Science-Based Occupations and the Science Curriculum: Concepts of Evidence

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Received 31 December 2003; revised 14 June 2004; accepted 12 July 2004

DOI 10.1002/sce.20046

ABSTRACT: What science-related knowledge is actually used by nurses in their day-to-day clinical reasoning when attending patients? The study investigated the knowledge-in-use of six acute-care nurses in a hospital surgical unit. It was found that the nurses mainly drew upon their professional knowledge of nursing and upon their procedural understanding that included a common core of "concepts of evidence" (concepts implicitly applied to the evaluation of data and the evaluation of evidence—the focus of this research). This core included validity triangulation, normalcy range, accuracy, and a general predilection for direct sensual access to a phenomenon over indirect machine-managed access. A cluster of emotion-related concepts of evidence (e.g. cultural sensitivity) was also discovered. These results add to a compendium of concepts of evidence published in the literature. Only a small proportion of nurses (one of the six nurses in the study) used canonical science content in their clinical reasoning, a result consistent with other research. This study also confirms earlier research on employees in science-rich workplaces in general, and on professional development programs for nurses specifically: canonical science content found in a typical science curriculum (e.g. high school physics) does not appear relevant to many nurses' knowledge-in-use. These findings support a curriculum policy that gives emphasis to students learning how to learn science content *as required* by an authentic everyday or workplace context, and to students learning concepts of evidence. © 2004 Wiley Periodicals, Inc. *Sci Ed* **89:**242–275, 2005

INTRODUCTION

One primary goal espoused for the science curriculum is to prepare students for science-related careers in, for example, industry, government, and the health professions. Curriculum developers expect students to integrate scientific content into their own thinking so that this content is accessible later when students are employed in a science-rich workplace (AAAS, 1989).

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Contract grant sponsor: University of Saskatchewan President's SSHRC Research Fund.

Several research studies, however, have shown a poor match between the scientific content generally taught in high school and university science courses and the type of scientific understanding required for success in science-based occupations in which knowledge of the practice of science is either *critical* to the job or *enhances* occupational competence (Chin et al., 2004; Coles, 1997; Gott, Duggan, & Johnson, 1999; Lottero-Perdue & Brickhouse, 2002). Duggan and Gott (2002), for instance, investigated in depth the science used by employees in five science-based industries: a chemical plant specializing in cosmetics and pharmaceuticals, a biotechnology firm specializing in medical diagnostic kits, an environmental analysis lab, an engineering company manufacturing pumps for the petrochemical industry, and an arable farm. Duggan and Gott discovered, along with the studies cited above, that most of the scientific conceptual understanding used by employees was learned on the job, not in high school or university courses. And furthermore, after analyzing employees' on-the-job knowledge-in-use Duggan and Gott (2002, p. 674) concluded, "A secure knowledge of procedural understanding appeared to be critical."

Chin et al. (2004, pp. 129, 130) accounted for similar research results involving high school students placed in science-rich co-op education settings, by concluding: "School learning is focussed predominantly on declarative knowledge [propositional knowledge—"knowing that"] while workplace learning is focussed predominantly on procedural knowledge [non-propositional knowledge—"knowing how"]. . . . The science found in the workplace. . . differed significantly from the science learned in schools." The distinction between declarative and procedural knowledge surfaces in the analysis of the data in the research reported here.

An employee's procedural understanding, the thinking directly related to the doing of science, draws upon a wealth of ideas about evidence itself. Duggan and Gott's (2002) research focused on ideas called "*concepts of evidence*" (Gott & Duggan, 1996) that help employees answer the following two questions:

1. When are data good enough (sufficiently scrutinized) to be considered as evidence?
2. When is evidence strong enough to warrant specific action?

Concepts of evidence, also known as "conceptions of scientific evidence" (Taylor & Dana, 2003), form a key component to procedural understanding in science-rich workplaces.

The present study extended Duggan and Gott's (2002) research program into an science-rich occupation not previously investigated: the health professions, specifically acute-care nurses working in a hospital unit where evidence-based practice now dominates educational and professional development programs in Europe and North America (Bonell, 1999; Closs & Cheater, 1999; Higgs & Jones, 2002; Kitson, 2002; Upton, 1999; Wallin et al., 2003; Winch, Creedy, & Chaboyer, 2002). Are the concepts of evidence identified by earlier studies in industry applicable to health professions such as nursing? A second reason for choosing nursing as a venue of research concerns a controversy in some universities over requiring high school physics as a prerequisite to a university's nursing program. Perhaps the present research could clarify what physics is applied in nursing.

Evidence-based practices are expected to improve nurses' clinical reasoning capabilities by providing nurses with an informed critical perspective on practice, thus enhancing their professional autonomy. To interpret evidence, nurses must draw upon a wealth of knowledge as they carry out orders from a doctor, follow an appropriate protocol, gather observational data on a patient, and engage in clinical reasoning to respond effectively to the patient's needs.

To clarify this knowledge-in-use, the present study investigated in a modest way the knowledge typically used by six acute-care hospital nurses when they engaged in clinical reasoning at the bedside of patients. This preliminary study sought to answer the following three research questions:

- What knowledge-in-use comprises canonical science content found in science curricula ("scientific knowledge")?
- What knowledge-in-use is associated with the technical field of nursing ("professional knowledge of nursing")? and
- Does a nurse's knowledge-in-use include a core set of concepts of evidence?

By learning more about nurses' knowledge-in-use on hospital wards, and by combining these findings with earlier studies, science educators may develop more effective high school science curricula for science-based occupations. For example, it would be helpful to know what conceptual content in physics has a role in everyday nursing, given the abundance of measuring instruments and physical procedures utilized by nurses. It would also be helpful to the nursing profession to know if there is a common core of concepts of evidence used by nurses as they engage in critical thinking, problem solving, and decision making (Greenwood, 2000; McCaughan et al., 2002; Thompson et al., 2001).

Although the investigation of nurses' critical thinking, problem solving, and decision making is beyond the scope of this research, these processes form the *context* in which evidence is acquired and used by nurses; and therefore, these processes form an important context for this research.

TYPICAL NURSING PROGRAMS

Nursing programs vary across North America, but over the past 15 years they have generally moved toward a problem-based learning approach taught as a four-year syllabus within a Faculty of Nursing. These programs have tended to move away from prenursing science courses taught in other faculties, usually with a traditional content-transmission approach (Scholer, 2004). A basic course in anatomy and physiology is common in all programs, while chemistry is required at some institutions. Nevertheless debate continues over which is better: "pure science" foundation courses taught in science departments, or "vocational science" courses taught by nursing faculty but usually not valued by departments of science (Stark & Lattuca, 1997). Nurses express a preference for courses that contextualize selected scientific knowledge, thereby making the course content credible and relevant to clinical practice (McCaughan et al., 2002; Ray, 1999), yet little research evidence has accrued to shed light on this debate. The present study contributes some evidence.

Obviously nurses at most hospitals will have different educational backgrounds depending on their age and their choice of university or college. This was certainly true for the nurses participating in this study.

Most nursing programs are very similar in their requirement of a high school diploma that includes credits in academic mathematics, biology, and chemistry. As noted above, some programs require high school physics while others do not. The content in these high school curricula is expected to be used by nurses in their day-to-day practice (Upton, 1999). This study examines this expectation by exploring the science content that nurses use in their clinical reasoning when they respond to patients' needs.

SCIENCE IN THE EVERYDAY WORLD

Interestingly, Duggan and Gott (2002) discovered that the *concepts of evidence* needed by employees in science-related occupations were also critical to a nonscience public who were involved with a science-related social issue, for instance, parents deciding whether or not to have their infant child immunized. This finding complements extensive research into the use of scientific knowledge in everyday science-related problem solving and decision making (Davidson & Schibeci, 2000; Dori & Tal, 2000; Goshorn, 1996; Irwin, 1995; Kolstø, 2000; Lambert & Rose, 1990; Macgill, 1987; Michael, 1992; Roth & Désautels, 2004; Tytler, Duggan, & Gott, 2001b; Wynne, 1991). Tytler and his colleagues (2001a, p. 817), for example, stated, "Judgements about evidence are often central in interactions between science and the public." Thirty-one different case studies of this type of research were reviewed by Ryder (2001) who emphatically concluded: When people need to communicate with experts and/or take action, they usually learn the scientific knowledge *as required*. The qualification "as required" needs clarification.

Even though people seem to learn science in their everyday world as required, this learning is not often the "pure science" (canonical content) transmitted by most school and university science courses. Research into the application of scientific knowledge to everyday events has produced one clear and consistent finding: *most often, canonical scientific knowledge is not directly useable in science-related everyday situations*, for various reasons (Cajas, 1998; Furnham, 1992; Jenkins, 1992; Layton, 1991; Layton et al., 1993; Roth & Désautels, 2004; Ryder, 2001; Scholer, 2004; Solomon, 1984; Tytler et al., 2001a; Wynne, 1991). For instance, when investigating an everyday event for which canonical science content was directly relevant, Lawrenz and Gray (1995) found that science teachers with science degrees did not use scientific knowledge to make meaning out of the event, but instead used other content knowledge such as values.

Equivalent research with nurses has not been conducted. What type of knowledge-in-use do they rely on in their everyday world of a hospital ward? Does canonical science content, particularly physics, play a role?

The pervasive failure of the curriculum's scientific content to be directly applicable to everyday science-related problem solving can be explained, in part, by the discovery that canonical science must be *transformed* (i.e. deconstructed and then reconstructed according to the idiosyncratic demands of the context) into knowledge very different in character from the "pure science" knowledge of science courses (Chin et al., 2004; Jenkins, 1992, 2002; Layton, 1991; Scholer, 2004; Tytler et al., 2001a), as one moves from "pure science" for explaining or describing, to "practical science" for action (e.g. professional knowledge of nursing). Based on this research, we would predict that transformed knowledge has agency in the workplace of nurses (e.g. a surgical ward) while the canonical content found in science courses would seldom have agency; a prediction empirically tested in the present study. Accordingly, I emphasize the distinction between, on the one hand, nurses' use of canonical scientific knowledge (e.g., knowing the concept of pressure well enough to calculate the exact pressure on a patient's skin caused by a blood-pressure cuff), and on the other hand, their professional knowledge of nursing (transformed science) (e.g. knowing the different cuff sizes available to a nurse).

Two general conclusions can be drawn from the literature reviewed here. First, empirical evidence consistently contradicts scientists' and science teachers' hypothetical claims that science is directly applicable to one's everyday life and to science-related jobs. What scientists and science teachers probably mean is that using scientific concepts is one of several ways to abstract meaning from an everyday or job-related event. The fact that this type of intellectual abstraction is only relevant to those who are predisposed to explaining everyday experiences this way (i.e. those who have a worldview that harmonizes with a worldview endemic to science; Cobern, 1991; Cobern & Aikenhead, 1998) suggests that scientific explanations do not likely appear relevant to those who do not personally embrace a scientific worldview.

Secondly, procedural knowledge (e.g. knowing how to choose the proper cuff size to take a patient's blood pressure) is conceptually distinct from declarative knowledge (mentioned above: either knowing the concept of pressure sufficiently to complete a scientific calculation, or knowing various cuff sizes available in a hospital). Moreover, *concepts of evidence* are an important component to procedural knowledge for people in science-related careers or in everyday circumstances requiring a decision on a science-related matter (Chin et al., 2004; Duggan & Gott, 2002; Kolstø, 2000; Osborne, Duschl, & Fairbrother, 2003; Zeidler et al., 2003).

THEORETICAL FRAMEWORK

Three ideas—worldview, concepts of evidence, and the nature of evidence—need to be clarified in the context of nursing in order to establish a theoretical framework in which to interpret the research results presented in this article.

Nurses' Worldviews and Science

Worldview refers to our fundamental unconscious presuppositions with which we give meaning to our experiences in the world around us. Drawing upon cultural anthropologists Geertz (1973) and Kearney (1984), Cobern (1991) synthesized the idea of worldview for the context of science and science education. The worldview that generally pervades scientific disciplines is characterized by assumptions that the world is materialistic and knowable through reductionist methods that yield universal, mechanistic, causal relationships and explanations.

To what extent do nurses' worldviews reflect features of a scientific worldview? Cobern (1993) conducted an in-depth study with nursing students enrolled in advanced university science courses. The students talked about nature and what it meant to them. Cobern's data showed that most students did not have a materialistic and reductionist view of nature as their science instructor did, but instead held aesthetic, religious, or emotional views toward nature. Several nursing students did not even associate science with knowledge of the natural world. Out of the 15 nursing students in Cobern's study, only Carla expressed views consistently similar to orthodox science. Five other students spoke in ways that suggested scientific ideas had become integrated into their thinking, but these students actually used their scientific knowledge in a heterodox fashion (e.g. neurological synapses were mentioned as evidence for a divinity's created world). Nursing students appeared more interested in their relationship with nature than their scientific knowledge of nature. How well had these nursing students integrated the content of science into their own thinking? "Student views in this study suggest that one can pass the exams and still not have had one's basic views of the world changed. Most of these students said little or nothing about science. When they did, the science was usually cast in an unorthodox context" (Cobern, 1993, p. 948).

Cobern's findings help clarify nurses' apparent resistance to incorporating scientific research results into daily practice (Closs & Cheater, 1999). Thompson (1999) characterized nurses' various approaches to clinical decision making as lying on a continuum between two extremes: "systematic-positivistic" and "intuitive-humanistic." A systematic-positivist type of nurse would tend to apply scientific research results to their practice (e.g. Carla in Cobern's study), while an intuitive-humanist type of nurse would not, due perhaps to their stereotypic view of quantitative/experimental methods (Bonell, 1999), or to their belief that scientific results lack clinical credibility and relevance (McCaughan et al., 2002). An intuitive-humanist type of nurse may represent the nursing students in Cobern's (1993) study who did not even associate science with knowledge of nature. Furthermore, Cobern's participants who appeared to integrate science into their thinking but did so in heterodox ways represent nurses between the extremes on Thompson's continuum; but according to Cobern's data, their distribution would seem to be skewed toward the intuitive-humanistic end of the continuum.

Cobern's study adds richness to our understanding that, in general, only a small proportion of people make sense of their world in a way that harmonizes with the worldview held by most scientists (Atkins & Helm, 1993; Costa, 1995; Lyons, 2003; Reiss, 2000), and everyone else feels more comfortable with other worldview orientations. Cobern, however, did not conduct his research in the context of professional practice, where nurses gather and evaluate scientific-like data as they attend to their patients. What declarative and procedural knowledge-in-use is evident in this science-rich context?

Concepts of Evidence

In the process of gathering and evaluating data to determine if the data warrant the status of evidence (a status described in the next section), and in the process of evaluating evidence to decide what to do next, people use conceptions (or misconceptions) concerning data and evidence (Duggan & Gott, 2002; Gott, Duggan, & Johnson, 1999; Sadler, 2004; Taylor & Dana, 2003). Gott, Duggan, and Roberts (2003) provide an encyclopedia of concepts of evidence empirically derived from extensive research (reviewed above) into events experienced by people in science-related careers and by people with no particular science background. The present study builds upon and seeks to enhance this compendium of concepts of evidence.

Concepts of evidence are usually applied unconsciously as tacit knowledge (French, 1999; Greenwood, 2000; Higgs & Jones, 2002) to determine how credible data are, and then in turn, how important the evidence is, given the social context in which action may occur on the basis of that evidence (Duggan & Gott, 2002; Ratcliffe & Grace, 2003; Zeidler et al., 2003).

Reliability is a well-known concept of evidence. According to Gott, Duggan, and Roberts (2003), the scientific meaning of reliability usually refers to the *consistency* of readings when multiple readings are gathered. Reliability generally is enhanced by repetitive readings from the same instrument, multiple instrument readings using similar types of instruments ("measurement triangulation"), and multiple observers to minimize human error in the use of an instrument.

A fundamental concept of evidence that underscores reliability is the concept "nonrepeatability:" repeated measurements of the same quantity with the same instrument seldom give exactly the same value. The sensitivity of an instrument is a measure of the amount of error inherent in the instrument itself (i.e. measurement error). Factors associated with the choice of measuring instruments must also be considered. These concepts of evidence are generally associated with reliability in science-rich workplaces.

The quality of a scientific measurement is determined not only by its reliability but also by its validity. Validity is concerned with: "Does the reading actually measure what is claimed to be measured?" (Gott, Duggan, & Roberts, 2003, section 9.2). For instance, a particular monitor on a surgical ward is electronically connected to a finger probe that produces a reading claimed to measure a patient's blood oxygen saturation (the patient's "sats"). But according to Gia, one of the nurses in this study, the finger probe may inadvertently be affected by a patient's smoking behavior (yellow fingernails), a patient's hand temperature, or a patient's hemoglobin count. Depending on the patient, the finger probe may not yield a valid measure of blood oxygen saturation.

Validity is often discussed in science-based industries in terms of how close a piece of evidence comes to the "true" value; in other words, a measurement's *accuracy* (Gott, Duggan, & Roberts, 2003, section 6.1). The two concepts, validity and accuracy, are very closely related. The word "accuracy" refers to a less abstract concept and it appeared in all the nurses' transcripts, while the more abstract word "validity" never did.

Although the concepts of reliability and accuracy differ considerably, they are related when one judges whether or not some data should be considered as evidence, for instance, unreliable readings do not engender the belief that an averaged datum is particularly accurate.

The Nature of Evidence

Evidence is normally thought to be data that have been scrutinized by various methods or validation criteria, such as comparisons with other data or consistency with accepted knowledge (Gott, Duggan, & Roberts, 2003). Scrutiny affords a degree of credibility; hence, evidence has a higher status than data.

Different science-related workplaces have varying degrees of data richness. Cases of high complexity in some industries led Gott and colleagues (2003) to stipulate the following definitions: several *readings* produce a measurement; several *measurements* establish a *datum*; and a datum repeated over time accumulates into *data*. For simple situations, however, one reading or measurement could establish a datum, defined by Gott and colleagues (2003, p. 1) as "the measurement of a parameter (e.g. the volume of a gas)," and when repeated in concert with a variable, more than one datum becomes data (e.g. the volume of gas measured at various temperatures). A datum can be either quantitative or qualitative. An example of a qualitative datum on a surgical ward is "type of oxygen equipment" (e.g. a nose prong or mask, along with several mask sizes).

Gott and colleagues (2003) devised a model (Figure 1, which should be read from the center to the outside) describing a measurement developing into evidence during a science-related event; evidence which in turn is evaluated with respect to a possible outcome, such as making a decision based on that evidence. This outcome is always embedded in a social context of the science-related event, represented in Figure 1 as the outer ring (e.g. Does the

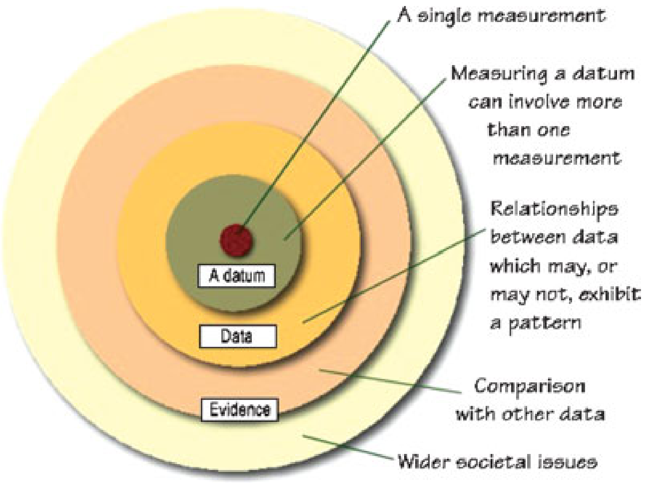

Figure 1. A model for measurement, data, and evidence (after Gott, Duggan & Roberts, 2003).

product meet quality-assurance standards?), and so the evaluation of evidence is influenced by factors related to this social context (e.g. cost, practicality, and time).

The model (Figure 1) implicitly encompasses concepts of evidence. According to Closs and Cheater (1999) and Ray (1999), there are some unresolved aspects to the nature of evidence in evidence-based nursing, which are causing unease in the nursing profession. This study may help ameliorate this unease when combined with results from other research (e.g. Thompson et al., 2001).

RESEARCH METHODOLOGY

The research reported here was a *preliminary* study carried out on a modest scale to explore the science-related knowledge-in-use of nurses in the context of their clinical reasoning.

Participants

With the approval of several layers of ethics committees, I contacted a Unit Manager (the administrative head) of a surgical ward, chosen by a regional health office of research, located in a prairie city. The Unit Manager agreed to involve her unit in the study and to contact nurses she thought might be interested and who had at least one-year experience on hospital wards. Six nurses volunteered (Aikenhead, 2003), four women and two men (out of a total of 43 women and 7 men), and they chose the following pseudonyms: Chloe, Gia, Jamie, Joan, Sarah, and Terry.

The Unit Manager was involved in the study to help ensure minimal disruption and optimum data collection, and to interact with a draft version of a research report (Aikenhead, 2003).

Procedures

My task as researcher was to interpret the words of the participants (Glesne, 1999) in order to identify their science-related knowledge-in-use, expressed during conversations about a personal, science-related, problem-solving or decision-making event on the ward. Because expert performers are seldom explicitly aware of the knowledge they use at any one moment (Schön, 1983), the usual type of semistructured interviewing is rarely successful (Duggan & Gott, 2002). Therefore, unstructured interviews were conducted and they focused on the participants' cognitive engagement in practice.

For ethical reasons concerning the professional confidentiality between a patient and nurse, I did not observe or have any contact with patients. This presented a challenge to observing a nurse with a patient in a way that I could subsequently discuss what data were collected and how those data were used in the nurse's clinical reasoning. The challenge was resolved by having nurses talk into a pocket-sized miniature tape recorder to describe a specific event with a patient. Nurses identified on-going events (both normal and discrepant events) related to their collecting scientific-like data. The content of the miniature tapes was kept private.

Each nurse was interviewed about some of these specific events on four occasions over a six-week period, usually one event per interview. The events were often identified after the nurse replayed portions of the miniature tape. Each 20-min interview took place in a private seminar room on the surgical unit, at a time convenient to the nurse. As the interviewer, I focused on the particular case of a patient, assuming I was standing by the nurse's side asking questions so I could learn how to make similar clinical judgments. By having the nurses instruct me on what had happened during that particular event (i.e. what I would have seen if I were there), and by ensuring the strict anonymity of each nurse, I believe that our use of miniature tape recorders did not interfere with the authenticity of the data collected in the interviews for the purposes of this study.

All interviews were audio taped, producing over 7 h of focused discussions with six nurses. Relevant portions of each tape were transcribed. Before a transcription became public data, it was cleared by the participant in terms of its accuracy in portraying the nurse's meaning and in terms of it safeguarding the nurse's anonymity. Each nurse scrutinized a draft of a transcript, made appropriate changes if they wished, and then signed a release statement. Quotations from these transcripts are referenced in this article by citing the nurse's pseudonym, the interview date, and lines in the interview transcript from which the quotation was taken.

The transcriptions were analyzed to identify, and in some cases to "tease out" (Glesne, 1999; Lincoln & Guba, 1985), concepts of evidence specifically, and declarative and procedural knowledge in general (in a way detailed just below in "Analysis of the Data") that contributed to the critical thinking, problem solving, or decision making in which a nurse had been engaged.

A draft version of a research report was read by the Unit Manager who checked it for accuracy and anonymity. She was interviewed to document her reaction to the report, and this information was included in the final draft of the research report (Aikenhead, 2003). This interview was audio taped, relevant portions transcribed, and the final transcription signed off by the Unit Manager.

Analysis of the Data

Health science researchers Higgs and Jones (2002) claim that categories which articulate nurses' knowledge-in-use comprise a significant description of their clinical reasoning. Although nurses normally do not stop to reflect on the various types of knowledge they happen to use during a problem-solving or decision-making event, it can be helpful to describe these types of knowledge in terms of categories that have already been empirically or philosophically established in the literature. This analytical method, clue structuring (Munby, Orpwood, & Russell, 1980; Roberts & Russell, 1975), logically suits the three research questions posed in this study: What canonical science content associated with science curricula ("scientific knowledge") comprises a nurse's knowledge-in-use? What ideas associated with the technical field of nursing ("professional knowledge of nursing") comprises a nurse's knowledge-in-use? and Does a nurse's knowledge-in-use include a core set of concepts of evidence? The categories employed to answer these questions are drawn from the literature discussed above, and are described here (summarized in Figure 2). They constitute the clue structure for coding, in part, the transcript data.

The first distinction to be made within the category of a nurse's knowledge-in-use is between *declarative* knowledge (knowing that) and *procedural* knowledge (knowing how) (Chin et al., 2004; Duggan & Gott, 2002; Higgs & Jones, 2002). The distinction was operationalized, for instance, in the research by Chin and his colleagues (2004) in which high school students were placed in dental or veterinary clinics to learn science. The researchers wanted to understand workplace learning from an instructional perspective for the purpose of clarifying for students the relationships between school science and workplace science. *Procedural* knowledge was simply defined as the ability "to perform the actions associated with assigned tasks" (p. 127), for example, preparing dental trays for a dentist. To carry out such a task, students assimilated a considerable amount of terminology and routines, that is, they learned procedural knowledge (the thinking directly related to doing science-like tasks).

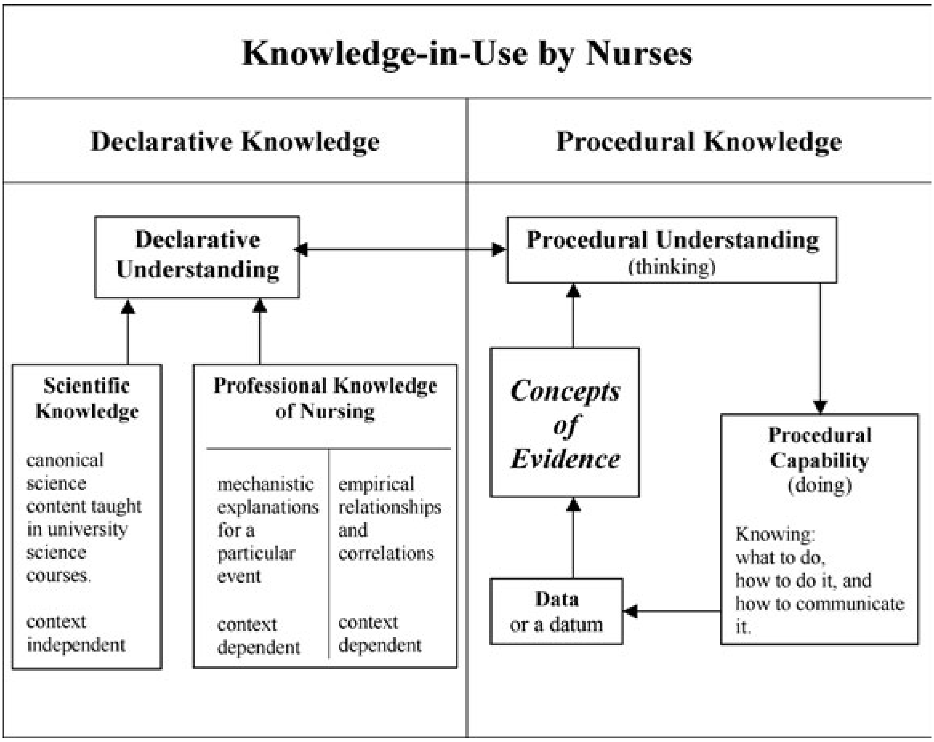

Figure 2. Knowledge-in-use held by acute-care nurses for use in clinical reasoning.

This learning is represented in Figure 2 mainly by "procedural capability"—knowing what to do, how to do it, and how to communicate this knowledge. Chin and colleagues also reported on an event in a veterinary clinic that required a student (Ruth) to determine what size of breathing bag to use, based on her observation (datum) of the size of the animal to be anesthetized. Similar to preparing dental trays, this simple routine did not appear to require a concept of evidence. By making the proper decision concerning the breathing bag and communicating this decision to the veterinarian, Ruth demonstrated procedural knowledge. (Procedural knowledge held by nurses on a surgery ward is described below.)

When a researcher in Chin et al.'s study (standing next to Ruth and the veterinarian) asked how she knew which bag to use, the researcher was introduced to two types of *declarative* knowledge, both of which made meaning out of the practice just witnessed. Ruth knew that there were three sizes of bags (cat, small dog, and large dog) and this pragmatic declarative knowledge served her well as a technician in this particular workplace. However, the veterinarian volunteered a second type of declarative knowledge: a specific calculation for a precise determination of bag size based on several scientific concepts such as lung capacity. In the veterinarian clinic, declarative knowledge can be abstract scientific or concrete pragmatic.

These two categories of declarative knowledge apply to more complex workplaces such as a surgical ward. The declarative knowledge possessed by a nurse ("declarative understanding" in Figure 2) can be divided into scientific knowledge (abstract canonical content, e.g. lung capacity, air pressure, and partial pressure) and professional knowledge of nursing (abstract or concrete technical content learned in nursing courses and apprenticeships; e.g. the correlation between patient size and equipment used for measuring blood pressure). Scientific knowledge pertinent to this study includes mechanistic explanations and classification schemes universally applicable (i.e. context independent), usually taught in high school and university science courses (Scholer, 2004).

Professional knowledge of nursing was described by Higgs and Jones (2002, Ch. 3) as declarative multiparadigmatic facts, concepts, and values, which give emphasis to research-based empirical information related to nurses' problem solving and decision making. In this context, according to Higgs and Jones, declarative knowledge has a clear purpose to inform wise intuitive clinical reasoning. (Figure 2 does not represent clinical reasoning itself, but only the knowledge-in-use involved in clinical reasoning.) Greenwood (2000) and Kitson (2002) affirmed that professional knowledge of nursing encompasses mechanistic explanations for a particular event (i.e. context-dependent) and empirical relationships and correlations (also context dependent). The following excerpt expresses a mechanistic explanation contextualized in a nursing event:

> Terry: What happened was this: he was accumulating a lot of fluid in his lungs, so the membrane was getting thicker. So when you have a larger barrier between the respiratory and circulatory systems, you're going to get poorer oxygen exchange. (June 25, 62–64)

That is, oxygen exchange between the respiratory and circulatory systems decreases as a result of a larger barrier between the systems (though it might be different between two other systems). Universal scientific explanations (e.g. biochemical mechanisms) are absent from Terry's comment; hence, this statement would not be coded as scientific knowledge.

Empirical relationships within professional knowledge of nursing are exemplified by the following excerpts, identified by italics:

> Sarah: Then I remembered from the day before, he had a lower potassium level, it was 3.1. So they were infusing him with some boluses to get it up. The normal is 3.5 to 5.5. *Sometimes when it's low it can cause confusion.* (June 23, 8–10, emphasis added)
>
> Sarah: Males and females are different. Males have more [hemoglobin]. (June 16, 48–49)
>
> Chloe: One of the comments the CCA [Critical Care Associate] made when he arrived was that *if the heart rate is greater than a rate of 140 minus the patient's age, it's not sustainable*. This is a "ventricular rate," and he [the patient] certainly fell into that category. (June 7, 134–136, emphasis added)

None of this professional knowledge of nursing identified here would normally be found in a science course but it certainly could be included in a nursing course. Further examples of both types of professional knowledge are identified below in the section "Evaluating Data."

The distinction between scientific knowledge and professional knowledge of nursing (Figure 2) can sometimes be vague, but a distinction has pragmatic value. A critical feature of the context of nursing is the uniqueness of each patient. Knowledge-in-use is relevant only to the extent that it acknowledges this unique individuality. Thus, decontextualized ideas (i.e. scientific knowledge) by their nature will be out of harmony with the contingencies of a unique patient. In comparison, chemical industries do not treat molecules as unique entities; quite the contrary, all molecules of carbon dioxide, for instance, are assumed to be identical (except for their statistically inscribed thermodynamic properties). Thus, the uniqueness of an individual patient would usually demand contextualized professional knowledge of nursing rather than decontextualized scientific knowledge. The patient's uniqueness constitutes a particular context for knowledge used in clinical reasoning.

The category "procedural knowledge" (Figure 2), as previously introduced, is manifested by nurses carrying out appropriate actions on the surgical ward. Their capabilities include a host of facts, concepts, skills, and values, functioning at various levels of concreteness and abstraction. Procedural knowledge informs problem solving and decision making, which involve, in part, an interaction between declarative understanding and procedural understanding (Chin et al., 2004; Duggan & Gott, 2002), an interaction acknowledged in Figure 2 by a simple two-way arrow. This interaction could be misunderstood as an indication that the two categories collapse into one.

Procedural understanding in nursing (Figure 2) is underpinned by (1) the *thinking* associated with the collection of data and the judgment of the data's significance as evidence (using concepts of evidence to do so); and (2) the *action* of nursing ("procedural capability"), described above as knowing what to do, how to do it, and how to communicate this with fellow nurses and doctors. Action (e.g. using a thermometer) produces data (e.g. a patient's temperature over a time period) that are processed using *concepts of evidence* to help judge the data's credibility. As described below ("Evaluating Data"), credible data inform a nurse's problem solving or decision making. As suggested in Figure 2, the relationship tends to be somewhat repetitive: thinking → doing → data → thinking → doing → data→ thinking; and then perhaps a decision is made. As mentioned previously, a nurse's problem solving or decision making itself is not represented in Figure 2. The italics in Figure 2 indicate a principal focus of this research study: implicit or explicit concepts of evidence used by acute-care nurses (the third research question).

In addition to the clue structure method of analyzing the transcript data, a constant comparison method (Lincoln & Guba, 1985) was employed to learn how the nurses evaluated data from their patients and what social contexts influenced that evaluation. This allowed me to determine categories that made sense out of the nurses' thinking and actions related to their procedural understanding represented by Figure 1 (a model for measurement, data, and evidence). These derived categories provide a systematic context for understanding nurses' knowledge-in-use.

The two methods of data analysis (clue structure and constant comparison) are illustrated in general by the following simple event. Chloe talked about a patient whose heart rate had climbed to 140.

> Glen: Were there some visual signs you were automatically looking for? The color and things like that?
>
> Chloe: Yes, he was pale. He didn't start to go blue at all. He was grimacing in a way that is quite typical of someone having a heart attack, in that he was clutching his fists in front of his sternum and frowning. So, he was clearly having that sort of expression of cardiac pain. (June 7, 124–128)

The data were pale complexion, grimacing in a particular way, and a heart rate that had risen to 140. Chloe's professional knowledge of nursing (declarative knowledge) suggested the inference cardiac pain. Her ensuing action (procedural knowledge) in this case was to alert other nurses so a team of four could properly attend to the patient, thus preventing an imminent cardiac arrest (social context, the outer ring of Figure 1). Chloe's action was taken only after she had evaluated the data, in a move I recognized as implicitly applying the concept of evidence "validity triangulation" (data acquired by different means to confirm or negate a particular inference—in this case cardiac pain and imminent cardiac arrest). A nurse may have called such implicit thinking "intuition" or "using your gut feeling" rather than a concept of evidence.

This analysis of Chloe's event illustrates how the clue structure of Figure 2 was applied to the interview transcripts. However, the event also hints at various categories of action not specifically represented by Figure 2 but related to Figure 1 (e.g. initiating an intervention, in this case) described in much more detail below. These categories were determined by the constant comparison method, and then they were confirmed through my consultation with the Unit Manager.

In summary, the clue structure summarized in Figure 2 allowed me to identify the data, the procedural knowledge (e.g. both the concepts of evidence that likely helped Chloe evaluate the data, and her action), and the professional knowledge of nursing that informed her decision to act the way she did. Furthermore, the constant comparison method of data analysis uncovered types of action (e.g. interventions) plus social contexts (e.g. patient survival) that may influence the evaluation of the evidence and subsequent action. All of these analyses unfold in detail in subsequent sections to this article, guided by the three research questions associated with three facets of Figure 2: scientific knowledge, professional knowledge of nursing, and concepts of evidence.

Limitations

It is important to note potential limitations to the interview data. The interviews took the form of a conversation between a nurse and myself, an outsider to nursing. Being an outsider gave me an advantage because I could "make the familiar strange" (a conventional process in qualitative research; Glesne, 1999) in order to discover implicit concepts of evidence used by nurses. However, being an outsider might have had disadvantages as well. Even though the nurses were aware of my science background as a science educator, they may have simplified their descriptions by using a nonscientific genre of communication in much the same way as they would with a patient. Because I did not observe nurses speaking among themselves or to other hospital professionals, I have no data with which to compare those conversations with my interviews. It was my sense, however, that the nurses spoke to me much as they spoke to each other professionally, because I continually had to ask them to translate abbreviations they automatically used (e.g. "BP," "sats," and "DC"), and because their description of a sequence of events relied on tacit knowledge of nursing and did not follow the actual sequence of actions, a situation that required my constant probing to sort out the actual sequence in my mind.

A second potential limitation in the data concerns the scope of the study. During the 24 interviews conducted, there were about 30 events discussed, some of which overlapped between nurses. This represents a limited number of events. Hence, some key events on the surgical ward are most likely missing from this preliminary research project. Events germane to other hospital wards are obviously missing as well. No generalizations about nursing are made in this research.

The results of this study are presented here in a sequence that first apprises the reader of various contexts in which specific concepts of evidence were enacted by nurses. The results are organized around the following general topics: research context, evaluating data, concepts of evidence, and scientific knowledge-in-use.

RESEARCH CONTEXT

The way scientific knowledge is used in any particular setting often depends on the setting itself (Layton, 1991; Layton et al., 1993; Ryder, 2001). Accordingly, Chin and his colleagues (2004) proposed that researchers attend to three features of any setting that involves science-related knowledge: purpose, accountability, and the substance (knowledge-in-use) found in that context. These three contextual features organize the following description of the context of this research study (a hospital's surgical unit).

In a number of science-rich workplaces studied by Duggan and Gott (2002), the purpose of the workplace was quality control of a product or process, a purpose that affords repeated measurements and the creation of new methods to defend claims made in the workplace. However, the main *purpose* of nursing on a surgical ward is “to improve the condition and comfort of the patient” (Chloe, May 26, 31). Given the constraints of time, resources, and the immediate consequences to a patient, empirical evidence serves a much different purpose for acute-care nurses than for workers in most other science-related occupations.

The nurses in this research study perceived their primary role as *advocates* for their patients’ physical and emotional healing.

> Terry: It’s more my responsibility to advocate for that patient, to make the surgeon aware of what my findings are, and you say, “Well, you know, these [chest tubes] have been in for so long, and this is what’s draining and there’s this bubbling or tidalling” [fluctuating]. (June 15, 8–11)

The *purpose* of knowledge-in-use for acute-care nurses encompassed three domains: healing their patients, proper use of resources (e.g. medication, tests, and procedures), and effective interactions with people (e.g. doctors, fellow nurses, and technicians). The last two domains always related back to the healing of patients—the primary purpose of a surgical ward.

Accountability in most science-related careers in business, industry, and government is assessed with respect to the quality and efficiency of the product, or with respect to the correctness and appropriate use of a procedure. The nurses in this study were held accountable for the patient’s physical and emotional well being, for the appropriate use of human resources (e.g. calling doctors/residents to perform a function), and for maintaining the hospital’s cultural standards of physical and emotional safety and comfort (e.g. managing a patient’s family and friends).

Knowledge-in-use (the substance of the workplace) enacted by nurses is the focus of this study. Their knowledge-in-use is presented here giving attention to how the nurses evaluated data, what concepts of evidence were relevant to this evaluation, and what canonical content of science was evident in their clinical reasoning.

EVALUATING DATA

Gott and colleagues’ (2003) model (Figure 1) captures the science-related work of nurses on a surgical ward. A typical datum, for example, is a patient’s blood oxygenation saturation (the sats). It can be a quantitative measure (e.g. taken by a finger probe; 82%) or a qualitative measure (e.g. taken by observing the degree of purple-bluishness in a patient’s lips). In terms of the measurement complexity found in other science-rich workplaces (e.g. chemical plants and environmental analysis labs), nursing appears to be at the noncomplex end of the spectrum. Thus, the nurses in the study generally used the following terms interchangeably: measurement, reading, symptom, and observation. In the context of the surgical unit, these terms were synonymous with the model’s term “datum.”

Becoming Evidence

Surgical nurses appeared to assess data in three different ways. Data became evidence when (1) a datum was collaborated by other data, (2) trends in the data were perceived, and (3) there was a consistency or inconsistency between a datum and its context. In some instances, these three different ways worked in various combinations to produce evidence.

The first category (collaborated by other data) is illustrated by the quantitative and qualitative blood oxygenation examples just above. The two examples are directly related to each other because each datum tends to collaborate the other: patients with very low blood oxygen saturation (i.e. 82%) tend to have purple-bluish lips—a condition called "cyanosis." (This relationship is an instance of "professional knowledge of nursing—empirical relationship," Figure 2.) The two measures taken together (each a datum) produce credible data; hence, together they likely constitute *evidence* upon which to make a nursing decision. In other words, several measurements can become evidence if they collaborate an inference about what is happening with a patient; in this case, oxygen deprivation. This type of data collaboration draws upon different ways of measuring the same variable and is known as "validity triangulation" (a concept of evidence).

A second category for describing how observations become evidence is a trend in data, which deals with repeated measurements over time (e.g. sats of 94%, 92%, and 90%). Because this occurrence produces data that form a trend or pattern recognizable to a nurse, the data become evidence. In the present example, 90% is not usually considered dangerously low, but the trend itself indicates an oxygen deprivation problem. Similarly, Chloe described the protocol for measuring blood pressure when attending a patient whose heart beat was dangerously increasing.

> Chloe: . . . So every 3 min it [a blood pressure instrument on a portable trolley] would pump up the cuff and then give you a reading. So then we had a sheet of graph paper and as soon as the 3 min past and the data came on the screen, we would chart them on the graph paper and we could see a trend. (June 7, 147–151)

A third way evidence emerges from measurements is when a datum, in concert with its context, becomes evidence. Jamie happened to notice a discrepant event concerning a patient in the special observation section of the surgical unit who had recently come from the hospital's intensive care unit after his operation. The patient was sitting comfortably upright happily eating a meal. These two observations (data)—upright and eating—taken out of context would have had no particular meaning. However, given the context that Jamie knew—recent surgery with a spinal anesthetic—the data had a highly significant, potentially harmful meaning, and therefore they became evidence:

> Jamie: Usually when they come back after a spinal anesthetic, the protocol is to keep the patient relatively flat for 6 hours postoperatively, because they [the anesthetists] drain off some of the spinal fluid. So if one sits erect, there is not so much spinal fluid surrounding the brain. Patients can get what we call a "spinal headache." It's hard to treat. (May 25, 6–9)

A ward aid had helped the patient into an upright position to make him more comfortable to eat. A nurse would have inclined the patient a maximum of 60°, in spite of it being less comfortable for the patient (an instance of "procedural capability," Figure 2). Jamie's *reason* for this protocol, captured by the quotation above, is an instance of "professional knowledge of nursing—mechanistic explanations."

Another case in which context affected a nurse's thinking was one of Terry's patients who was recovering from surgery that produced a colostomy. The patient had experienced a sudden stoppage in his colon output. When the vitals were taken, the data showed higher than normal blood pressure and heart rate (100 to 110 beats per minute rather than 60 to 80). Were these data credible enough to be evidence in formulating an inference? No, the idea of "normal" needed to be contextualized due to the patient's pain, as Terry explained (drawing upon his "professional knowledge of nursing—empirical relationships"):

> Terry: If someone is in pain, you expect a slight rise in blood pressure. You expect a rise in the heart rate. If somebody is having signs of infection then you are expecting those and an increase in temperature. (June 20, 95–97)

Thus, a heart rate of 110 could be normal if someone were in pain due to a blockage of the colon. But temperature needs to be contextualized in another way as well, because:

> Terry: On this unit in the afternoon in the summer time, you come in at 3 o'clock in the afternoon and you can see everyone is running a low-grade temperature because it's hot outside. Your environment is hot; therefore you're going to be warm. (June 20, 136–138)

Terry looked for a trend in the temperature change in a patient (category 2, trends in data) in light of the context (time of day and season) before reaching a tentative conclusion. In Terry's words:

> Terry: So it is not only looking at the blood pressure and thinking, "Well, the blood pressure is up." You have to take it in concert with all of the other things [triangulation and context]. It's only one little test and you have to take it and you have to synthesize all of the information together before you can actually even form a hypothesis. (June 20, 100–103)

The context to be considered in the evaluation of a datum can be, for instance, type of surgery, a patient's immediate circumstances (e.g. pain), a patient's past history, and time of day or season.

In summary, applying the model (Figure 1) devised by Gott and colleagues (2003) to clinical reasoning on a surgical ward, one detects three pathways for moving from a datum to evidence. The pathways, either singular or in combination, lead to the next stage in Gott and colleague's model, evidence evaluation: How credible and important is the evidence? Two main functional purposes for evaluating evidence became apparent in the nurses' interviews: to move "to the next level" in attending to a patient's well being, and to initiate a procedure or intervention. Each is examined separately, although in reality they naturally occur simultaneously, as indicated by events mentioned in the following two subsections.

Taking It to the Next Level

Measurements seemed to form a hierarchical pattern on the surgical ward: (1) symptoms (detected by a nurse's senses), (2) vitals (blood pressure, heart rate, temperature, respirations, and blood oxygenation saturation), and then (3) targeted tests to gather further data. Each represents a different level of data gathering, and therefore, each represents a different function for evidence at each level. To move from one level to another, nurses made a clinical decision that required credible evidence. (These transitions from one level to another are illustrated by events on the surgical ward reported just below.) Once a nurse reached level 3 (targeted tests), other levels and decisions became apparent: (3.a) targeted tests that a nurse can carry out, (3.b) tests that require hospital specialists, and (3.c) tests that require decisions by residents or doctors. Some of these tests are simple/inexpensive while others are complex/expensive. The decision over what instrument to employ lies in predetermined protocols ("procedural capabilities," Figure 2) or in the hands of hospital specialists and doctors (e.g. whether to obtain data with an X-ray or NMI).

Often patients will report a discomfort or pain to a nurse, or alternatively, a nurse will spontaneously notice something about a patient upon approaching a bed. The following example illustrates moving from the symptom level directly to the targeted tests level.

> Joan: A patient rang for me the other day and they were exhibiting symptoms; they said they felt "low". It's what the patient said specifically.
>
> Glen: Now, when they said "low", that's a verbal message. What was the body language? By just the way they said it? What did *you* perceive?
>
> Joan: They looked tired. They were sweating, a little shaky, felt sick to the stomach; all those kinds of things. (June 11, 4–10)

The expression "all those kinds of things" suggests Joan has tentatively recognized a pattern she associates with, in this case, diabetes ("professional knowledge of nursing—correlations," Figure 2). She continued:

> Joan: So those are the things that I see. . . . Then we automatically go and do a blood sugar testing. This patient was low. They read 2.3, which is low. A normal glucometer reading would be 4 to 6, somewhere in there. (June 11, 10–13)

In this illustration, the decision to move to a higher level of data collection was a straightforward protocol ("procedural capability," Figure 2). However, the datum "2.3" had sufficient credibility in the context of the surgical units' familiarity with diabetes to warrant a different type of clinical decision by Joan, a decision to initiate a procedure or intervention—a second function of evidence (discussed below). In this case, she gave the patient sugared apple juice, one intervention among several, each justified by evidence. For renal patients with high blood sugar counts of 10 or higher, for instance, a different intervention would be required (Unit Manager, October 14, 111–115).

Sometimes moving to a higher level of data collection does not bring evidence that a nurse seeks, and a nurse needs to move on to the next level, as this next example demonstrates.

> Gia: I walked into a room (that was about half an hour to 45 min after giving an Indocid suppository to a woman patient) and she had reacted to the Indocid suppository.
>
> Glen: What did you notice?
>
> Gia: Something was wrong because she was very confused, her eyes were really twitching, and she said she felt very heavy and her whole body felt heavy. . . . She said she felt kind of paralyzed, she couldn't move. So, I took a set of vitals, but her vitals were fine. (May 22, 4–17)

The baseline data (vitals) caused a discrepancy for Gia. Her professional knowledge of nursing did not help her in this event other than to tell her something was wrong. But she did not know what targeted measurement she should take next. By consulting a doctor she went to a higher level (level 3.c).

> Gia: Indocid had affected her central nervous system. I had talked to Dr. [X] about it because I knew that something was off. He happened to be up here, anyway. He said there was a higher incident of reaction in women than in men. And that it was not uncommon, and so he discontinued the Indocid and put her on a different pain reliever called "Naprosyn". (May 22, 22–26)

In the future, Gia will remember this event when she gives a patient Indocid: "I had no idea that it could do that. I will put that in the vault for future reference" (May 22, 44–45).

"Vault" seems to be her expression for "professional knowledge of nursing," and in this case "empirical relationships" (Figure 2).

Given the constraints of time and limited resources, nurses' decisions are based on the evaluation of the evidence that might warrant the decision to go to the next level. Joan succinctly summarized this conclusion herself: "To make the choice, evidence is necessary to go to the next point" (May 29, 131).

Initiating an Intervention

We have seen that Joan gave sugared apple juice to a patient who had a low glucometer reading. A more extensive example of initiating an intervention is described here.

Under Chloe's care, a patient recovering from vascular leg surgery showed the following symptoms (data): increased pain in the calf when the patient flexed his foot, redness of the skin, hot to the touch, and the patient was reluctant to get up. The patient's pain in this context had special meaning to a nurse ("professional knowledge of nursing—empirical relationships"):

> Chloe: The other significant thing was with the pain; it wasn't the fact that he had pain in the calf, but the fact that when he flexed his foot the pain in the back of his calf got worse. It is a positive Homan's sign, so it's a specific pain that worsens with a specific movement. (May 26, 66–69)

Another concept in the professional knowledge of nursing was the correlation between pain and swelling in this context (Chloe, May 26, 71). These data became evidence to warrant going to the next level of a targeted test, in this case measuring the degree of swelling over time (data that showed a 2 cm increase in the leg's circumference over 3 h). Now, the data reached the status of evidence to support a concern that the patient may have a deep vein thrombosis (DVT, also known as a blood clot). Was the circumference increase of 2 cm the evidence by itself? No.

> Chloe: Not in isolation. But if there was significant pain when he flexed his foot, and redness that was hot to touch, all of those things together. So, it is not necessarily any one factor in isolation, but all of them together, you'd want to be sure there was no clot, and that the symptoms were caused by something else. (May 26, 88–91)

Chloe did have evidence for an immediate intervention (i.e. applying anti-amboli—anticlotting—stockings to the patient's leg) and for going to a higher level of targeted tests (level 3.c) by talking with a resident who authorized a Doppler ultra sound, the result of which ruled out DVT. The resident was then able to tentatively account for the patient's pain by focusing on the muscle damage caused by the surgery. The anti-amboli stockings (support hose) resolved the patient's swelling and pain within a day.

In Chloe's scenario, a cluster of symptoms became evidence for moving to the next level (level 3.a), which was a targeted test (leg circumference measurement) and which in turn yielded validity triangulation data (2 cm increase over 3 h). Both the cluster of symptoms and the triangulation datum suggested the possibility of DVT (i.e. a blood clot) and led to the decision to initiate an intervention (i.e. applying anti-amboli stockings).

CONCEPTS OF EVIDENCE

A comparison between the concepts of evidence used by nurses and the compendium of concepts of evidence derived from extensive research (Gott, Duggan, & Roberts, 2003) is not in anyway an evaluation of nurses. Comparing and contrasting is only a reporting strategy.

Reliability

One key concept of evidence used by industrial employees in the UK but not by nurses in this study was *repetitive readings from the same instrument* (after which an average datum is calculated), that is, "repeated measures." When Chloe discussed her measurement of the circumference of a patient's leg, the following exchange occurred:

> Glen: When you explain carefully how you want things to be measured, there is an old problem of, "How do you know that if you measured it directly afterwards, you'd get a slightly different measure only because of the tightness that you held it [the measuring tape]?" Do you re-measure or do you just take one reading?
>
> Chloe: Usually just one. (May 26, 63–65)

Nurses seldom had time or the need to take several measures and calculate an average value because the purpose and accountability in the surgical unit militated against it. Precious time could better be spent acquiring validity triangulation data that produce more credible evidence for a nurse to decide what to do next. My questions to all six nurses about taking repeated measurements were often met with either polite incredulity or a diversion of the conversation to a topic that made sense. The nurses' transcripts illustrated the low status afforded the concept of evidence called "repeated measures" (Aikenhead, 2003).

When asked about taking an immediate second reading from a Dynamap (a mechanical blood pressure instrument on a portable trolley), Terry described how he would compare the original datum to its context rather than take a second reading, which is one of the ways a datum acquires the status of evidence. If Terry detected a discrepancy between a Dynamap reading and contextual information, he would use a different instrument to measure the blood pressure (e.g. a manual reading), thus demonstrating the use of the concept of evidence "validity triangulation." He would not, however, double-check the Dynamap reading.

> Glen: So what I was focusing on was when you take a reading, how do you know if you need to take another reading for just—
>
> Terry: It gets to be intuition.
>
> Glen: You told me you take it and look at the chart and if it's that much different than the chart—
>
> Terry: Then I immediately go to the manual reading, because I want to know exactly what I am dealing with. (June 8, 161–166)

Terry also used another concept of evidence about *how* the measurement was taken (i.e. reliability related to instrument use, in this case using a proper cuff size).

> Terry: If I get a big change, first thing I do is check to see if I have the right cuff size. If I have a larger cuff on the machine, I'm going to get a lower reading. If I took your blood pressure with a pediatric cuff right now on your arm, you would have an outrageously high blood pressure. (June 8, 168–170)

With time constraints and pressure to go to the next level (if necessary), the first and only measurement (datum) is often assessed in terms of its consistency with the context, using one's "intuition," as Terry stated above. Gia expressed the idea slightly differently:

Gia: I think that around here our gut judgment is everything. And just because it's a machine, doesn't mean that it's always right. (June 13, 136–137)

If a measurement is not consistent with a context of symptoms or with a nurse's practical knowledge (i.e. intuition or gut judgment), then a nurse will usually go to the next level (i.e. they apply the concept of evidence "validity triangulation"), as Gia did:

Gia: I think you always have to go with your gut feeling and if it's not what you expect, then find something more accurate.
Glen: Right, instead of just measuring it again.
Gia: Yes. (June 13, 139–140)

Nurses did not tend to think of an instrument as having an inherent measurement error. For instance, when explaining the fluctuations in oxygen saturation measurements produced by a figure probe instrument, Joan talked about a patient's *condition* changing, and about the need for validity triangulation with more accurate data:

Joan: It [the sats] can change often, all the time, a very little bit. But if all of a sudden the person were to get extremely short of breath, it can drop to a significant number, very quickly. And that will be alarming.
Glen: That's good information, because now I can ask, "When you take the reading, how do you know it is the right reading rather than one of the fluctuations?"
Joan: This oxygen finger probe can be backed up by a blood test of the oxygen. And that one will be more accurate. (May 29, 17–23)

Gia (June 13, 16–20) mentioned the temperature of a patient's hands as a factor that might cause fluctuations in a finger probe reading. Similarly, according to Jamie, the margin of error (the ± value) in a hemoglobin measurement was not caused by the instrument itself but was caused by other factors that could affect the measurement using a sensitive instrument:

Jamie: Depending on, again, what's happening, what kind of surgery they've had. In some kind of surgeries we expect them to bleed a moderate amount. Other surgeries, you don't. (June 18, 94–95)

Here we see an instrument's measurement error being ignored for practical reasons, as a nurse focuses in on factors related to a patient's unique individuality and well-being.

Unlike the nurses in the study, the Unit Manager distinguished between two similar portable machines, the Dynamap manufactured by Critikon and another manufactured by Welch-Allyn. She described occasions when nurses actually measured one instrument against another (measurement triangulation).

UM: I've seen people take a blood pressure with a Critikon, check it with a Welch-Allyn, and then if they are still in doubt they'll do a manual. But there is enough doubt about the Critikon's accuracy that the nurses are not really that confident in its measurement. (October 14, 60–71)

This type of measurement triangulation did not arise in the 24 nurse interviews conducted during this research project (a circumstance mentioned in the subsection "Limitations"). Except for a few isolated instances, however, the concept of evidence "repeated measures" did not seem to guide a nurse's actions.

In science, the degree of reliability is conventionally expressed in terms of an instruments' error of measurement, the ± value associated with a measurement. As already indicated, the nurses did not seem to have had a need to consider ± values during any of the events they discussed. Two other issues were more important to a nurse's clinical reasoning: (1) the variation in a reading is accounted for by a patient's *unique differences*, differences that supersede any ± value inherent in an instrument reading; and (2) the variation in a reading is accounted for by *changes* in a patient's environment or body system, changes that supersede any ± value in an instrument reading. For instance, Gia accounted for fluctuations in heart rate measurements by mentioning a patient's arrhythmias and the context of what is normal for the unique individuality of a patient. Jamie (June 18, 121–145) rationalized a hemoglobin measurement fluctuation by describing contextual factors (e.g. type of operation). Sarah (June 16, 59–70) considered any change in a hemoglobin count to be a possible *change in the patient's condition*, rather than being within the error of measurement of the instrument. It is also realistic that the ± value correctly associated with an instrument's measurement error is significantly less than normal changes observed in a patient, in which case the measurement error would be insignificant on scientific grounds.

There was another complicating factor related to measurements on the surgical ward: whether a measurement fell within, or outside, the *normal range* for the particular circumstances of the patient's unique individuality. For instance, Joan considered a variation in a patient's systolic pressure of ±5 to be insignificant when it lay within the patient's normal range, but she was sensitive to an even smaller change (e.g. ±2) when it lay outside the normal range (June 18, 88–99).

In the following exchange, Terry underscores the practical reasons for nurses to ignore the concepts of evidence "measurement error" and "repeated measures."

> Glen: So if this person who in this circumstance had a blood pressure of 160 over something and you came back half hour later and it was a 170 over whatever, you would think, "Well, maybe that's in the reading," rather than—
>
> Terry: Well maybe it's in the reading but, once again, you are going to ask, "*And what else?*"
>
> Glen: "And what else." Okay.
>
> Terry: What else is causing that? How is he lying? Was he sitting up the last time the blood pressure was taken? Because if your body is *sick* and weak, it doesn't compensate for lying down and standing up. (June 20, 117–124)

Of prime importance to a nurse is "what else?" because the central purpose of a nursing unit is "to improve the condition and comfort of the patient" (Chloe, May 26, 31), not to justify a measurement on the basis of the instrument's reliability. In other words, the surgical ward was patient oriented more than it was measurement oriented. From the surgical Unit Manager's way of thinking, "this is what encompasses the *art* of nursing" (Unit Manager, October 14, 47, emphasis in the original), an instance of being at the "intuitive-humanistic" end of Thompson's (1999) systematic-positivistic versus intuitive-humanistic continuum. In contrast to a surgical ward, science-rich workplaces that are product oriented must rely heavily on an instrument's reliability to claim a certain product quality, thus making these workplaces more measurement oriented than is the case for a surgical ward.

Gott and colleagues (2003) wrote about establishing reliability of a measurement by multiple observers taking identical readings with the same instrument. On the surgical ward, this procedure did not appear to occur, likely because there was neither the time nor the need. Pervasively, nurses did seem to repeat measurements (e.g. a patient's symptoms or vitals) when they first took on responsibility for a patient. Nurses did so not to double check the previous nurse's measurement, but to continue a collection of data on a patient to look for a pattern or trend that might be important if a nurse had to decide whether or not to go to the next level.

In the context of nursing, a measurement (e.g. blood pressure) was more than a representation of a physical condition of a unique individual patient. A measurement often represented a *changeable* (i.e. dynamic) condition of that patient. This unpredictable variability within a patient's complex body can affect an instrument reading, which may or may not have critical implications for the patient. This was Terry's concern when he asked, "And what else?" (June 20, 120). By contrast, in many industries the entity being measured (e.g. gas pressure) is generally assumed to remain static during the measurement process, and consequently, the fluctuations in measurements are attributable to the measurement process itself, that is, the error of measurement. But for the nurses in this study, fluctuations in measurements were either attributed to the changing condition of the patient being measured, or to the inaccuracy of an instrument, in which case a nurse engaged in validity triangulation with a more accurate instrument that used a different process to arrive at a measurement (a topic to which we now turn).

Accuracy

During my early interviews, nurses talked about a machine in terms of its *accuracy*. In my later interviews, I discussed the notion of accuracy with them. I asked, "Of all the machines that are used on this ward, which one do you think is the *most* accurate? And which do you think is the *least* accurate? As one should anticipate, the word "accuracy" had nuances of meanings depending on the context.

The interviews strongly reflected the belief that nurses should not trust a machine, especially when a nurse can take a manual reading (e.g. for heart rate, blood pressure, etc.). When talking about a heart rate reading of 140, displayed on a Dynamap digital screen, the following exchange occurred.

Chloe: At that point, it was a case of implementing some other means of gathering evidence. I've always been taught never assume your machine is right. Get your hands on, take a radial pulse, get your stethoscope out and listen yourself directly to the heart.
Glen: That's why you used the stethoscope.
Chloe: Yes. By then, the rate I heard myself was 170. So then when we attached the cardiac monitor, we saw it [the patient's heart rate] was all over the map and still going up. (June 7, 115–120)

A similar view was expressed by Joan, Jamie, and Gia. However, when Gia talked about her patient hooked up to a 3-lead cardiac monitor (not a Dynamap), and talked about a medical paper trail, she seemed to put more trust in this particular machine:

Gia: ... But in the heat of the moment, when everything's happening, I tend to trust the monitor unless something would spark me otherwise. If I took a radial pulse and it didn't match the monitor, I would tend to think that the radial pulse I was getting is wrong because when it's that quick it's difficult to count every beat; whereas, the monitor would actually pick up every beat.
Glen: But when you have a moment, you'd go ahead and print it out just to have—
Gia: A copy of it to put in the chart for proof, or evidence, ... [we'd have proof] that that was really on the monitor.
Glen: In business, they call it a paper trail.
Gia: Right. It's our medical paper trail. (June 4, 71–79)

Here Gia has provided an additional social context for dealing with data: permanent records create evidence to be used in the distant future (e.g. if a review took place perhaps), in addition to be used immediately to decide on an intervention. In the specific context described by Gia, a computer-generated printout had greater value than a nurse's manual reading. Except for this one occasion in which Gia questioned the accuracy of a manual heart rate measurement taken "in the heat of the moment," the nurses never once mentioned human error inherent in a manual reading when they discussed accuracy. The Unit Manager, on the other hand, spoke specifically about human error in a manual reading:

> UM: . . . There is so much subjectivity in a manual measurement of blood pressure. Yes, you can say, "I'm confident that his blood pressure was 100 over 70, because that's what I heard." But maybe now that I'm older my hearing isn't as good as it used to be, and some young 22 year-old might take it and all of a sudden it's 120. Well that's a significant difference that a machine would probably have picked up. I think that, although we've been traditionally taught that manual and tactile measurements are the most accurate, in some ways we don't realize how subjective some of them are. (October 14, 55–61)

Once again we see that context is everything in nursing. The crucial role of context in the evaluation of evidence is represented by the outer circle of Gott, Duggan, and Roberts' (2003) model for measurement, data, and evidence (Figure 1).

Just above, Gia stated that a 3-lead cardiac monitor was more accurate than a manual reading. Her concept of accuracy seemed to be related to the *detail* provided by the machine.

> Gia: It [the 3-lead cardiac monitor] takes a reading of your heart and translates it to the monitor. And it makes waveforms on the screen. To us, every wave means something different that the heart is doing. And depending on how many of those waveforms you get in a certain amount of squares (which is time) that tells us what the heart rate is. (June 4, 52–55)

Joan (June 18, 109–114) and Jamie (June 24, 87–101) agreed.

A topic directly related to accuracy is how well an instrument is functioning. Normally this quality is assured by a routine calibration of an instrument. This process entails using concepts of evidence such as (Gott, Duggan, & Roberts, 2003): end points, intervening points, zero point, and scales. However, instrument calibration does not lie within the jurisdiction of nursing; it is the responsibility of the clinical engineering staff who takes care of repairs and maintenance (Gia, June 4, 80–85). In a hospital, the concept of evidence called "validity" is primarily an engineering responsibility, except in the cases where nurses are cognizant of variables that would jeopardize an instrument's accuracy (e.g. yellowed fingers interfere with a patient's sats reading).

Other Concepts of Evidence

A question remains concerning Gott, Duggan, and Roberts' (2003) compendium of empirically based concepts of evidence: Do nurses use concepts of evidence not found in the compendium? Three were noted earlier: a normalcy range for a patient, the unique individuality of the patient (the object of a measurement), and the variability within a patient's complex body (i.e. Terry's "And what else?"). However, another very different type of concept of evidence emerged from the nurses' transcripts.

In the science-rich workplaces studied by Duggan and Gott (2002), people measured and assessed *physical* attributes of various entities. In the present study, however, nurses measured and assessed both physical and *emotional* attributes of patients. The nurses' transcripts clearly indicated that human emotions defined an important subset to concepts of evidence not found in Gott, Duggan, and Roberts' compendium, a subset related to such fields as psychology, sociology, and anthropology. This new subset is acknowledged here because of its role in the science-rich workplace of the surgical ward, but a detailed explication of specific, emotion-related, concepts of evidence is beyond the parameters of the present study.

In several events recounted by nurses, emotion-related observations were assessed as evidence from which to make clinical decisions on how to improve the condition and comfort of a patient.

> Chloe: Evidence [concerning the emotional state of patients] is often based on your own observations of people and what you're told in the reports. (June 1, 7–8)

A patient's improvement may be influenced by the interaction between the patient and their visiting relatives or friends. A nurse must therefore attend to these visitors to benefit the recovery of a patient. In one encounter, Chloe found herself dealing with extremely stressed relatives. The patient had undergone an amputation the night before.

> Chloe: Over the course of the day the family became increasingly anxious to the point of being abusive and obstreperous, according to the night nurse's report. I guess they had been up for three nights in a row by then (an elderly wife and three daughters). (June 1, 12–14)
>
> . . .
>
> The night before they had been very aggressive and abusive to the point that the surgeon had actually said to us that if these things happened again, call security and have them removed from the hospital. (June 1, 50–52)

Chloe described her first encounter as follows:

> Chloe: When I entered his room in the morning, the patient was very comfortable and there was his elderly wife who just looked absolutely shattered. So I started to do my assessments and introduce myself to her. It was a situation in which I tried to make assessments of the patient and ask him about his level of pain or level of well-being, but she would start to talk and answer for him. He was a perfectly lucid man. (June 1, 22–26)

The capability to notice symptoms of someone being emotionally shattered, as the wife was, required "watching for body language a lot" (Chloe, June 1, 81).

In order to collect more emotion-related data, Chloe needed to interact with the wife in a way that would help Chloe's patient heal. Some of Chloe's procedural and declarative understanding involved in this encounter seems best described as intuition or intuitive-humanistic knowledge, a component of clinical reasoning (Higgs & Jones, 2002, p. 7; Thompson, 1999). Her interaction with the wife occurred as a result of the clinical decision to "establish a relationship with his wife by asking her some questions" (June 1, 28–29). Chloe's procedural capabilities were guided by a subset of concepts of evidence related to the domains of psychology, sociology, and/or anthropology. As a result, the patient's wife was successfully cared for by Chloe over the next several hours and the wife did not impede the patient's recovery.

Although a patient's emotional well-being is constantly on the mind of a nurse focused on the patient's physical attributes, sometimes the focus does shift to the patient's emotional attributes, as it did for Sarah (June 23). Her patient was found wandering around the ward unsafely at 7:30 a.m., a time when most patients continue to rest. Sarah apprised herself of his physical attributes (e.g. his old age, bags under his eyes, his meds, and his low potassium level of 3.1 measured the day before, for which he was being bolused). However, Sarah attended to his psychological attributes, for instance, his tone of voice, and his body language (e.g. no eye contact and pacing around), and to his social behavior (e.g. irrational conversations), all of which served as evidence for the conclusion that he was confused. The intervention Sarah initiated was not a physical one so much as a purely emotional one. She engaged him in an authentic human-to-human conversation, rather than in a professional nurse-to-patient conversation. Within a short time, the patient calmed down and began to rest comfortably.

> Sarah: I think that maybe he needed someone to talk to because his family hadn't been in for a couple of days. We're often so busy, we just run in and out [of a patient's room], not having time to just talk. (June 23, 96–98)

When Sarah considered the patient's emotional attributes, she collected data (feedback) and assessed those data with concepts of evidence strictly related to the patient's emotional well-being.

In these situations, *sensitivity* is a necessary quality in a nurse, but the word "sensitivity" has a much different meaning in this context than it has in Gott and colleague's (2003, section 4.5) catalog of concepts of evidence: "The sensitivity of an instrument is a measure of the amount of error inherent in the instrument itself." Emotional sensitivity and instrument sensitivity are two very different concepts of evidence; reflecting the difference between emotional attributes and physical attributes considered by nurses in their evidence-based clinical reasoning.

In addition to exploring emotional sensitivity, future research into emotion-related concepts of evidence in nursing may want to investigate the roles played by such concepts as empathy, equity, and respect, and may want to explore nurses' "aesthetic perception of significant human experiences" (Higgs & Jones, 2002, p. 27).

SCIENTIFIC KNOWLEDGE-IN-USE

Earlier in this article the following points were made: (1) research strongly suggests that most scientific understanding required in a science-rich workplace is learned on the job; (2) a pragmatic distinction can be made between scientific ideas and professional knowledge of nursing, on the basis of generalizable decontextualized knowledge versus transferable contextualized knowledge, respectively, although the distinction may be vague in some specific instances; and (3) the context of nursing predictably predisposes a nurse to draw upon professional knowledge rather than scientific knowledge. This prediction for nurses was predicated on the literature cited at the beginning of this article that concluded: the transformation of canonical science knowledge into useful everyday knowledge requires that it be deconstructed from its universal context and then reconstructed according to the idiosyncratic demands of an everyday context. Most nurses would face a formidable task if they were required, in addition to all their other demands, to deconstruct abstract scientific concepts and reconstruct them to fit the demands of an idiosyncratic event on a surgical ward.

In the present study, the transcripts of five of the six nurses were almost devoid of references to scientific knowledge (except for the use of anatomical terms, an issue discussed below). The transcripts of one nurse, Terry, however, were replete with descriptions and explanations from a scientific worldview perspective. In the following exchange, Terry made his viewpoint very clear when he stated, “You really have to understand the physics of what’s going on with those chest tubes.”

> Terry: . . . And that’s also monitoring what’s happening with those chest tubes.
>
> Glen: That’s when the evidence comes in.
>
> Terry: Oh, absolutely. And for that *you really have to understand the physics of what’s going on with those chest tubes*. You have to understand why those chest tubes are there in the first place. Chest tubes are put in for two major reasons: either a haemothorax (“haemo” meaning blood, “thorax” meaning thoracic cavity) or pneumothorax (air in thoracic cavity). Then you have an open or closed haemothorax or pneumothorax. And “open” means it is open to the extreme environment through a hole through the rib cage through the intercostal spaces between the ribs. . . . (June 15, 37–44, emphasis added)

Gia (June 20), on the other hand, described how she successfully solved a chest-tube problem but her account was formulated on professional knowledge in nursing (i.e. what patients do when they pull their chest-tube equipment with them as they go to the bathroom) rather than a scientific explanation of differential gas pressures in closed or open systems. This is not to say that Gia could not describe how a scientist would explain her patient’s situation (she was not asked for that information), but rather, a scientific explanation for her was not relevant to the problem-solving task at hand. Gia represents the majority of student nurses in Cobern’s (1993) study, while Terry is similar to Carla in that study.

Terry’s scientific worldview descriptions and explanations included conceiving blood pressure in terms of a hydraulic closed system in which the heart was the pump, leading deductively to systolic and diastolic blood pressures (June 8, 16–26); conceiving BP cuff size in terms of surface area (June 8, 174); conceiving the act of breathing, in part, as differential air pressure in an open system (June 15, 39–58); conceiving of pain in terms of mechanistic features of the sympathetic and parasympathetic nervous systems (June 20, 47 ff.), conceiving of an edematous patient in terms of a series of closed systems within the body (June 25, 89–105); and conceiving the alveoli as a place for “the oxygen and carbon dioxide to exchange through osmosis” (June 25, 60). Although many events discussed by Terry were communicated within a scientific genre, he also drew upon his professional knowledge of nursing as did his peers; for example, citing the empirical relationships between pain and blood pressure (June 20, 46) and between breathing/coughing and bringing a patient’s temperature down (June 20, 169).

My interpretation of Terry’s claim that a nurse needs to understand science so “you know if something is going wrong” (June 15, 70) is that *Terry* himself needs to understand the science because, like Carla in Cobern’s (1993) study, he likely explains nature from a scientific worldview perspective. Because I can share his perspective with him, communication between us was effective. Thus, one use of scientific knowledge in nursing may only be to facilitate communication among professionals who happen to share a scientific worldview. This use represents a very limited view of the application of scientific knowledge to nursing, restricting it to a small minority of nurses.

The other five nurses in the study appeared to engage in clinical reasoning without expressing a need to draw upon scientific descriptions and explanations. Only three incidental exceptions occurred during their 20 interviews: Sarah’s (June 16) mechanistic description of the role of hemoglobin in the body, Gia’s (June 4) explanation for the beta-blocking effect of the drug Metroprolol, and Joan’s (May 15) explanation of how she solved a technical problem associated with a patient’s medication. On the other hand, when Gia described the event in which a patient’s nervous system reacted negatively to the medication Indocid, Gia mentioned that she would store her newly discovered empirical relationship “in the vault for future reference" (May 22, 45), which I interpreted as a reference to her professional knowledge of nursing. At that moment in the interview, I steered the conversation toward the topic of scientific knowledge.

> Glen: Were you at all curious about the actual mechanism that explains how that medication works in the body? Or why the central nervous system seems to close down to some extent?
>
> Gia: I never had time to look it up, but that would be interesting.
>
> Glen: Does that affect how you would observe things?
>
> Gia: Probably, I think you will have a more in-depth *understanding* of it, so you could probably recognize other signs and symptoms of an Indocid reaction. So, probably that will be helpful if I got into it deeper and actually knew the mechanism. But I don't at this time.

It seemed as if a scientific explanation would hypothetically have had potential value, but at that moment, it was not salient to the clinical reasoning in which Gia was engaged. She was perfectly capable of learning the scientific mechanistic explanation but it did not seem particularly relevant in the realities of a surgical ward with all its pressures. One can only speculate that her worldview perspective was not a scientific worldview, as Terry's seemed to be. It was beyond the scope of this study to inquire into the worldviews or self-identities of the nurses.

Although all six nurses made use of anatomical terms (appropriate noun labels) as they talked about events, this ability to apply scientific/nursing vocabulary is not considered in this study to be a demonstration of understanding scientific knowledge. Instead it is taken as evidence for the *procedural capability* (Figure 2) to communicate unambiguously with other health professionals.

Another pattern emerged from the interview data. Successful clinical reasoning did not use measurement units grounded in scientific knowledge. The nurses could only identify a few of the measurement units when I specifically asked what they were, and only Terry remembered all but one of the units (Aikenhead, 2003). On a surgical ward, measurement units likely get in the way of efficient data management and communication. On the other hand, units of measurement are central to scientific thinking. Thus, clinical reasoning and scientific reasoning differ in this regard.

An alternative interpretation arises from a perspective on professional knowledge of nursing that does not partition it from scientific knowledge because both are evidence-based practices. The Unit Manager explained:

> UM: I look at evidence-based practice as something that becomes part of you. So maybe I can't remember all the scientific ideas (e.g. the loop of Henley), but I still know that a water pill does its job. After thinking about it from *that* point of view, I think the nurses have assimilated the scientific principles that they learned, and they've taken the common denominator of: "This is how I understand that this is your water pill." (October 14, 8–12)
>
> . . .
>
> If I'm talking to a patient I might not say, "This is your Furosemide pill." I'm more apt to say, "This is your water pill." I'm not going to go into all the intricacies of how that works (the sodium/potassium pump, etc.), I'm probably just going to say, "It takes the water off, so it alleviates fluid on your heart and helps take fluid off your feet." I think sometimes when we're responding to the public, we don't come across as being scientific experts. But I think to really fully understand what we do, there has to be some grounding there somewhere. (October 14, 14–20)

If one clearly conceives professional knowledge of nursing and scientific knowledge as two different systems of thought, a problem arises:

> UM: But it's like it almost changes the discourse. It no longer becomes a discussion about scientific principles as much as it actually becomes a system all by itself; nursing, if you will; whereby it uses all the principles from other disciplines but has developed most [principles] around science. (October 14, 32–35)

The issue raised here (i.e. whether or not to partition professional knowledge of nursing from scientific knowledge) is reminiscent of the "science versus technology/engineering" issue debated in science education during the 1970s and 1980s (Gardner, 1994; Layton, 1991). Today in academia, science and technology are generally conceptualized as two distinct ways of knowing, even though they interact and borrow from each other extensively (Collingridge, 1989) and can be indistinguishable in certain R&D projects (Jenkins, 2002).

The general public, hospital patients included, do not generally distinguish between science and technology (Ryan & Aikenhead, 1992), and the public tends to confer prestige and expertise on scientific discourse and methods. Therefore, the *science* of nursing may have a public relations role to play alongside the *art* of nursing. In the science education research community, however, professional knowledge of nursing can be distinguished from scientific knowledge just as engineering is distinguished from pure science. This distinction does not in the least denigrate the intellectual expertise required of nurses; the distinction only acknowledges key differences, a perspective that has implications for curriculum development rather than for public confidence in nursing.

SUMMARY AND CONCLUSIONS

What knowledge is actually used by nurses as they attend to the data acquired from their patients? This research identified a core set of concepts of evidence that appeared to be shared by all six nurses on the surgical ward. Concepts related to reliability but missing from Gott and colleagues' (2003) compendium of empirically based concepts of evidence included normalcy range, uniqueness of the patient measured, and variability within the patient's array of physical attributes. On the other hand, the nurses seldom had reason to draw upon the key concepts of evidence such as repeated readings and measurement error. The measurement error of some medical instruments may have been less than the observable fluctuations attributed to changes in a patient's condition; and, of course, a scientist would be correct in ignoring the instrument's measurement error as well. However, the interview data, including the Unit Manager's contribution, did not show any consideration for measurement error in any circumstance. It would seem to be a concept of evidence irrelevant to nursing.

Concepts of evidence related to scientific validity centered on accuracy; validity triangulation; and a general predilection for direct, sensual, personal access to a phenomenon over indirect, machine-managed access. The concept of evidence called "data presentation" (Gott, Duggan, & Roberts, 2003, section 16.0) surfaced during the interviews as well, when nurses spoke about graphing data to detect trends.

The above concepts of evidence have a common characteristic: they all deal with *physical* attributes of patients. Missing from Gott, Duggan, and Roberts' (2003) encyclopedia of empirically based concepts of evidence, but apparent in the surgical unit, is a set of emotion-related concepts of evidence associated with psychology, sociology, and anthropology (e.g. cultural sensitivity). This is an area for future research.

The nurses' concepts of evidence functioned within two interrelated contexts: taking it to the next level, and initiating a procedure or intervention. Both contexts exist for the prime purpose of healing patients (bounded by the realities of available time, resources, and interactions with other professionals in a hospital). Before engaging in either of these two types of procedures (i.e. taking it to the next level or initiating a procedure or intervention), nurses considered the credibility of their observations, which they tended to evaluate as being either sufficient or insufficient. The parallel distinction is made in Gott, Duggan, and Roberts' (2003) model (Figure 1) between data and evidence. The surgical nurses in this study appeared to evaluate their data in three different ways. Data became evidence when a datum was collaborated by other data, trends in the data were perceived, and there was a consistency or inconsistency between a datum and its context. In some instances, these three ways worked in various combinations to confer the status of evidence on data. Figure 1 captures the dynamic nature of nurses' measurements, data, and evidence, contextualized by the social functions and moral consequences that subsequent clinical action might bring (the outer ring of the model).

What conceptual content in physics has a direct role in nursing, given the abundance of instruments and physical procedures utilized by nurses? The answers "some" and "none" are both correct but depend on the worldview of an individual nurse. The perspectives embraced by Terry and perhaps the Unit Manager, for instance, indicate *some* role for physics content. On the other hand, for the large majority of the nurses in this study (a proportion consistent with the research literature reviewed above), "none" seems to be the evidence-based answer. A high school physics course would not seem to be a relevant prerequisite to successful nursing, although Terry would enjoy it. This issue could be investigated further, however, with a greater number of nurses in more diverse roles (e.g. in other hospital units, in community clinics, and in homecare units).

For science educators siding with the Unit Manager who surmised that somehow canonical science concepts must play a role in the development of a nurse's professional knowledge, the challenge is to conduct the appropriate research to advance such an evidence-based argument. Concerning the university debate over foundational science courses versus professional courses in nursing, the findings of this study side with the surveyed opinions of nurses (McCaughan et al., 2002; Ray, 1999). Although little research evidence seems to exist in support of traditional science courses, Scholer (2004) did investigate effective *instructional practices* in her college science course (anatomy and physiology) that encouraged nursing students to contextualize (deconstruct and reconstruct) scientific concepts into declarative professional knowledge of nursing or into procedural understanding.

The evidence to date certainly supports the tentative claim that most nurses draw upon their professional knowledge of nursing rather than upon science curriculum content when engaged in clinical reasoning. McCaughan et al. (2002) and Ray (1999) discovered that nurses tend to feel that context independent, hypothetical, scientific information lacks clinical credibility because scientific knowledge fails to offer a level of clinical direction needed by nurses who work in real time under real constraints. Nurses' reticence was due to a number of factors, including the unique individuality of each patient (a notion ubiquitous among the six nurses in this study), the medium used to convey the scientific information (formal texts or electronic sources carried little weight compared to a third party trusted by nurses, Thompson et al., 2001), and perception barriers created by nurses' nonscientific worldviews that inhibited the uptake of scientific knowledge (Bonell, 1999; Closs & Cheater, 1999; French, 1999; McCaughan et al., 2002). Some of these factors can be modified to promote a more successful utilization of scientific knowledge, to some degree (Wallin et al., 2003).

Yet nurses may have reason to be skeptical of abstract decontextualized science concepts, given some recent cases in which medical scientism (a blind faith in the extreme systematic-positivistic approach to medicine) worked against the well-being of patients (Hoggan, 1997). For instance, systematic-positivistic medicine was biased against, among other things, diet remedies (e.g. gluten-free diets) for some health problems (e.g. celiac disease); a bias that caused many to suffer needlessly over the past century. Scientism has also led to such misunderstandings as medical practice advances only because of the direct application of scientific knowledge, often supported by the myth that antiseptic surgery developed in the 19th century as a result of applying Pasteur's germ theory (Collingridge, 1989). Medical scientism blurs the distinction between scientific knowledge and the professional knowledge of nursing.

As indicated by the research into the use of science content in the everyday world (reviewed above), there is a relationship between scientific knowledge and professional knowledge of nursing. Some professional knowledge content used today was certainly developed as a result of the deconstruction and reconstruction of scientific concepts in a context of specific interest to most nurses; but it would not be recognized in its present form as legitimate science content to a science instructor (Chin et al., 2004; Eijkelhof, 1994; Layton, 1991; Stark & Lattuca, 1997). The *result* of the deconstruction/reconstruction of that scientific knowledge will likely be relevant to nurses' clinical reasoning, but the original scientific knowledge itself does not seem to be.

The present study supports earlier research that questioned the direct applicability of scientific knowledge to a nurse's knowledge-in-use, except for a nurse who happens to have a worldview in harmony with the worldview underlying scientific knowledge. These results, combined with other research in the literature, harbor important implications for the high school science curriculum. For employees in science-rich workplaces, salient scientific concepts were learned on the job, rather than recalled or directly applied from high school or university science courses. In the context of nursing, the evidence in this study suggests that when engaged in clinical reasoning, nurses could rely on their professional knowledge of nursing rather than on scientific knowledge (even if a nurse's personal worldview happened to coincide with the worldview inherent in science).

In science-rich workplaces, procedural knowledge had greater credence than declarative knowledge (Chin et al., 2004), and employees consistently used concepts of evidence in their work to such an extent that Duggan and Gott (2002) concluded: procedural knowledge generally, and concepts of evidence specifically, lie at the heart of scientific literacy for science-based occupations.

Similarly, informed consumers of the mass media, or thoughtful decision makers in a science-related event, extensively draw upon procedural knowledge and concepts of evidence (Duggan & Gott, 2002; Ratcliffe, 1999; Zeidler et al., 2003). In a case study of the lay public's involvement in an environmental concern, Tytler, Duggan, and Gott (2001a, p. 828) concluded, "The critical condition for becoming meaningfully involved in any aspect of the issue was the ability to ask questions of the evidence that was generated by the company and EA [environmental agency], or at least to be able to make sense of the questions that were being asked." The researchers pointed out that posing critical questions arose mainly from a grasp of procedural knowledge, not declarative knowledge.

This study provides support for Sadler's (2004) and for Duggan and Gott's (2002) recommendation that there should be a greater emphasis on the explicit teaching of procedural understanding related to data and evidence, and a reduced emphasis on teaching canonical science content. This approach to high school science would improve the occupational preparation of most science-career bound students, while at the same time improve the scientific functional literacy of the general public (Chin et al., 2004; Jenkins, 2002; Layton, 1991; Ryder, 2001; Tytler, Duggan, & Gott, 2001a). This expectation is mirrored in the literature advocating science education for citizenship (e.g. Jenkins, 1999).

Explicit instruction has been shown to significantly improve high school students' ability to use data and evaluate evidence (Kortland, 2001; Ratcliffe, 1999; Ratcliffe & Grace, 2003).

A sense of urgency emerges when this research is juxtaposed with research that reports low capabilities in students' understanding data, scientific evidence, and its use (Sadler, Chambers, & Zeidler, 2004).

Concepts of evidence are not normally emphasized in a science curriculum (Gott, Duggan, & Johnson, 1999). However, where they are found (e.g. the Pan-Canadian Science Framework (CMEC, 1997), various UK syllabuses (Gott, Duggan, & Johnson, 1999), or the OECD's PISA project (Fensham & Harlen, 1999)), concepts of evidence are normally treated as *skills*, not conceptual knowledge. The status of skills diminishes their appearance on typical achievement tests, particularly in high-stake testing, and thus the value placed on them in the curriculum. In some industries, concepts of evidence are considered to be common sense, not science (Gott, Duggan, & Johnson, 1999).

What canonical science knowledge seems relevant to science-related occupations or to public consumers of science-related information? The research unequivocally points to the need to learn scientific knowledge *as required*, even for nurses. Thus, one central role of the science curriculum would be to teach students *how to learn* science content as required by the context in which students find themselves (Hurd, 1989; Jenkins, 2002; Resnick, 1987; Roth and Désautels, 2004). As far as preparing students for science-related occupations or for citizenship is concerned, it would not seem to matter what science content is placed in the curriculum, as long as it enhances students' capability *to learn how to learn* science content within a relevant context, including potential occupation contexts. This recommendation does not subscribe to the view that coherence with the grand narratives of past curricula has a place in learning how to learn science.

Curriculum developers require criteria to decide what content should appear in such a curriculum (Roberts, 1988). The selection criterion "student interest" can achieve the goal "to learn how to learn science content" equally well as the status quo criterion "prerequisite coherence with first-year university courses." Moreover, given that student interest has far greater motivational currency than prerequisite saliency (though not necessarily for a small minority of students whose personal worldviews are similar to a scientific worldview, for example, Carla and Terry), the selection criterion "student interest" promises greater success for achieving the learning-how-to-learn goal. Chin and colleagues (2004) are exploring this prediction as they investigate students' views on workplace science and school science, in the context of co-op educational experiences.

Curriculum policy based on learning how to learn will produce a much different science curriculum document than a policy based on screening students through pre-university course content. For instance in Canada, the policy of learning how to learn is suggested by the STSE (science-technology-society-environment) approach to school science found in some provincial curricula and in the Pan-Canadian Science Framework (CMEC, 1997). At the moment, however, STSE content is largely absent in the provincial and national assessment of students, and STSE content in the Pan-Canadian Science Framework is misconstrued by provincial policy makers who embrace the criterion prerequisite coherence with first-year university courses (Sammel & Zandvliet, 2003).

In short, school science that holds greatest potential for enhancing students' success in science-related occupations and their capacity as a lay public to communicate with experts (e.g. health professionals) is a curriculum that teaches procedural knowledge of science, particularly concepts of evidence, in a context that authentically engages student interest in almost any legitimate science content.

I am indebted to the Research Services Unit of the Saskatoon Health Region and especially the surgical ward Unit Manager and the six nurses who generously gave their time and expertise. Ros Roberts and Richard Gott's reactions to early manuscripts are gratefully acknowledged, as well as the helpful comments from anonymous reviewers.

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