gap. Successive interview questions could address other aspects of the theory-

practice gap such as coursework preparation and additional coursework required by their employer.

Finally, this study begins to add to the foundation for the development of a large scale assessment, such as a concept inventory or diagnostic test, for use in both anatomy and physiology and nursing courses. The results of phase II of the study add support that nursing students, even after extensive bioscience coursework, harbor similar alternative conceptions to undergraduates in introductory courses (Michael et al., 2002). Open ended questionnaires are not viable in large enrollment courses so there is a need for a quick, effective way to pre and posttest student knowledge in such courses.

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APPENDIX A

Student demographic information

Student Consent Form

You are invited to be in a research study entitled "Examining Nursing Students' understanding of the Cardiovascular System in a BSN program" which will investigate nursing students' alternative ideas about the cardiovascular system. You will be asked to answer questions based on scenarios created from expert nurses in the field of cardiovascular care. The survey will take approximately 30 minutes to complete and all participation is voluntary.

The study: This study is being undertaken to determine areas of cardiovascular anatomy and physiology which nursing students have difficulties understanding and applying their knowledge to real world situations. You will answer questions pertaining to different scenarios which nurses encounter in their practice. We hope to involve as many people as possible in the study to produce valid data.

Risks and benefits: There are no risks involved in this study, and there are no penalties for people who choose not to participate. The study will benefit those who choose to participate and answer questions. It will also benefit nursing education as it will provide data for areas where anatomy and physiology instructors need to cover more in depth. It will also benefit you because the scenarios are authentic situations which nurses encounter at their job.

Confidentiality: The records of this study will be kept private. Any personal, identifiable information will be changed or removed after collection. All of the hard copy data will be stored in a locked filing cabinet in a locked office. Any electronic data will be stored on a password protected computer or password protected server.

Voluntary nature of participation: Your decision whether or not to participate will not affect your current or future relations with University of Missouri-Columbia or the Sinclair School of Nursing. If you decide to participate, you are free to withdraw at any time without affecting your relationship with University of Missouri-Columbia or the Sinclair School of Nursing. Furthermore, you may refuse to participate or discontinue participation at any time.

The researchers conducting this study are Parker Stuart, Doctoral Candidate in Learning, Teaching and Curriculum at the University of Missouri, Columbia and Dr. Lloyd Barrow, Professor of Science Education at the University of Missouri, Columbia. You may reach Parker Stuart at 515-408-1005, or pes4kc@mail.missouri.edu. Dr. Barrow can be reached at 573-882-7457 or BarrowL@missouri.edu. Please feel free to ask any questions you have now, or at any point in the future. In addition, if you have any questions or concerns about your rights as a research subject, you may contact the University of Missouri- Columbia Campus Institutional Review Board (IRB) at 573-882-9585, or you may access their website at <http://research.missouri.edu/cirb/>.

Consent: I have read and understand the above information, and I have received a copy of this form. By signing below, I indicate my willingness to participate in this study.

Student's name: _____

Signature of Student: _____ Date: _____

1. Name:
2. Email Address:
3. Gender:

Female

Male

4. Age:

18-24

25-34

35-44

45+

5. Ethnicity:

Asian/ Pacific Islander

Black or African American

Hispanic or Latino

Native American or American Indian

White or Caucasian

Other (Please specify)

Prefer not to respond

6. Do you have any previous college degrees or health care licenses?

Yes (Please specify below)

No

7. Which of the following science courses have you taken in college (check all that apply)?

- Chemistry
- Organic Chemistry
- Biology
- Physics
- Pharmacology
- Pathophysiology
- Human Anatomy
- Human Physiology
- Anatomy & Physiology I
- Anatomy & Physiology II
- Other (please specify below)

8. In which of your college science courses have you learned about the cardiovascular system?
9. What cardiovascular system topics were covered in your college science courses?
10. Have you had any of the following health care experiences (check all that apply)?

- EMT
 - LPN
 - CNA
 - Worked in a nursing home
 - Home health care
 - Clinical practicum experience (please specify the department(s) or specialties)
-
- Other (please specify)

11. Are any of your family members in the medical professions?

- Yes (please specify the position below)
- No

Appendix B

Nursing students' self-reported content covered in their bioscience coursework

Table 1A

Nursing student Self-reported Cardiovascular content covered in their bioscience course work

Participant	Cardiovascular content
1	CV disease, CV medications, nursing care
2	MI, aneurysms, CV diseases
3	structures, disease processes, diagnostic procedures, pathophys
4	abnormalities, circulatory, surgeries and assistive devices used
5	everything...
6	structures and patho, complications with diagnosis and treatments, pharmacology, hemodynamic monitoring
7	diseases, risk factors for diseases, pathophysiology of disease progression, treatments (lifestyle changes, meds, surgeries), anatomy and malformations/congenital disorders
8	pathways, defects, medications, sympathetic nervous system, EKG tests
9	patho/anatomy, pathophys, drugs affecting CVS
10	structures, blood flow, conditions, dysrhythmias, malformations etc.
11	pathways, defects, medications, EKG
12	diseases, normal flow route, treatment procedures, anatomy, function
13	diseases, assessments, drugs, interventions, anatomy, effects on the rest of the body
14	anatomy of heart and structures, blood flow, cardiovascular diseases along with their patho and manifestations, medications used to treat cardio problems etc.

Continued

15	how the system works, dysrhythmias, vascular pathologies, compensatory mechanisms etc.
16	heart structures, blood flow, blood components, medications
17	structure, physiology, hormones affecting, pathology, pharmacology affecting CV
18	heart diseases, how heart works, vascular system, how blood moves throughout body, vascular diseases, how to identify and treat said diseases
19	basic anatomy and physiology, all the diseases most nurses would see, CHF, cancer, congenital defects
20	diseases, medications, anatomy or the heart
21	mechanisms of Cardiovascular System, problems with the CV system, structures of cv system
22	vascular system, heart, lungs, complications, structures, pathophysiology
23	anatomy, gas exchange, blood flow, common disorders, effects on other systems, etc.
24	circulation, parts of heart, how heart pumps blood, what affects function
25	oxygenation, pressures, circulation
26	anatomy, diseases, probably a lot more but that is all I remember? Meds for treatment
27	all

APPENDIX C

Scenarios

Scenario #1

#1 Maggie comes into the ER complaining of difficulty breathing and a dull pain in her elbow for the past two weeks. You have her take several deep breaths and auscultate coarse crackles in the lung bases which indicate fluid building up in her lungs. You continually monitor Maggie's vitals and the attending physician orders an EKG. The results of her EKG and blood pressure readings suggest that Maggie has coronary artery disease and her heart has been damaged. Oxygen, nitroglycerin (a vasodilator), morphine for the pain and aspirin are ordered to help get Maggie more comfortable in the ER.

1. What is the effect of the nitroglycerin on Maggie's blood pressure?

2. Explain why you think the nitroglycerin will have this effect.

The crackles in her lungs have gotten worse and her oxygen saturation level is extremely low suggesting hypoxia. Maggie is transferred to the Cath Lab and prepared for a coronary angioplasty.

3. What is the effect of the hypoxia on the Maggie's heart and blood vessels?

4. Why do you think these changes are happening in the cardiovascular system?

Scenario #2

#2 Louise, who is in her early 50's, comes into the hospital stating she is tired all of the time and her feet and calves hurt when she walks and while standing at work. You do a physical exam and note that Louise has been a smoker since she was a teenager, does not exercise regularly which has caused her to gain weight and her arterial pulse is very weak. You also notice that when her feet are elevated they change color and become bright red upon lowering. Louise is diagnosed with peripheral artery disease.

1. How is peripheral artery disease causing the color change in her extremities?

2. How would peripheral artery disease affect her blood pressure?

An echo cardiogram is ordered with results suggesting that Louise has atrial fibrillation and mitral valve stenosis.

3. How does the presence of atrial fibrillation and valve stenosis affect Louise's flow of blood in her heart?

4. Why do you think the stenosis and atrial fibrillation are affecting her flow of blood in this way?

Scenario #3

#3 Joe is a 65 year old male who has smoked for 33 years. Joe has crackle sounds in his lungs when you listen to his chest. Sputum cultures, blood tests and an x-ray are ordered. The blood tests reveal that B-type Natriuretic Peptide (BNP) levels are elevated which indicates failure of the ventricles. Cultures come back positive for pneumonia and the x-ray reveals that Joe's ventricles are enlarged. He has been diagnosed with congestive heart failure on the right side (cor pulmonale).

1. How could Joe's enlarged ventricles contribute to the excess fluid in his lungs?
2. Explain your reasoning for your answer.
3. What is the pathway one of Joe's blood cells takes in his body upon returning to the heart through the superior vena cava to entering the capillary beds in his left hand?
4. What effect does the enlarged heart have on Joe's cardiac output?
5. Explain your reasoning for your answer.

Scenario #4

#4 Ron was admitted to the ER with chest pains, shortness of breath, edema in his feet and a 100% occlusion of the circumflex artery. Blood work shows that his troponins and CKMB levels are elevated. Ron is sent to the Cath lab where doctors put in a stent to open the artery. He is then sent to the cardiac ICU where you are in charge of his care. The vessel occlusion has led to heart damage which is evident by the increased blood levels of troponin and CKMB. Furosemide is ordered to help with the edema.

1. Which side of the heart is most likely damaged based on your knowledge of cardiovascular anatomy?

2. Explain how you know this.

3. How would Ron's blood pressure be affected from the vessel occlusion?

4. How will the furosemide affect Ron's blood pressure?

5. Explain why the furosemide will affect his blood pressure in this way.

APPENDIX D

Expert Permission Form

Parker Stuart
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Columbia, Mo 65211

Expert Permission Form

Parker Stuart, a doctoral candidate at the Missouri University Science Education Center, is interested in conducting a research study "Examining Pre-Nursing Students' understanding of the Cardiovascular System in a BSN program" which will investigate nursing students' alternative ideas about the cardiovascular system. In order to do this, Cardiac critical nurses will be asked to answer interview questions about their experiences working as a critical care nurse. The interviews will last no more than an hour (60minutes) and all participation is voluntary.

The study: This study is being undertaken to determine the areas of cardiovascular anatomy and physiology which critical care nurses feel are important for their job. To be considered for the project the expert nurses will need to be certified in critical care and have been working as a critical care nurse for at least two year. We hope to involve as many people as possible in the study to produce valid data. The interview responses will be used to create authentic scenarios which critical care nurses face at their job. Open-ended questions will accompany the scenarios for nursing students to answer.

Risks and benefits: There are no risks involved in this study, and there are no penalties for people who choose not to participate. The study will benefit those who choose to participate and because they will be able to influence future nursing students' education. It will also benefit nursing education as it will provide data for areas that anatomy and physiology instructors need to cover in more detail. It will also benefit nursing students because the expert nurses' answers will be used to create authentic scenarios which will expose the nursing students to possible situations they will encounter during their nursing careers.

Confidentiality: The records of this study will be kept private. Any personal, identifiable information will be changed or removed after collection. All of the hard copy data will be stored in a locked filing cabinet in a locked office. Any electronic data will be stored on a password protected computer or password protected server.

Voluntary nature of participation: The decision whether or not to participate will not affect the expert nurses' current or future relations with University of Missouri-Columbia, the Sinclair School of Nursing or their employer. If a nurse decides to participate, they are free to withdraw at any time without affecting their relationship with University of Missouri-Columbia, the Sinclair School of Nursing or their employer. Furthermore, a nurse may refuse to participate or discontinue participation at any time.

The researchers conducting this study are Parker Stuart, Doctoral Candidate in Learning, Teaching and Curriculum at the University of Missouri, Columbia and Dr. Lloyd Barrow, Professor of Science Education at the University of Missouri, Columbia. You may reach Parker Stuart at 515-408-1005, or pes4kc@mail.missouri.edu. Dr. Barrow can be reached at 573-882-7457 or BarrowL@missouri.edu. Please feel free to ask any questions you have now, or at any point in the future. In addition, if you have any questions or concerns about the research project or the research subjects, you may contact the University of Missouri-Columbia Campus Institutional Review Board (IRB) at 483 McReynolds Hall, University of Missouri (573-882-9585), or you may access their website at <http://research.missouri.edu/cirb/>.

Permission: I have read and understand the above information, and I have received a copy of this form. By signing below, I indicate my awareness of the project and give my permission to solicit nurses working at the hospital to participate in this study.

Name: _____ Position Title: _____

Employer: _____

Signature: _____ Date: _____

APPENDIX E

Interview protocol

Say to participant: The purpose of the interview is two-fold. The first is to understand what cardiovascular anatomy and physiology concepts you consider most important to your practice. The second purpose is to understand how you use those concepts in your daily practice. Please keep in mind that there are no right or wrong answers. I want to understand which your perceptions of what cardiovascular knowledge is important to you.

Expert Demographic questions

1. How many years have you been a practicing nurse? How many of those have you been working as a cardiac critical care nurse?
2. How did you become certified as a cardiac critical care nurse?
(Probe for fellowship, additional course work in CVS,)
3. What science courses were required for your nursing degree?
4. How in depth did the courses go into the cardiovascular system?
5. How did these courses impact your cardiovascular knowledge?
6. How would you describe your knowledge about the cardiovascular system when you graduated versus now?
(Probe for perceptions of preparedness, how did experience affect knowledge)

Important cardiovascular concepts

Say to participant: I want you to think about 2-3 common cases (patient scenarios) involving the cardiovascular system that you deal with often at your job. Now, I want you to focus on one of those cases.

1. Please describe the common patient case you are thinking about?
2. What is going on in the circulatory system in this case?
(Probe for interactions with other systems, treatments, diagnosis)
3. What cardiovascular knowledge do you need to care for the patient?
4. How well did your coursework prepare you for this type of case? Please explain your answer.

5. For this particular case, what do you know about the CVS system now that you didn't know from your coursework?
6. How would you describe what is happening in the cardiovascular system to the attending doctor or medical team?
7. What would you consider to be a difficult area of the cardiovascular system for a new cardiac critical care nurse in this scenario?

Say to participant: Let's now focus on the other patient scenario you often deal with.

1. Please describe the common scenario you are thinking about?
2. What is going on in the circulatory system in this case?
(Probe for interactions with other systems, treatments, diagnosis)
3. What cardiovascular knowledge would or did you use to care for the patient?
4. How well did your coursework prepare you for this type of case? Please explain your answer.
5. For this particular case, what do you know about the CVS system now that you didn't know from your coursework?
6. How would you describe what is happening in the cardiovascular system to the attending doctor or medical team?
7. What would you consider to be a difficult area of the cardiovascular system for a new cardiac critical care nurse in this scenario?

Say to participant: I want you to think about an unusual or advanced case where your knowledge of the cardiovascular system was stretched. I do not need to know patient specific details, just focus on the cardiovascular aspects of the case.

1. Please describe the type of case you are thinking about?
2. What is going on in the circulatory system in this case?
(Probe for interactions with other systems, treatments, diagnosis)
3. What cardiovascular knowledge would or did you use to care for the patient?

4. How well did your coursework prepare you for this type of case? Please explain your answer.
5. For this particular case, what do you know about the CVS system now that you didn't know from your coursework?
6. What would you consider to be a difficult aspect of the cardiovascular system for a new cardiac critical care nurse in this scenario?

Wrap up questions

Say to participant: Academic Physiologists have created a list of 15 broad concepts associated with the CVS. <Show them the list & allow them to read over>

1. Which of these concepts are important for future cardiac critical care nurse preparation?
(Probe for how they relate to the CVS)

Say to participant: We have talked about your preparation to become a cardiac critical care nurse such as the courses you took and how they prepared you for your job, multiple cases and how you used your cardiac knowledge.

2. What CVS concepts would you add to the list?
3. After talking to experts, like yourself, it is clear that drug pharmacology is very important. My goal is to get to students alternative conceptions about the CVS so would you advise to put medications cardiac nurses use often into the scenarios?
4. Is there anything you would like to add about the CVS or preparation of cardiac critical care nurses?

Reminders

Recruit others

Contact for member checking scenarios

Incentive?

Core Principle	Description
Causality ^{1,3}	Living organisms are causal mechanisms (machines) whose functions are explainable by a description of the cause-and-effect relationships that are present.
Cell-cell communications ²	The function of the organism requires that cells pass information to one another to coordinate their activities. These processes include endocrine and neural signaling.
Cell membrane ²	Plasma membranes are complex structures that determine what substances enter or leave the cell. They are essential for cell signaling, transport, and other processes.
Cell theory ^{1,3}	All cells making up the organism have the same DNA. Cells have many common functions but also many specialized functions that are required by the organism.
Energy ^{1,3}	The life of the organism requires the constant expenditure of energy. The acquisition, transformation, and transportation of energy is a crucial function of the body.
Evolution ^{1,3}	The mechanisms of evolution act at many levels of organization and result in adaptive changes that have produced the extant relationships between structure and function.
Flow down gradients ^{2,3}	The transport of "stuff" (ions, molecules, blood, and air) is a central process at all levels of organization in the organism, and this transport is described by a simple model.
Genes to proteins	The genes (DNA) of every organism code for the synthesis of proteins (including enzymes). The functions of every cell are determined by the genes that are expressed.
Homeostasis ¹⁻³	The internal environment of the organism is actively maintained constant by the function of cells, tissues, and organs organized in negative feedback systems.
Interdependence	Cells, tissues, organs, and organ systems interact with one another (are dependent on the function of one another) to sustain life.
Levels of organization ³	Understanding physiological functions requires understanding the behavior at every level of organization from the molecular to the social.
Mass balance ²	The contents of any system or compartment in a system is determined by the inputs to and the outputs from that system or compartment.
Physics/chemistry	The functions of living organisms are explainable by the application of the laws of physics and chemistry.
Scientific reasoning	Physiology is a science. Our understanding of the functions of the body arises from the application of the scientific method; thus, our understanding is always tentative.
Structure/function ^{1,3}	The function of a cell, tissue, or organ is determined by its form. Structure and function (from the molecular level to the organ system level) are intrinsically related to each other.

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Sarah's ranking of the academic physiologist's important 15 concepts

Core Principle	Description
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Gary's ranking of the academic physiologist's important 15 concepts

Core Principle	Description
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② Cell-cell communications ²	The function of the organism requires that cells pass information to one another to coordinate their activities. These processes include endocrine and neural signaling.
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Tom's ranking of the academic physiologist's important 15 concepts

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Structure/function ^{1,3}	The function of a cell, tissue, or organ is determined by its form. Structure and function (from the molecular level to the organ system level) are intrinsically related to each other.

Claire's ranking of the academic physiologist's important 15 concepts

APPENDIX G

Expert use of the five important concepts when describing a myocardial infarction

For each of the following excerpts the five important concepts have been highlighted using different methods of text underlining. The five major concepts are: a) cardiovascular anatomical concepts; b) cardiovascular physiological concepts; c) homeostasis and diseases of the CVS; d) the interdependence and interaction of the CVS with other organ systems and e) the intersection of the CVS and technology in patient diagnosis and treatment. The first tier of the model was combined into one method of underlining due to the similar nature of the two concepts.

Sarah's example of application of the five concepts for a MI

Sarah: Okay. They tell me I am getting a patient who is having a STEMI which is a ST elevation, myocardial infarction, it is showing up on the EKG and they need to go to the cath lab immediately. But the cath lab is not ready so they are coming to me first. So here is this person having active chest pain, it is not the typical elephant on my chest but they just have that look on their face and now I can look at somebody and gut instinct tells me we have a problem. This is the guy who is kinda pale, greyish looking. Kinda just not saying anything he is kinda just lying there so I am like he is having a heart attack. You can just tell. So you are getting him hooked to the monitor, you are getting him oxygen on, getting lab work whether it is ordered or not we are doing it. The EKG, the whole bed. What are we going to use for pain, are we going to us nitro, we going to use morphine. are we going to have to start a drip. I can anticipate we are going to need o2, nitro, morphine and have a drip. and then he going to go off to the cath lab whether I have assessed him or not.

Interviewer: for this STEMI case I want you to describe to me what is going on specific to the CVs. What do you think of when you say that person has a STEMI?

Sarah: They either got a clot sometimes it is a blood clot, sometimes it is cholesterol that is narrowing a vessel on the coronary arteries which is what supplies blood to the heart muscle itself. He has muscle dying and time is muscle. So you gotta act quick, got to be quick.

Interviewer: When this person is having a STEMI are there any interactions with other systems of the body?

Sarah: the respiratory system is the initial one. your shortness of breath and depending on how long they are having this pain. Some people wait way too long. I am having this pain for two weeks by then they could be having some respiratory systems based on which part of the heart is affected and which heart muscle is weakened as to where that fluid is going.

Interviewer: could you describe for me the right side is weakened

Sarah: The right side is weakened then for the most part they are going to be getting peripheral edema and their breathing is going to be bad cause it is backing up. Either side but more so the right side.

Interviewer: What is the difference for the left side?

Sarah: the left side is the power house of the heart, so if it is weakened you are not getting blood elsewhere, particularly the brain. You worry about those types of things.

Interviewer: so what I am getting is that if it is the left side, almost all of the other systems are affected?

Sarah: In time all systems can be affected

Interviewer: but for this STEMI it is the brain and respiratory?.

Sarah: other than the cardiac. and kidneys follow soon after

Interviewer: is that more they just shut down?

Sarah: it depends on the profusion the heart can send to those systems. Those are the vital ones. The heart will shut down peripherally before it will shut down there. like your gut.

Interviewer: when you are caring for this patient. What knowledge of the CVS do you need to care for this patient

Sarah: we need to know that you have got something going on with those major coronary arteries because that like I said supplies the heart itself and based on which part of that muscle affected will determine what else is going on so you need to know that as well as they could have a valve issue thrown in on top of that which will complicate that problem. If the muscle isn't pumping the valve is defected it is not going to get that supply as well.

Tom's application of the five concepts for a MI

Tom: A STEMI get a whole work up. I like to bring them into the ER and within 15 minutes have them in the cath lab. The standard is 25 and I like to beat that by 10 so patient comes in the door. Big lines on both sides, big bore IV, by big bore I mean 16 to 18 gauge needles. Fluids running, medications pharmacological wise. We are going to hang him on a nitro drip, expand those coronary arteries. We have to open those coronary arteries because what causes a myocardial infarction is lack of oxygen to the myocardium, the heart muscle. so we are going to open those vessels up and put him on oxygen, oxygen therapy. These patients are usually awake; we put them on a non-rebreather if they are failing too badly. The minimal, the least invasive. If they are still away and talking and sometimes they are I put them on 2-4L nasal cannula. A good review of medications, anti-coagulants, baby aspirin times 4, a shot of Lubinox, we don't want to throw a clot and have a stroke. hypertension control, usually these patients are hypotensive because their heart is dying. Their heart is dying so we want an immediate intervention and that is why we go to the cath lab and do percutaneous angiography angioplasty. Get in there and open the vessels that are closed. open it and restore blood flow to the heart muscle that is being affected. Sometimes it is more than one vessel. sometimes it could be 2-3 vessels. Or sometimes it is the main vessel that goes down, the widow maker, the big anterior descending.

Interviewer: When you thinking of STEMIs what other systems are involved?

Tom: everything becomes involved further down the line because when you drop a portion of your heart you lose cardiac output. When you lose cardiac output your kidneys aren't being fed, aren't being perfused. Perfusion a multitude of things are taking place. Your red cells going and dumping oxygen. they are also picking up waste, metabolic waste and toxin and carrying them to the kidneys for disposal. You got white blood cells moving into the area, fibrin and fibrinogen moving into the area to form clots cause this is a damaged area. You have to get on top of their anti-coagulation to make sure they don't form a clot and throw it off and lodge it in their lungs or their brain and leave them unfortunately dead. You have to worry about extremities, other stuff isn't immediately being fed and they clamp down their arms and legs and their skin to save that blood flow and shunt the vital organs, your brain, heart and lungs. so those things, even kidneys get shut down before those things give out. Your body has a systemic way of shutting it down. It will start shutting itself down so you have to reverse that.

Gary's application of the five concepts for a MI

Interviewer: ok. This first common patient case can you describe what you are thinking about?

Gary: SO heart attack. It is common for cardiac and it is what you think a lot of what we do is somebody who walks into the hospital or calls 911 with chest pains, trouble breathing. They have some sort of coronary artery allusion. They come in and if they have EKG changes or very symptomatic and they have increased troponins or CKMG changes and they go to cath lab immediately. They have triple vessel disease they go to CABG (Coronary artery bypass graph). Open heart surgery, coronary bypass surgery. That is probably the biggest population is the heart attack or occlusion.

Interviewer: When we are thinking about a heart attack. You can pick what caused the heart attack. Maybe the more common things you see. What is going on in the CVS in this case?

Gary: Occlusion of the coronary arteries so you usually have hyperlipidemia, hypertension, some sort of wall disease, plaque built up.

Interviewer: How is this interacting with other systems?

Gary: So a lot of times, you decrease pumping power of the heart, you have decreased oxygenation of the heart muscle so it doesn't pump as well or tissue starts dying or doesn't move as well. You have heart wall a kinesis and so you get fluid backed up in addition you have higher demand so other parts of the heart have to work harder or the heart wants more oxygen so you see people with shortness of breath, we see people with people with fluid in their lungs, Pulmonary edema because the left side of the heart isn't pumping well so it starts to back up. People that are chronic oh I have had chest pain for 3 or 4 weeks they start to get edema in their feet because now the right heart cannot keep up because it is back up so far. A lot of other things too depending on what arteries are occluded the right heart could be affect. The right heart we talk about pre-load and the starling effect, fluid load when our right heart is affected and you don't have good right ventricular function then people are usually severely hypotensive so you know that the balancing fluid and good pressure with am I going to overload their lungs with fluid. Those are the things that we think about or relate to pathophysiology. EKG is specific. Where are the SD segment changes or other EKG changes on it and where they lead to? If you see changes of leads 2, 3, and AVF the 12 lead we know it is right heart. We know it is inferior and technically, probably right and you say do I need to give them fluids or do I need to not give them nitroglycerine and so those are the considerations that you don't get until you are out of school. You might see an EKG but it doesn't make sense yet.

Interviewer: When we are talking about caring for this patient. What knowledge of the cardiovascular system are you tapping to think through? I don't want you to focus on the tests you would run, what is going on in the heart.

Gary: If you are talking about heart attacks the big things are the vessel, the coronary arteries what vessels are, is it right main, left main, circumflex. What are we talking about, what vessels and where they correspond on the heart and different presentations. So if you have damage on the right heart what does that look like clinically? If you have damage to the left heart, what does that look like clinically? That kind of thing. How does the heart affect the lungs so the heart has to work and the other systems?

Claire's application of the five concepts for a MI

Claire: How about a STEMI, is that alright with you?

Interviewer: What is a STEMI?

Claire: A heart attack, there is a blockage and the heart is not getting o₂. ST elevation. need to get them to cath lab. Usually pressure radiation to the left arm, jaw neck, sweaty short of breath nausea. They call it cath lab because they do the catherization to the block.

Interviewer: In this STEMI, what is going on in the CVS?

Claire: There is a blockage of some kind and the heart itself is not getting good blood flow, oxygenation. it is getting ischemic.

Interviewer: For this heart attack is there any interactions with other systems.

Claire: Yeah, lungs everything really. You brain of course. Blood flows everywhere. You are not getting blood flow to heart, not going to get oxygenation anywhere else for much longer if you don't take care of it.

Interviewer: when you have someone come in with a STEMI how do you diagnose them?

Claire: You have to get the EKG of course. You draw blood to see if their troponin is elevated. IT is a cardiac enzyme. Based on those two things usually they go straight to cath lab. Sometimes of one of those things they go. Sometimes it doesn't have to be either one of those things. They just send them if they suspect them they go to cath lab. They go up into them and see if there is blockage.

[00:17:10.02] Interviewer: When you are working with this patient what CVS knowledge do you need to care for this patient?

Claire: The EKG and the troponins tell you if there is ischemia in the heart. If there is damage being done. The troponin is an enzyme that comes from CV damage and the EKG shows the ischemia. If it is an ST elevation you look for the elevations.

Interviewer: You said there is a blockage in the heart. What is blocked in the heart?

Claire: usually it is, there are two big vessels that wrap around. The LVC, I don't remember the name of it. Usually it is the one that curves. I should know.

Summation of individual responses for each question set or stand alone

Table A1.

Summation of Individual responses for each question or question set (n=10)

Student	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Question set 2	
	Question set 1	Question set 2	Question set 1	Question set 2	Question set 1	Question 2	Question set 2	Question set 1	Question 2	
1	NA	NLK	NA	NA	NA	NA	CA	NA	IA	NA
2	CA	NA	NA	NA	NA	NA	NA	NG	IA	NA
3	NA	CA	NA	NA	IA	LK	NA	LK	NA	LK
4	NA	NLK	NA	NA	LK	IA	CA	IA	NA	NA
5	NA	NLK	NA	NA	NA	NA	NA	NLK	LK	NA
6	NA	NLK	NG	CA	NA	NG	CA	LK	IA	NA
7	NA	CA	LK	LK	LK	LK	LK	LK	LK	LK
8	NA	IA	NA	LK	IA	IA	CA	IA	NA	NA
9	NA	CA	LK	LK	LK	LK	LK	LK	LK	LK
10	NA	NLK	CA	IA	NA	IA	CA	IA	CA	NA
11	NA	NA	NA	NA	IA	CA	CA	NG	NA	NA
12	NA	NA	CA	IA	IA	NA	CA	LK	NA	LK
13	NA	CA	NA	NA	NA	NA	CA	NG	IA	NA
14	NA	CA	LK	LK	LK	LK	LK	LK	LK	LK
15	CA	NA	NA	NA	NA	NA	CA	NA	NA	NA
16	NA	NA	NA	IA	IA	IA	LK	NA	CA	NA
17	NA	NA	NA	NA	CA	CA	CA	IA	NA	NA

VITA

Parker Emerson Stuart was born on October 5, 1980 to James and Katherine Stuart of Fort Dodge, Iowa. He has one younger sibling, Marshall Doran Stuart. Parker has his Bachelor of Arts in Biology with Biomedical Emphasis and his Masters of Arts in Biology from the University of Northern Iowa. Parker spent three years as an adjunct professor of Biology at Northern Iowa teaching majors and non-major biology labs prior to enrolling in the doctoral program at the University of Missouri. He follows a long line of educators upon completing this dissertation.

Parker married Kelsey Danielle Stuart (Lees) on September, 28, 2013 during his doctoral program. Kelsey holds a BA in biology, a MS in biology and a MA in education. They, along with their corgi, Millie, will be residing in mid-Missouri following graduation as Parker has accepted a position at the University of Central Missouri teaching Human Anatomy.