Promoting patient safety through informatics-based nursing education

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KEYWORDS
Patient safety; Education; Nursing; Evidence-based practice; Informatics

Summary The Institute of Medicine (IOM) Committee on Quality of Health Care in America identified the critical role of information technology in designing safe and effective health care. In addition to technical aspects such as regional or national health information infrastructures, to achieve this goal, healthcare professionals must receive the requisite training during basic and advanced educational programs. In this article, we describe a two-pronged strategy to promote patient safety through an informatics-based approach to nursing education at the Columbia University School of Nursing: (1) use of a personal digital assistant (PDA) to document clinical encounters and to retrieve patient safety-related information at the point of care, and (2) enhancement of informatics competencies of students and faculty. These approaches may be useful to others wishing to promote patient safety through using informatics methods and technologies in healthcare curricula.

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1. Introduction

The Institute of Medicine (IOM) Committee on Quality of Health Care in America identified the critical role of information technology in designing safe and effective health care [1]. In addition to technical aspects such as regional or national health information infrastructures, to achieve this goal, healthcare professionals must receive the requisite training during basic and advanced educational programs [2]. In this article, we describe a two-pronged strategy to promote patient safety through an informatics-based approach to nursing education: (1) use of a personal digital assistant (PDA) to document clinical encounters and to retrieve patient safety-related information at the point of care, and (2) enhancement of informatics competencies of students and faculty. These approaches may be useful to others wishing to promote patient safety through using informatics methods and technologies in healthcare curricula.

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competencies of students and faculty. For our educational purposes, we broadly conceptualized patient safety to include both errors of commission (e.g., wrong medication dose) and errors of omission (i.e., failure to provide care consistent with best evidence). In the following sections, we briefly describe the methods associated with each component of our approach and the status of the components. This is followed by a summary of the lessons learned.

2. Columbia University School of Nursing

The approaches described in this paper are implemented at the Columbia University School of Nursing in the entry-to-practice (ETP) and Master’s (MS) programs. The ETP Program at Columbia University School of Nursing is designed to prepare students with bachelor’s degrees in other fields for the first step in a career as an advanced practice nurse. Phase I (ETP–BS) prepares the student for basic practice as a registered nurse (RN) and Phase II (MS) focuses on preparation for an advanced practice role (nurse anesthetist, nurse midwifery, nurse practitioner (NP)). RNs with baccalaureate degrees enter the MS program directly. The student body includes approximately 150 ETP students and 300 MS students. The patients cared for by the students are predominantly African–American or Hispanic and consequently considered at higher risk for health disparities. Educational approaches aimed at reducing errors of commission and errors of omission have the potential to reduce health disparities for these vulnerable populations.

3. Integrating use of PDAs into the curriculum

The motivation for integrating PDAs into the curriculum was to: (1) facilitate clinical documentation and analysis, and (2) provide access to patient safety resources. In the following paragraphs, we share our experiences in developing a PDA-based student clinical log and associated database and knowledge base and in selecting patient safety resources for the PDA.

3.1. Developing the clinical log interface, database, and knowledge base

The electronic student clinical log and related database and knowledge base were designed to serve multiple purposes. First, students learn to document clinical encounters using standardized nursing terminology and other healthcare-related coding systems. Second, through benchmarking reports, students learn to critically examine their own practice over time. Third, faculty members review reports to determine if students are receiving appropriate experiences that will prepare them to safely deliver care and to provide feedback to students on care that is inconsistent with the best evidence or is potentially unsafe.

Key steps that were required to create a system that supported these multiple purposes include: design of the system architecture; selection of data elements and standardized terminologies for the data elements; design and implementation of the user interface; design and implementation of the database and knowledge base; and design and implementation of reports.

3.1.1. System architecture

We designed a system architecture (Fig. 1) that supports documentation and analysis of student encounters in an electronic clinical log and implemented it initially for the ETP program. Subsequently, we implemented the architecture for the NP specialties in the MS program. The architecture includes Palm M500-515s [3] and other Palm OS PDAs as input devices, satellite forms [4], XTND-Connect Server™ synchronization software [5], and Access database software.

3.1.2. Data elements and standardized terminologies

A major consideration in the selection of which data elements to include in the clinical log was to decide which elements of the students’ clinical encounters were important to capture for analysis purposes and at what level of granularity the data should be collected. For the ETP program, the overarching framework for the data elements was the nursing process and data elements were selected to represent the diagnosis, expected outcome, and intervention phases of the nursing process. Additional data elements included those related to patient...
demographics (e.g., age, gender, race/ethnicity) as well as student information such as clinical site and level of independence in performing interventions.

For the MS students, we needed to select a framework consistent with NP practice and expand the data elements to include medical diagnoses and treatments. The framework for the NP application is the SOAP (subjective, objective, assessment, plan) note augmented by categories of NP assessment and plan as taught in our curriculum. Following selection of the framework, we initiated a process to ascertain which data elements should be collected across NP specialties and to determine which standardized terminologies should be used for defining structured data elements. We first interviewed program directors and analyzed the content of the current clinical logs. Second, we created a superset of the data elements from the clinical logs. Next, we asked each program director to identify which data elements were currently collected and which data elements should be collected.

A variety of media was used by the program directors to collect clinical log data from NP students including paper, excel spreadsheets, and audiotapes. A total of 57 unique data elements resulted from the analysis of the clinical logs. In all instances but one, the number of desired data elements (range = 19–48, mean = 27) exceeded the number currently collected. Sixteen data elements met our pre-set criterion of selection by five of seven program directors for inclusion in the NP log (Table 1).

After selection of the data elements, we generated a list of criteria for selection of the standardized terminologies for the structured data elements:

- included in the Unified Medical Language System (UMLS) [6];
- recognized by American Nurses Association (ANA) [7];
- registered with Health Level 7 (HL7) for vocabulary domain specification [8];
- priority given to systems in the public domain.

Based on the criteria, we selected terminologies to represent the data elements (Table 1).

Our initial set of standardized terminologies included: International Classification of Diseases-Clinical Modification (ICD9-CM) [9]; National Institutes of Health (NIH) race/ethnicity codes; and Home Health Care Classification (HHCC) [10]. In some instances, no terminologies that met our criteria were available, so it was necessary to select alternatives. For example, in the NP Clinical Log, we used the Physician’s Current Procedural Terminology codes for procedures including those related to diagnostic tests [11]. We also created custom terminologies for local concepts such as student names, clinical sites, and rotations.

3.1.3. User Interface

The user interface was designed and implemented in Satellite Forms for the Palm OS. We tailored the values for clinical encounter-related data elements (e.g., only relevant nursing diagnoses, medical diagnoses, teaching interventions, and medications) for each ETP rotation (e.g., community, childbearing family) or NP program (e.g., women’s health, pediatrics) in order to minimize searching through irrelevant information. This is illustrated in the data entry screen shown in Fig. 2. The strategy for managing the tailoring of user interface items in the knowledge base is described in detail in [12].

Fig. 2  Data entry screens illustrate tailored interfaces. In the upper screen, the available interventions are limited to those relevant to the selected nursing diagnosis in the ETP medical/surgical application. The lower screen shows the GI diagnoses for the gerontology nurse practitioner (GNP) application.
### Table 1 Data elements and associated terminologies

<table>
<thead>
<tr>
<th>Data element</th>
<th>Standardized terminology</th>
<th>UMLS</th>
<th>ANA</th>
<th>HL7</th>
<th>Public domain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student-related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Custom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinical site</td>
<td>Custom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Patient demographics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Patient ID</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>HL7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td>NIH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Encounter-related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encounter date</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary medical diagnosis</td>
<td>ICD 9-CM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursing diagnoses*</td>
<td>HHCC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected outcomes*</td>
<td>HHCC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical/surgical history</td>
<td>ICD 9-CM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chief complaint (patient’s words)</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial exam (yes/no)</td>
<td>CPT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostics</td>
<td>CPT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursing Interventions*</td>
<td>HHCC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referrals</td>
<td>CPT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prescriptions</td>
<td>HHCC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient teaching</td>
<td>Custom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up date</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*These data elements were in the original ETP clinical log, but did not meet the criterion of selection by five of the seven NP program directors for inclusion in the NP clinical log. However, the development team selected a small set of nursing diagnoses for use across the NP clinical logs.

#### 3.1.4. Database and knowledge base

The database for the project is currently implemented in Microsoft Access, but care has been taken in the design to permit migration to higher capacity database engines, such as Microsoft SQL Server or Oracle, when needed. The logical database is implemented as a set of linked Access databases implementing a synchronization database (functioning as the input buffer), the scrubbing database, the repository, and the knowledge base. The design of the synchronization database is dictated by the tooling used to implement the palm user interface and is a collection of Access database files generated from the satellite forms development environment. The scrubbing database is a single database file implementing the main clinical data model, links to the synchronization database files, and links to the knowledge base. It also contains a collection of tables used in auditing, data transformation, and scrubbing processes. All processing and transformation of the data are performed in the scrubbing database. The same data model is implemented in both the scrubbing database and the repository. Upon completion of the data transformations, clean data are moved into a set of staging tables, which are linked to the repository. The repository contains tables for the final resting place of the main clinical data model and the data analysis queries and reports. The knowledge base is embedded within the repository and is implemented in a simple two-table structure of concepts and relationships. This structure provides functions such as version control of standardized terminologies for structured data elements, sort order of items in the user interface by specialty or program, control of which value lists belongs to which specialty (e.g., dementia in gerontology nurse practitioner (GNP), but not pediatric nurse practitioner (PNP)), and linking of nursing interventions to nursing diagnoses (ETP only).

#### 3.1.5. Reports

We extract a wide variety of knowledge from the collected data using simple SQL queries. We generate individual student and aggregate reports every 2 weeks for distribution to students, faculty, preceptors, and program directors. ETP reports focus on aspects of the nursing process, e.g., which
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<table>
<thead>
<tr>
<th>Assessment diagnoses</th>
<th>N</th>
<th>Diagnostic tests</th>
<th>N</th>
<th>Teaching/counseling</th>
<th>N</th>
<th>Referrals</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well child</td>
<td>39</td>
<td>CBC with differential</td>
<td>15</td>
<td>Nutrition care</td>
<td>12</td>
<td>Other</td>
<td>2</td>
</tr>
<tr>
<td>Asthma</td>
<td>5</td>
<td>Urinalysis</td>
<td>8</td>
<td>Safety precautions</td>
<td>8</td>
<td>Dermatologist</td>
<td>1</td>
</tr>
<tr>
<td>Otitis media</td>
<td>2</td>
<td>Lipid profile</td>
<td>3</td>
<td>Health promotion</td>
<td>7</td>
<td>Ophthalmologist</td>
<td>1</td>
</tr>
<tr>
<td>Child behavior alteration</td>
<td>1</td>
<td>Lead</td>
<td>1</td>
<td>Medication side effects</td>
<td>5</td>
<td>Medical social worker</td>
<td>1</td>
</tr>
<tr>
<td>Gastroenteritis</td>
<td>1</td>
<td>Pregnancy test</td>
<td>1</td>
<td>Disease process</td>
<td>4</td>
<td>Occupational therapy</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2 Sample summary reports

Interventions are done for a particular nursing diagnosis. A typical cumulative report for the NP students includes frequencies for items such as gender, race, medical diagnoses, diagnostic tests ordered, nursing diagnoses, nursing interventions, classes of medications prescribed, and referrals (Table 2).

3.2. Patient safety resources

The second aspect of PDA use that we have implemented is retrieval of patient safety-related information at the point of care. Selection of resources is at the discretion of the program director. For the ETP students, only Micromedex, a pharmacy database that includes drug–drug and drug–food interactions, is required. At the Master’s level, the faculty for each program selected a set of required and recommended references. For example, Micromedex, Growth 2, Kidometer, National Institutes of Health asthma guidelines, and Journals to Go are required for pediatric nurse practitioner students. PNP students also purchase Isilo, a document reader, so that they can use pediatric and cardiology databases. Resources required for acute care nurse practitioners (ACNPs) include: Pocket Guide to Diagnostic Tests [13], Principles of Critical Care Companion Handbook [14], Harrison’s Manual for the PDA [15], Essentials of Diagnosis and Treatment for PDA [16], and Major Incident Medical Management and Support [17]. The ACNP students also select a PDA pharmacy knowledge base such as Epocrates or Micromedex to assist in prevention of medication errors (Table 3).

4. Enhancing informatics competencies of students and faculty

Provision of informatics tools and resources in the curriculum is insufficient to influence patient safety. Students and faculty must also possess the necessary competencies to appropriately use the tools and resources. Consequently, we initiated activities to enhance the informatics competencies of students and faculty.

4.1. Student informatics competencies

For students, we derived an initial list of informatics competencies from three sources: American Nurses Association [18], Staggers et al.’s Delphi study of nursing informatics competencies [19]; and Bakken’s informatics competencies for evidence-based practice (EBP) [2]. For ETP students, we selected the set of beginning nurse informatics competencies from Staggers et al. as the basis of the curriculum development and competency assessment.

At the Master’s level, NP program directors participated in a series of meetings and e-mail discussions to: (1) rate which competencies should be included in the NP curriculum, (2) indicate if a particular competency was currently included in a course in their program, and (3) indicate whether each competency on the final list should be integrated into a specialty course, taught in a core course (e.g., research), or taught in an “intensive” that program directors could elect for students in a particular NP program. See [20] for details of this process.

Nursing Informatics competency assessment surveys were developed based upon the competencies that the program directors selected [21]. Our data show that significant changes in informatics competencies occur during the course of our educational program and that at program completion, ETP students meet the Staggers et al. competencies for beginning nurse in all but one area [21]. We subsequently augmented the curriculum to address that area.

Based upon the input of the ETP and NP program directors, we also created two intensives to support development of the competencies: (1) decision making and decision support, and (2) web-based information for consumer education. The intensives are required of ETP students and available to MS students as well. Examples of competencies with
<table>
<thead>
<tr>
<th>Application</th>
<th>Source</th>
</tr>
</thead>
</table>
Journals to Go [http://www.journaltogo.com/default.asp](http://www.journaltogo.com/default.asp)  
Palm reader [http://www.palmdigitalmedia.com](http://www.palmdigitalmedia.com)  
Tealpoint [http://www.tealpoint.com/softinfo.htm](http://www.tealpoint.com/softinfo.htm) |
Stat cholesterol 1.02 [http://www.statcoder.com/cholesterol.htm](http://www.statcoder.com/cholesterol.htm)  
Emcalc [http://wwwcebmonteron.ca/palm/emcalc](http://wwwcebmonteron.ca/palm/emcalc)  
Blood pressure manager [http://www.palmgear.com](http://www.palmgear.com)  
STAT cardiac clearance [http://www.statcoder.com/cardact1.htm](http://www.statcoder.com/cardact1.htm)  
STAT MCD lab coverage [http://www.statcoder.com/mcd.htm](http://www.statcoder.com/mcd.htm)  
Epocrates RX 6.0 [http://www.epocrates.com](http://www.epocrates.com)  
Medrules (requires Math library) [http://pbrain.hypermart.net/medrules.html](http://pbrain.hypermart.net/medrules.html)  
Micromex [http://www.micromex.com](http://www.micromex.com)  
Pediatric cardiology (requires Isilo) [http://pages.sprint.ca/Spiros/general3.html](http://pages.sprint.ca/Spiros/general3.html)  
Medmath [http://pda.rcp.net.pe/palm/preview/45487.html](http://pda.rcp.net.pe/palm/preview/45487.html)  
GRACE ACS Risk Model. 25 [http://www.euromed.com/author/1author=8799](http://www.euromed.com/author/1author=8799)  
Statcoder [http://www.statcoder.com](http://www.statcoder.com)  
Riley kidometer [http://kidometer.com](http://kidometer.com)  
Emedicine [http://www.emedicine.com/specials](http://www.emedicine.com/specials)  
American College of Cardiology Foundation [http://www.acc.org/clinical/palm_download.htm](http://www.acc.org/clinical/palm_download.htm)  
Table 4 Informatics competencies for NP students

<table>
<thead>
<tr>
<th>Competency</th>
<th>Example objective</th>
<th>Course(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converts information needs into answerable questions</td>
<td>Example objective: Integrates technology into clinical practice by developing answerable questions from practice</td>
<td>Core (Assessing Clinical Evidence) and clinical specialty</td>
</tr>
<tr>
<td>Uses data and statistical analyses to describe and evaluate practice</td>
<td>Example objective: Utilizes the clinical log to evaluate one's own practice against EBP standards</td>
<td>Clinical specialty</td>
</tr>
<tr>
<td>Evaluates health information on the Internet using a structured critique format</td>
<td>Example objective: Analyzes a specific site using criteria for web evaluation</td>
<td>Informatics intensive</td>
</tr>
<tr>
<td>Applies the principles of data integrity, professional ethics, and legal requirements for patient confidentiality and data security</td>
<td>Example objective: Maintains privacy and confidentiality in clinical log management</td>
<td>Core; also requires the development of school policy</td>
</tr>
</tbody>
</table>

4.2. Faculty informatics competencies

Because of variation in faculty informatics competencies, we are working with NP faculty to develop their own competencies, so that they may implement the competencies designated for integration into NP specialty courses. We utilize a three-pronged approach to enhance NP faculty competencies:

- small workshops and seminars related to informatics;
- consultation on appropriate assignments for selected competencies;
- guest lectures or co-teaching by informatics faculty members.

Topics for workshops or seminars have included: (1) diagnostic decision support (Dxplain software [22]), (2) decision analysis (Data 4.0 software, http://www.treeage.com), (3) computer-based patient preference assessment (CHOICES [23]), and (4) web-based health information resources. We anticipate that the topics of workshops and seminars and consultations will evolve over time as faculty members improve their knowledge and skills in this area and as new informatics processes and tools are developed (e.g., bioinformatics applications).

5. Lessons learned

We have learned a number of key lessons related to the organizational, financial, educational, and technical aspects during the initial 2 years of the project. These include the following:

- As with clinical informatics projects, organizational buy-in is critical. Incorporating the approaches we have described into the curriculum requires a change in organizational culture and collaboration from administration, information technology services, faculty, preceptors, and students.
- It would be difficult to implement such approaches without dedicated funding. In our instance, funding from the Health Resources and Services Administration supported faculty and programmer time as well as PDAs for pilot groups of students and faculty. In addition, foundation funding supported purchase of PDAs for the first group of ETP students.
- Domain expertise is essential to developing an application that is considered useful in the educational process. For example, in our NP application development, this included knowledge about how NP students were taught to practice and to document, as well as new informatics processes and tools.
- Equipping students with informatics competencies and tools that preceptors and nurses in their clinical sites do not have may cause issues. For example, preceptors may not trust the information on the PDA. Another issue is that students may feel that if practicing nurses don’t use such tools and apply such competencies, they are irrelevant to nursing practice. To address this challenge, we plan to spend more effort helping the preceptors understand the role of the clinical log and PDA resources in our curriculum and how the
data generated can assist them to monitor and evaluate the student.

- Each new application and the associated changes in the database and knowledge base require extensive testing to determine usability and to maintain consistency of structure and performance across various rotations and specialties. This remains challenging because each application is tailored to the rotation or specialty, and we currently have six ETP applications and eight NP applications in use (GNP, PNP, ACNP, Adult NP, Neonatal NP, Women’s Health NP, Family NP, and Oncology NP). We are in the process of developing standardized policies and procedures to assist us in project management.

- A sophisticated knowledge base is required to manage the data collection and analysis over time. We made the decision early on to manage complexity in the knowledge base rather than in the user interface. When we add new content, the concepts and relationships in the knowledge base are updated and the new content is extracted through queries from the knowledge base into tables suitable for export into the interface development environment.

- It is challenging to keep up with the rapidly evolving changes in parts of the system architecture. For example, the release of a new PDA OS version is likely to precede the availability of the development software and the synchronization software. Consequently, students may have a PDA that is incompatible with the rest of the architecture. We are moving toward a strategy that would allow us to support various versions of Palm OS and Windows CE devices.

6. Conclusions

Patient safety is a vital concern and informatics-based approaches have a significant role to play in prevention of errors of commission and omission. An informatics-competent workforce is a significant component of a safer healthcare environment for all patients including those from traditionally underserved populations. We believe that through the types of educational activities described in this paper, we are preparing advanced practice nurses competent in the use of information technologies to promote safe and evidence-based nursing practice.

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